IMPACT OF UTILIZING 3D DIGITAL URBAN MODELS ON THE DESIGN CONTENT OF URBAN DESIGN PLANS IN US CITIES

A Dissertation

by

FIRAS A. SALMAN AL-DOURI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2006

Major Subject: Architecture

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ABSTRACT

Impact of Utilizing 3D Digital Urban Models on the Design Content of Urban Design Plans in US Cities. (August 2006)

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Some experts suggest that urban design plans in US cities may lack adequate coverage of the essential design aspects, particularly three-dimensional design aspects of the physical environment. Digital urban models and information technology tools may help designers visualize and interact with design alternatives, large urban data sets, and 3D information more effectively, thus correcting this problem. However, there is a limited understanding of the impact that these models may have on the quality of the design product and consequently hesitation about the appropriate methods of their usage. These suggest a need for research into how the usage of digital models can affect the extent with which urban design plans cover the essential design aspects. This research discusses the role digital models can play in supporting designers in addressing the essential design aspects. The research objective is to understand how the usage of digital models affects the coverage of the essential design aspects. The research applies a novel perspective of examining both the methods of modeling-supported urban design and the design content of urban design to attempt to reveal a correlation or causal relation.

Using the mixed method approach, this research includes three phases. The first, literature review, focused on reviewing secondary sources to construct theoretical propositions about the impact of digital modeling on urban design against which empirical observations were compared. Using qualitative content analysis, the second phase involved examining 14 plans to assess their design content and conducting structured interviews with the designers of four selected plans. The third phase involved sending questionnaire forms to designers in the planning departments and firms that developed the examined plans. The analysis results were compared with the theoretical propositions and discussed to derive conclusions.

The extent of design aspects coverage was found to be correlated with the usage of digital modeling. Computational plans appear to have achieved a higher level of design aspects coverage and a better translation of design goals and objectives. In those plans, 3D urban-wide design aspects were addressed more effectively than in conventional plans. The effective usage of the model's functions appears to improve the quality of the decision-making process through increasing designers' visualization and analytical capabilities, and providing a platform for communicating design ideas among and across design teams. The results helped suggest a methodological framework for the best practices of modeling usage to improve the design content.

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DEDICATION

To my wife Zaineb,

whose dedication, support and sacrifice made my success possible and whom I wish to reward for her patience

To my sons Ahmed, Abdulhamid, and Omar,

whom I wish to reward for their continuous encouragement, support and enduring patience

To my Parents,

for their love, guidance and prayers

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CHAPTER I

INTRODUCTION

1.1 Overview of Problems of Urban Design Practice in US Cities

Urban design is essentially a three-dimensional process that focuses on shaping urban elements and their relationship within a coherent functional and visual structure. However, some experts suggest that few urban design plans adopted in US cities portray an explicit spatial strategy, while consideration is rarely given to three-dimensional aspects of design (Gosling and Gosling 2003, p.8, p.16, p.173; Lang 1994, p.442; Southworth 1989, pp.474-375).

This situation is due, in part, to three types of problems: information-related problems, communication-related problems, and representation-related problems. Information-related problems may be a result of an increasing access to, and overwhelming volume of information and data pertinent to the design problem that leads to poor management of that data and ultimately poor analysis. In information-related problems, literature suggests that there are three distinct categories of information processing operations: derivation of solutions, consistency testing, and comparison and selection. In arriving at decisions, the designers' impediments are twofold. The first is lack of objective information as to what ends are desirable as well as the relationships between ends and means. The second is the designers' own limitations as a human being, and the paucity of tools at his command. Therefore the emerging design is likely to be the one that was, or appeared to be, the easiest to produce (Levin 1984, pp.117-119). As such, information-related problems may be a result of an increasing access to, and overwhelming volume of information and data pertinent to the design problem that leads to poor management of that data and ultimately poor analysis. Designers, as such, have rarely been able to utilize the growing volume of information to translate 3D information into a three-dimensional structural framework for the city, or to generate sound design alternatives (Rivard et al 2003, p.51; Whyte 2002, p.103, p.199). As there is a growing tendency to collect and use more 3D data and information, there is a need to develop techniques for visualizing and interacting with these large and complex datasets effectively.

Communication-related problems may be due, in part, to the incapability of conventional urban design tools and techniques to meet the requirements of an increasingly distributed

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This dissertation follows the style and format of the *Journal of Urban Design.*

design process and knowledge. This reflects in designers' inability to visualize and discuss the design concepts, alternatives, and strategies. Some experts, as such, argue that urban design is full of assumptions and conventions because 3D information and spatial structure had to be communicated on a 2D medium (Bourdakis 2001, p.404). Most design and planning applications have been considered within the framework of two-dimensional land-use and rigid zoning codes (Gosling and Gosling 2003, p.8). Representational and visualization problems may be due, in part, to lack of interactivity and reality in conventional presentations and unsupported cognitive and comprehension skills.

Accordingly, the analytical content and 3D information are not likely to effectively underpin the resulting urban design strategies. Therefore, 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 (Carmona, Punter, and Chapman 2002, p.55; Punter & Carmona 1997 a, pp.170-173). In light of these findings, designers and professionals need tools to save, communicate, exchange, and import relevant information and knowledge.

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. Some researchers expressed their faith in the capabilities of those technologies, and identified a wider context for their role (ElAraby 2002, p.457; Langendorf 2001, p.335; Laurini 2001, p.192). It becomes essential thus to develop new design methods that use these design tools and techniques effectively to support designers and professional in performing these tasks during the design process. The increasing range and variety of information, communication, and visualization technologies represent a potential solution to these problems. Urban design processes that have incorporated 3D digital modeling and information technology tools may result in plans that may better address the entire array of design aspect and particularly 3D considerations.

1.2 Research Background and Methods

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 focused upon 3D digital models as one promising type of digital and information technology. The research examined the modeling methods used in several case studies and urban design plans which were 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 design aspects. The research applies a novel perspective of examining both the methods of modeling-supported urban design and the design content of urban design to attempt to reveal a correlation or causal relation.

This research provides evidence that the extent of design aspects coverage was correlated with the usage of digital modeling. Computational plans appear to have achieved a higher level of design aspects coverage and a better translation of design goals and objectives. In those plans, 3D urban-wide design aspects were addressed more effectively than in conventional plans. The effective usage of the model's functions appears to improve the quality of the decision-making process through increasing designers' visualization and analytical capabilities, and providing a platform for communicating design ideas among and across design teams. The results helped suggest a methodological framework for the best practices of modeling usage to improve the design content.

CHAPTER II

RESEARCH DESIGN AND METHODS

The previous introductory literature review has provided an outline of the problems inherent in current urban design practice in US cities, and presented background information verifying the potential role that 3D digital models and information technology (IT) tools can play in improving that practice. My goal was to understand how the usage of 3D digital modeling and IT tools may improve the quality of the urban design product in US cities by improving the coverage of its design aspects. I pursued this goal by examining the design aspects coverage in several urban design plans that were developed with computer-assisted methods and comparing them with their coverage in plans that were developed with conventional design methods. Towards that goal, I began by developing a measurement instrument that can serve as an assessment tool for the plans' design aspects coverage. This chapter introduces the research problem in detail by breaking it into its components. In this chapter, the research methods used for the attainment of the research goal are explained and justified. First, the research sample, experimental variables, research hypothesis, questions, objectives, and significance are described. Second, the plan for attaining the research objectives are explained and justified. Third, measurement instrument development, data collection and analysis and methodology assumptions for achieving high reliability and internal validity are explained.

2.1 Outline of Research Problem, Goals and Methods

Urban design is essentially a three-dimensional process that focuses on shaping urban elements and their relationship within a coherent functional and visual structure. Yet, in current urban design practice in US cities, few plans portray that spatial strategy explicitly, while consideration is rarely given to three-dimensional aspects (Gosling and Gosling 2003 p.22) Most importantly, urban design products lack coverage of many design aspects that would normally be considered as central to their design content (Punter and Carmona 1997 p. 173), and they are often developed without being underpinned by relevant analytical content (Southworth 1989, pp. 374-375). Poor analytical content has lead to failure to express strategic design considerations, failure to relate design to differing scales of development, and failure to achieve detailed coverage of design issues (Southworth 1989, pp. 374-375, Gosling and Gosling 2003, p.8).

These problems are due, in part, to information- related problems and communication-related problems where conventional urban design tools and techniques are incapable of meeting the requirements of a multidisciplinary and an increasingly distributed design process and knowledge. Literature suggests that 3D urban models may represent a potential solution to these problems. They offer functions that are particularly powerful in visualizing the urban environment and in supporting information management and communication within the design process (Gosling and Gosling 2003 p.250; El-Araby p.461). However, there are many potential barriers to applying their capabilities in practice, namely: inadequate technical support and inappropriate and unsophisticated methods of their usage in design practice (Whyte 2002 p.93). There is little consensus on the methodologies by which these models should be used to improve the decision-making process (Whyte 2002 pp. 132-134). In particular, there have been very few efforts that seek to integrate them with other technologies such as GIS and the Internet (Huang, Jiang, and Hui 2001 p.441). Therefore, further research is needed to investigate methods of using these models in core design tasks, and how they could support designers in developing urban design plans.

This research will examine the impact of various methods and degrees of effectiveness of models usage on the design content of urban plans. It will investigate that impact in urban design plans developed for six US cities that integrate 3D models in their planning departments: Philadelphia, Chicago, New York, Pittsburgh, Milwaukee, and Boston. It aims to understand how urban design and planning departments are using 3D models in support of early design process. The research objective is to understand the impact of various methods and degrees of 3D urban models usage on the design content of urban design strategies in order to suggest a methodological framework for their usage that may improve that content. This framework is 3D model-supported, information-based, and is meant to establish a three-dimensional framework that relates urban elements to public space network, and provides a vital framework for individual development projects.

The research has used the mixed method approach that combined qualitative (case studies) and quantitative (questionnaire) methods sequentially to address issues of internal and external validity, and to generalize the anticipated findings beyond the selected cases. The research involved three phases. The first, literature review, focused on reviewing secondary sources to construct theoretical propositions on which subsequent phases can be based and with which research results would be compared and contrasted. The second, case studies, involved content analysis of 14 recent urban design plans in the six aforementioned US cities to examine their design content. This phase includes structured interviews with urban designers and planners in planning departments in those cities. These plans, 10 of which were developed with 3D models support, were either at a district, city center, or city-wide scale. They were drawn from US cities that integrate 3D models in their planning departments, and known for established history and academic or research institutions pertinent to urban design practice. The third phase, questionnaire, involved sending 120-140 survey forms to urban designers and planners in planning departments in those cities and in the firms that developed those plans to identify the methods and degrees with which the planers used models in developing design strategies. Finally, three case studies were selected for in-depth interviews with key designers and decision-makers in those firms to help unravel certain undocumented subjective and creative design decisions, and to help interpret certain design aspects in findings of content analyses and questionnaires.

Data collected from content analysis and interviews was coded, categorized, and then analyzed using pattern matching and other techniques such as explanation building technique to build and test plausible explanations for the change in the design content in 3D model-supported plans, and to compare it with that content in conventional plans. Questionnaire responses were subjected to descriptive statistical analysis to analyze the general trend of using 3D urban models in supporting design tasks. By using several analytical techniques, I have assessed the impact of various degrees of usage of 3D models on the design content of urban design plans.

2.2 Problem Statement

According to some experts, urban design plans adopted in US cities are often developed without being underpinned by relevant analytical content, or are not based on in-depth analysis for the specific problem of the study area (Southworth 1989, pp.64-66). These plans exhibited a lack of coverage of urban design topics, which would normally be considered as central to design control (Punter and Carmona 1997 a p.173). Many major US cities, as such, demonstrate a lack of any coherent urban design policy except in historic districts and neighborhoods. Although the public realm is considered the three-dimensional skeletal structure of the city, there is still no real statutory provision for it in US cities (Gosling and Gosling 2003 p.22). They demonstrate two procedural gaps, one between theory and practice, and the second between analysis and alternatives generation phases (Lang 1994, p.403, p.442).

These gaps may be due to information-related problems, and communication-related problems. The information-related problems may be a result of an increasing access to, and overwhelming volume of information and data pertinent to the design problem that leads to poor management of that data and ultimately poor analysis. 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. Communication-related problems may be due, in part, to the incapability of conventional urban design tools and techniques to meet the requirements of an increasingly distributed design process and knowledge. Although there is a change in the role, format, content, and use of the conventional plan, 3D information is still communicated in 2D medium. Consequently, 3D information and the analytical content are not likely to effectively underpin the resulting urban design strategies.

Literature suggests that few urban design plans exhibited an explicit spatial strategy (Gosling and Gosling 2003, p.170). Urban design plans fail to recognize the specific characteristics of the study area, and fail to cover the basic design aspects that would normally be considered central to design control. As such, designers and professionals need tools to save, communicate, exchange, and import relevant information and knowledge. The increasing range and variety of information and communication technologies may represent a potential solution to this problem and fulfill some of the designers needs. If 3D urban models are integrated with flexible databases, GIS, and Internet, they may provide valid communication and information management tools, and may help visualizing and interacting with large urban datasets and 3D information effectively (Whyte 2002, p.103, p.132; Danahay 1998, pp.356-357; Huang et al 2001, pp.439-440). However, further research is required to enable designers to use 3D digital urban models effectively in generating and testing alternative strategies in urban design plans of US cities. Accordingly, there is a need to develop a consistent methodological framework (Whyte 2002, p.132; Bourdakis 2002, p.404; Gosling 1993, p.37).

Therefore, this research aims to develop an information-based, 3D model-supported methodological framework for improving the design content in urban design strategies of US cities. It will examine the impact of various methods and degrees of models usage on the design content of the design and three-dimensional characteristics of these cities.

2.3 Research Hypothesis, Questions, Objectives, and Significance

2.3.1 Research hypothesis

The research is guided by a central hypothesis:

> If the urban design process employs 3D digital urban models integrated with GIS databases to support design tasks of developing urban design plans, then they will effectively address the basic design issues and aspects of the urban environment and will incorporate 3D design aspects efficiently.

2.3.2 Research questions

The research will address the following primary questions:

1. How does the degree of 3D models usage affect the design content of the resulting urban design plan?
2. Under what set of conditions of methods, or a methodological framework, are 3D digital urban models effective tools in the development of design content of urban design plans?

To address these primary questions, the following secondary questions will be addressed:

1. To what extent have urban design plans for a sample of cases of US cities addressed the design aspects of the urban structure?
2. What is the methodological framework underlying the generation and testing of alternative design strategies in typical urban design plan in US cities?
3. To what extent have the usage of digital urban models made a difference and impact on the urban design process?
4. What new rules or methodological framework have designers set and applied to using 3D models in generating and testing design strategies in typical urban design plan in US cities?

2.3.3 Research objectives

The study aims to understand the impact of 3D digital urban models usage upon the design content of urban design strategies and to suggest a methodological framework for the best practices of their usage that may improve that content. The expectation is that the framework will be 3D model-supported, information-based, and capable of establishing three-dimensional structure that relates urban elements and buildings to public space networks, and provides a vital framework for individual development projects.

2.3.4 Research significance

The research is significant because it is expected to contribute to a methodological framework for the best practices of 3D digital urban models usage that may improve the design content of urban design plans of US cities. This new methodological framework is expected to exploit advanced computer technologies, and is likely to increase the conformance of urban design practice to its theory. Therefore, the expected significance of this study will stem from making the following contributions:

1. The research will document and critically examine the methods used and the approaches followed in designing the urban structure of selected urban design plans

in US cities. The outcome will help assess the impact of various methods and degrees of 3D models usage on the design content of urban design strategies.

2. The research will assess the impact of various methods and extents of models usage on the design content of urban design strategies. This involves measuring to what extent have urban designers used the models functions and thus made a difference in the design process.
3. The research will help suggest improvements to the urban design methodological framework that incorporates digital models.

This information-based, 3D model-supported urban planning and design process may enable urban developments that are more rich, sophisticated, spatial, and successful.

2.3.5 Intellectual merit

This research applies a novel perspective of examining both the methods of modeling-supported urban design and the quality (design content) of urban design to attempt to reveal a correlation or causal relation. It contributed to two areas of urban planning inquiry: Urban design and 3D urban modeling. It was the first study to examine how various functionalities and degrees of 3D models usage affect the design content of urban design plans. Understanding the impact of 3D models usage will contribute to efforts to understand the relation between new model-supported design methods and the quality of their outcome, and how that relates to the decision-making process.

Through analyzing the content of 14 conventional plans and model-supported plans, and interviewing key informants of six model-supported cases, the research produced qualitative data with high internal validity that is particularly important to assess the causal relation between the independent and dependent variables, and in turn, the impact of model-supported design methods on their design outcome. Quantitative data helped triangulate and confirm findings and thus established their external validity. By using the framework of Punter and Carmona (1994) to analyze the design content, and the framework of Batty et al (1998 b) to survey models' functionalities, the research built on empirically-tested research to develop a reliable measurement instrument.

2.3.6 Research benefits

The main benefit of this exploratory study for Architectural profession is adding and diffusing knowledge that may enhance the current planning and architectural education and practice. The research helps establish and document best practices that can be promulgated through education. The suggested set of rules of 3D urban models usage may help urban design and planning teams and departments in design process by identifying the appropriate methods that are likely to improve the design content of urban design plans. The findings also may represent a departure point towards conducting further research that aims to integrate 3D urban models with other tools to create a decision-support system for the urban design practice in US cities.

2.3.7 Broader impacts

This research has practical applications for urban designers seeking support in core design tasks by establishing a methodological framework for the best practices of models usage in design generation and development. This will contribute to efforts to understand how designers may effectively use models' capabilities and networking tools collaboratively as an interface with other professionals among and across teams, as well as with non-professionals and stakeholders. Such usage may help public and non-design professionals comprehend design alternatives and can foster a broader involvement of an otherwise-excluded group in the design process. A broader involvement helps establish greater certainty and objectivity which may translate into greater confidence in decisions made by various participants in the design process. By identifying the usage and support of models functionalities at each phase, the research may have other practical applications in urban modeling industry by highlighting options of developing and coupling models of infrastructure with new databases and networks that may potentially provide further support to planning practice and research.

The research might contribute to the change of role, format, content, and use of conventional urban design plans in favor of a new information technology-supported approach.

2.4 Research Design and Variables

2.4.1 Research variables

2.4.1.1 Independent variables

There are three independent variables that identify the degree of 3D models usage in supporting design tasks in the process of developing of urban design strategies and plans (see Table 2.1). These variables are:

1. The **number of model's functionalities** designers use to support core design tasks in the design development process such as: navigation, analytical, communication (decision-support), and manipulation functions.
2. The **extent of designers' usage** of these functionalities to support alternatives design generation and development.
3. The **extent of designers' usage** of models to support major design tasks of the conceptual phase.

I expect a correlation between these variables and the dependent variable. Values for these variables are determined by examining the process of producing an urban design plan.

2.4.1.2 Dependent variable

The dependent variable is the design content of the urban design plans for selected cases of urban design plans of US cities (see Table 2.1).

2.4.1.3 Control variables

Control variables are specific identifiable error variables that may cloud the study results, and whose effects on a dependent variable may need to be limited. They include:

1. Extent of the 3D model.
2. Public access to the model.
3. Development year or model's age and version.
4. Extent, size, and complexity of the urban design strategy.
5. Methodology of the design process.
6. Number of project participants.

2.4.1.4 Confounding variables

Confounding variables are factors that may conceal or confuse relation between the independent and dependent variables. They include:

Table 2.1. Definitions and measurements of research variables

No.	Name	Type	Measurement	Scale	Source
1	**The degree of 3D digital models usage in developing urban design plans in US cities.**	Independent	Change in the **number of Modeling functionalities** that designers use in supporting design tasks of developing urban design plans such as: ▪ Navigation functionalities; ▪ Communication functionalities; ▪ Manipulation functionalities; and ▪ Analytical functionalities. The **extent with which 3D** modeling supported designers at each design phase of the process of urban design plans development. The **extent with which The modeling usage use** affected the quality of the design products of each phase and the extent of design aspects coverage.	Continuous / 1-5 1-5 1-5	Questionnaire/ Interviews
2	**Design content of urban design plans in US cities**	Dependent	Change in the **number and Categories of design aspects** covered by the urban design plan. This will include the following parameters: ▪ Design aspects covered in the design strategy ▪ Scales of intervention ▪ Level of Details	Continuous / Interval	Content analysis

1. Company culture.
2. Regional customs.
3. Political factors affecting decision-making process.
4. Participant's profile and experience.

These error variables may account for some of the dependent variable variation which can result in confusing the causal relation between the independent and dependent variables. The overall aim of the research design is then to try to control them by using three measures. Firstly, as many confounding and control variables as possible are identified by careful definition of variables and acquisition of valid data through the questionnaire and interviews with key informants. Secondly, as far as possible, case studies within the sampling frame are randomly selected. Thirdly, careful preliminary study and search of the literature of other related research attempts should reveal the possibility of any large, single, independent influence. A pilot study has been conducted to help in explicating and controlling these variables.

2.5 Plan for Attaining Research Objectives

2.5.1 Methods of inquiry

The study used the mixed method approach described by Creswell (2003), which combines qualitative (case studies) and quantitative (questionnaire) methods sequentially to address issues of internal and external validity and generalize the anticipated findings beyond the selected cases. Hence, three main phases comprised the study: literature review and theoretical propositions, case studies, and questionnaire.

Phase one: Literature review and theoretical propositions

This step focused on reviewing secondary sources to construct theoretical propositions on which subsequent phases could be based. Hence, it involved investigating literature pertinent to three primary topics:

1. The basic components of the design content of urban design strategies in US cities
2. How and to what extent could 3D models' functionalities support designers in generating design strategies and improving that content
3. The new insights that urban designers may gain by using these tools effectively and efficiently.

Literature review was also meant to refine the research questions, goals, and hypothesis, and build the measurement instrument. It was followed by preliminary studies that helped test the validity and reliability of the measurement instrument.

Preliminary studies

The research involved conducting a preliminary study for two cases in Houston: a conventionally developed plan, The *Main Street Corridor Plan,* and a model-supported plan, *Northside Village Revitalization Plan*. The study involved analyzing and comparing their design content to examine the impact of models' usage. It involved field observations and interviews with key informants at the Planning and Development Department at the City of Houston, and with urban designers in the firms that contributed in their development; EE&K Architects, and Environment Simulation Center (ESC) respectively. Interviews and observations were meant to investigate the methods with which designers use 3D models, and how and to what extent models supported them in core design tasks and affected the outcome of each design phase. The pilot studies produced data and information that was useful in organizing the questionnaire's content and developing its scales.

The preliminary studies involved pre-testing the questionnaire and the checklist of design aspects and categories that measure the design content of urban design plans. The findings were intended to improve the reliability and content of these measurement instruments. This study helped identify the institutions that have been involved in 3D urban modeling such as Environmental Simulation Center (ESC), Urban Simulation Team (UST) at the University of California at Los Angeles (UCLA), Center of Advanced Spatial Analysis (CASA) at the University College London (UCL), Urban Data Solution (UDS) and Great Cities Urban Data Visualization, (GCUCDV) at the University of Illinois at Chicago (UIC). Their identification helped define the sampling frame of cities from which the case studies were selected.

Phase two: Case studies

Upon completion of the preliminary study, case studies were conducted. The case studies involved two operational measures to assess the impact of 3D models usage on the design content of urban design strategies in US cities: content analyses and structured interviews. The content analysis examined 14 recent urban design plans (developed after 1999) in six US cities. Eight of these cases were developed using computer-assisted design methods while the rest were developed using conventional design methods. This investigation was meant to discover the design aspects covered in urban design strategies, their scales of intervention, and their levels of details. Following the approach developed and used in previous research (Punter and Carmona 1997 a and b), the structure of the content analysis has been organized to comprise three major sections: general design approach, coverage of design aspects, and policy representation and expression. This study will be described in detail in chapter III. Structured interviews produced descriptions of how 3D models have been used and subjective evaluation of their effectiveness (see Table 2.2).

Phase three: Questionnaire

Questionnaires were sent to 63 architects, urban designers, and planners in planning departments and in firms that developed these studies. The questionnaire form was designed to identify degrees with which firms and planning departments used 3D models in supporting the design tasks of the conceptual phase. The questionnaire form was organized to comprise six main categories of questions, five of which were closed-ended and one was open-ended question. Closed-ended questions focused on quantifying and measuring the extent with which designers use various models functionalities. Using a scale of 1 to 5, the questions measured the extent with which that usage has supported designers, affected their design outcome and product, and improved the decision-making process (See appendix A). Open-ended questions allowed exploration of methods of 3D model usage in support of design development tasks as well as the design phases in which they have been used.

The questions were based on two main sources: literature in the areas of computer-aided urban design methods, urban research, survey methods, and responses to the pilot study questionnaire and interviews. Their organization has adopted the framework of Batty et al (1998 b) to organize the major categories of 3D models functionalities, and has adopted the study developed by Royal Town Planning Institute (RTPI) in (Carmona, Punter, and Chapman 2002) to organize the design aspects and output. The framework of Batty et al (1998 b) will be described in detail in chapter IV. Finally, three cases were selected to conduct structured interviews to add depth and detailed information to the content analysis findings. For each case, 4-6 structured interviews were conducted with key informants and decision-makers in the planning departments and firms that contributed in the development of those cases. The interviews were intended to reveal certain undocumented subjective and creative decisions made by designers, and to help interpret certain design aspects in the content analysis and questionnaire findings. Phase three identified the relation between various methods and degrees of 3D models usage and the design content of the urban design plans in all the selected cases (see Table 2.2).

The research design has several strengths. The first strength is the use of an exploratory strategy that combines qualitative (case studies) and quantitative methods (questionnaires) sequentially. The qualitative method, which is the primary method, established internal validity. Literature suggests that the case study methodology is suitable for ill-defined problems, in general and particularly to urban design and planning problems (Scholz and Tietje 2002 p.26). It suggests that it has many advantages over other methodologies. In particular, it can better handle complex urban processes with unclear boundaries, inputs, and outputs. The most influential urban planning research has arguably been based on case studies rather than large statistical analysis, and on exceptional rather than typical cases (Campbell 2003, p.1). The quantitative data allowed generalization beyond the cases to assure and increase external validity. The second strength is the distribution of multiple cases from six US cities which allowed analyzing and comparing between cases at two levels: within the same city and across cities. These comparisons allowed triangulation and confirmation of findings and identification of the impact of most of the control variables and confounding variables. They accordingly helped establish internal validity and the causal relationship between the dependent and independent variables. The third strength is the use of a questionnaire based on Batty's framework of models functionalities to measure the degree of model usage, support, and impact on the outcome of each design phase. The fourth strength, the use of interviews with key designers and planners helped in interpretation of certain findings in content analysis and questionnaires. They allowed collecting more in-depth information than would be available with only questionnaires.

2.5.2 Data collection

2.5.2.1 Sampling and choosing key informants

The sampling frame comprised a list of cities of greater than 1 million population which developed and used 3D digital urban models in their planning practice. This list was developed based on the surveys conducted by Center of Advanced Spatial Analysis (CASA) at the University College London, and published in Batty et al (2000) and Shiode (2001). From this list, I have selected a purposive sample of six US cities. They were selected because their planning departments have largely employed 3D digital urban models in their planning practice, and are known with established history of, and academic or research institutions pertinent to, 3D modeling in urban design practice. These cities are Philadelphia, Chicago, New York, Milwaukee, Boston, and Pittsburgh. According to Gosling and Gosling (2003) and Batty et al (2000), the cities of Chicago, New York, and Boston employ the

Table 2.2. Categories of research data that have to be collected

No.	Category	Subcategory	Measurement	Collection
1	**The degree of 3D digital model usage in supporting design tasks of generating alternative design plans in US cities.**	**Design functionalities** that designers use in developing urban design plans under the following categories: o Analytical functionalities, o Navigation functionalities, o Manipulation functionalities, o Communication functionalities ▪ **Extent of designers' usage of each of these functionalities** in of developing urban design plans. ▪ **Extent of designers' usage of models** in developing urban design plans	Interval Interval Interval	Questionnaire and interviews Questionnaire and interviews Questionnaire and interviews
2	**Design content of the urban design strategy**	▪ **Category/Number of design aspects** addressed by the urban design plan ▪ **Levels of intervention** addressed by urban design plans.	Interval/ Continuous Interval	Content analysis
3	**Methodological Framework**	▪ Design methodology adopted in each case. ▪ Number of design alternatives ▪ The extent of city modeled by the 3D model ▪ The model's level of details ▪ Accessibility of model to public ▪ History of using the model to support the firm's designers ▪ Number and profile of model users ▪ Changes to conventional methodologies due to model usage	Categorical Continuous Interval Interval Interval Continuous Continuous/Categorical Categorical	Questionnaire and interviews
4	**Best practices of using 3D models to improve the design content of urban design plans**	▪ **Methods** of using 3D models to improve the design content of urban design plan	Categorical	Questionnaire and interviews

most advanced 3D models in urban design practice in US cities. Although choosing a purposive sample limits generalizing from the study findings, the purposive sample enabled me to investigate the methods and degrees of models usage in planning departments and firms in those cities.

Within each city, I selected two or three urban design plans as case studies, one of which was developed using conventional design method, while others were developed using 3D model-supported design methods. The selection of all cases was subject to two main conditions underlying their year of development and scale. All selected plans were recently developed (after 1999), and were either at a scale of a district, downtown, or city center. These conditions were meant to regulate the impact of the control variables, particularly the extent of the 3D model, development year and the model's technical capabilities, extent, size, and complexity of the urban design plan. The scale of the urban design plan, according to literature, may affect the methodology of the design process which is another control variable. The impact of the scale of the urban design plan on its design methodology and approach to address its constituent design aspects will be discussed in detail in chapter III.

The size of sample case studies is small enough to subject them to content analysis. Upon analyzing these cases, I selected key informants from the list of urban designers and planners in firms and planning departments who contributed in their design development. Having several key informants with various profiles and types of contributions in the design process allowed me to unravel certain undocumented design decisions and to document the extent with which 3D models usage has affected various design tasks.

2.5.2.2 Measurement of design content

To examine the design content (dependant variable) of the selected plans, I subjected these plans to content analysis using computer-aided manual content analysis. I followed the approach of Punter and Carmona (1997 a) to organize the structure of content analysis into three major sections: design objectives, design content, and plan's representation and expression. To identify the components of design content, I adopted the definition of Punter and Carmona (1994) for the parameters of design content. Therefore, content analysis produced data for the following variables: number and categories of design aspects addressed in the plan, their level of details, and their scale of intervention, design objectives, and its type of representation and expression. The components and assessment of design content in urban design plans are explained in detail in chapter III.

Attempts to quantitatively measure only the number of design aspects addressed may result in serious measurement errors. Some design aspects may not be explicitly addressed but implicitly within other design categories and levels of intervention. Instead, data concerning the design aspects considered that various scales of design intervention require a change in emphasis and level of detail. I adopted the study of Frey (1999) to determine the design aspects relevant to each level of urban design intervention (see Table 2.3). I adopted the agenda of Carmona, Punter, and Chapman (2002) for categories of design issues that should be reflected in a core design strategy. This agenda will be explained in detail in chapter III. The advantages of adopting these studies are that they have been practically applied in research on design content in US and UK cities, and are comprehensive and flexible enough to accommodate various scales of plans. Hence, their adoption across all cases enhanced the reliability of collected data and external validity of findings.

2.5.2.3 Measurement of degree of models' usage

To determine the degree of 3D models usage (independent variable), questionnaires were sent to 80 designers and planners in planning departments and in firms that participated in developing the selected case studies. The questionnaires were designed to identify degrees with which firms and planning departments use 3D urban models to support the design tasks of developing urban design plans. The questions were based on the following two main sources:

1. Literature in the area of computer-aided urban design methods, urban research, and survey methods
2. Responses to the pilot study's questionnaire and interviews.

The design and implementation of the questionnaire survey adopted Dillman's Revised Total Design Method (2000). The questionnaire form adopted the framework of Batty et al (1998 b) to organize the major categories of 3D models functionalities, and adopted RTPI's agenda (Carmona, Punter, and Chapman 2002) to organize the design aspects and output. The questions were organized into six main categories, five of which were closed-ended and one category of open-ended questions. Closed-ended questions focused on quantifying and measuring the extent with which designers used the various models functionalities. They produced data for the following variables (see Table 2.2):

1. The number of model's functionalities that designers use to support design tasks of developing urban design plans.
2. The extent with which designers use each of the functionalities to support the development of urban design plans, in a scale of 1 to 5.
3. The extent with which designers use models to support each design phase, in a scale of 1 to 5.

4. The impact of 3D model usage on the outcome of each design phase, in a scale of 1 to 6.

Open-ended questions allowed exploration of methods of 3D models usage in supporting conceptual design functions as well as the design phases in which they have been used. They produced qualitative data that triangulated the questionnaires' quantitative data and enabled me to determine how models' usage affected design methodology, and what new insights designers gained due to their usage. They also formed the basis for the subsequent individual interviews with key informants.

Table 2.3. The levels of strategic urban design intervention (Frey 1999, p. 21)

LEVEL	ISSUES	SCOPE
Level one Strategic urban design at the city/conurbation level	Form and structure Land-use patterns Relationship to hinterland Access, linkages, transport, and communication systems Definition, role, and interaction of districts Image Environmental impact and energy consumption	Sets development framework for city/conurbation which co-ordinates the development of individual districts within the city. The general development structure (e.g. linear, network, cluster, etc) is fixed. The scale and form of the development of individual districts remain open
Level two Strategic urban design at the city district level	Role of districts in the city Form and structure Land-use pattern, social mix Relationship public to private realm Access, linkages/permeability and transport system Identity and legibility Image Environmental impact and energy consumption	Sets development framework for individual urban districts which co-ordinated the development of individual spaces and projects in the districts. The general development structure and form of individual districts (e.g. hierarchical, spatial, etc.) is fixed. The scale and nature of the development of individual projects within districts remain open.
Level three Urban design of individual spaces or groups of spaces	▪ Role of individual or groups of spaces in the city /district (hierarchy) ▪ Form and structure ▪ Use pattern, social mix ▪ Relationship between public and private realm ▪ Detail design (use profile, surfaces, furniture, landscaping, etc) ▪ Identity, legibility, and image ▪ Environmental impact and energy consumption.	▪ Sets design guidelines for individual urban spaces and buildings within framework for districts. ▪ The primary design features of the public spaces are fixed ▪ Use patterns, detail design,(unless coordination is essential) remain open

2.5.2.4 Documenting best practices of using 3D models

Structured in-depth interviews were conducted with 4-6 key informants for each of the six selected model-supported cases. The interviews were conducted primarily with urban designers and planners with various professional profiles, degrees of expertise, and contributions in design development. Therefore, some interviews took place at the design firm that developed the plan, while others took place at the planning department of the host city. They were formal structured interviews that addressed the main issues pertinent to the research topic and elicited in-depth qualitative data.

Structured in-depth interviews with key informants produced qualitative data for the following variables (see Table 2.2):

- Best practices of using 3D models that may improve the design content of urban design plans;
- Design methodology adopted;
- History of using models to support design development;
- Number and profile of model users; and
- Changes to conventional design methodology due to models usage.

With respondent’s permission, I recorded interviews using a digital sound recorder (Maloney and Palisso 2001), and also photographed or videotape design tools and products whenever possible. This procedure enabled me to collect unpublished design documents that explain in detail the usage of 3D modeling and IT tools during the design development.

2.5.3 Data analysis

2.5.3.1Data entry and coding

In the content analysis phase, I used prior research-driven code development approach (Boyatzis 1998) to develop a checklist of categories against which the content of urban design plans will be analyzed, quantified, and tabulated. Data analysis of the selected cases involved classifying and categorizing their content according to the criteria established by Royal Town Planning Institute’s study (RTPI) (Carmon, Punter, and Chapman 2002),Punter and Carmona (1994, 1997 a and b) and Punter (1999) for classifying the content of urban design plans. The main categories are general design approach, coverage of design aspects, and policy representation and expression. The main design aspects are: townscape, urban form, public realm, connections and movement network, land-use, sustainability, landscape architecture, architectural character, and conservation areas.

These tables will be used to measure the change in the number and categories of design aspects addressed in ratio scale, and the change in the scale of intervention and levels of details in interval scale. The content analyses data was subjected to two main levels of comparison, computational cases with conventional cases, and across computational cases. The first level involved a comparison of the design content of model-supported plans with its counterpart in conventional plans. The first level of comparison involved several analytical tasks that were explained in detail in chapter VI. The second level involved an in-depth comparison of the design content across two selected model-supported plans. The second level of comparison involved several analytical tasks that were explained in detail in chapter VIII. These categories were analyzed using several analytical techniques, such as pattern matching and explanation building techniques. Pattern matching helped identify predicted patterns of the dependent variable - design content of the design strategies developed by 3D models - and compare them with their counterparts in conventional plans. Explanation building technique was used to build and test plausible explanations for the change in the dependent variable at two levels: the first was for various model-supported plans, and the second was across plans to help triangulate and generalize the findings.

In the questionnaire phase, I subjected the responses of questionnaires and interviews to inductive content analysis, which involved classifying, tabulating, and coding data into four main categories as follows:

1. Methods with which 3D models were used;
2. Degrees of model usage;
3. The impact of model support on each design task and product; and
4. The degree with which model usage has affected the extent of covering the major design aspects in the urban design plan.

Data obtained was tabulated, scored and transformed into spreadsheets and figures. Calculating closed-ended responses helped identify frequencies to assess the predominant approaches of using 3D models in urban design practice. That data was used to measure three interval-level independent variables: number of functionalities used, degree of usage of each functionality, and the degree of model usage to support each design phase.

In interviews, the quantitative part of that data was used to construct an interval measure for the change in design methodology, change in number of design alternatives, level of details of the 3D model, and change in number and profile of model users. Qualitative assessment of the responses helped identify the degree of 3D model usage in developing the urban design plans as well as the significance of outlining a methodological framework for model usage to improve the design content. The qualitative part of that data was coded and tabulated using the data-driven code development approach (Boyatzis 1998). The results of the questionnaires and interviews are explained in detail in chapter VIII.

2.5.3.2 Units of analysis and case sampling

The units of analyses are:

1. Urban design plans at a district, corridor, or city centre scale. The samples were drawn from cities that employ models in their urban design and planning practice and design development. These cities were: Philadelphia, Chicago, New York, Milwaukee, Boston, and Pittsburgh.
2. Urban designers and decision-makers in planning departments and architectural firms that developed the afore-mentioned urban design plans.

2.5.4 Research reliability

Content analysis of the case studies clearly stated scoring and data categories to avoid any overlap and to ensure reliability. This was achieved by clear decision rules and criteria based on previous studies by RTPI (2002), by Punter and Carmona (1994, 1997 a and b) and Punter (1999) for classifying the content of urban design plans. To support quantitative analysis, I developed an Internet questionnaire survey that is primarily based on closed questions as a standard instrument. The open-ended questions were the basis for the structured in-depth interviews. This instrument was tested in a pilot study in Houston to investigate the range of perspectives and views of urban designers and decision-makers relative to the effect of 3D urban models usage on the design content of urban design plans. The design and implementation of the questionnaire survey adopted Dillman's Revised Total Design Method (2000). The organization of the categories of model functionalities in the questionnaires followed the framework defined by Batty et al (1998 b). In order to maximize response rates and reduce the overall survey errors, the questionnaire forms were distributed electronically through a professional survey agent to the e-mail addresses of the prospected respondents. The implementation involved sending a cover letter, keeping the questionnaire short, providing an incentive such as a copy of the results, and sending two follow-up mailings which include reminder letters and additional copies of the questionnaire. The measures that have been taken in this research to ensure reliability in content analyses are explained in detail in Chapter III.

2.5.5 Research validity

The validity has been tested in a pilot case study. The results were compared with the theoretical propositions of the literature review. To assure research validity, three main measures have been taken:

1. Designing the research in an exploratory sequential strategy whereby a qualitative method that establishes the internal validity is the primary method.
2. Careful selection and distribution of the selected cases in terms of location, scale, design objectives and problems. This distribution, which involves selecting three various cases in each of the six cities, allows conducting analyses of cases at two levels: between cases within the same city, and between cases across cities, to allow triangulation and confirmation of findings. This may help establish internal validity and causal relationship between the dependent and independent variables.
3. The quantitative data that allows generalization beyond the cases, and the distribution of cases from six cities, may assure and increase external validity.

The types of validity and the measures that have been taken in this research to ensure their achievement in content analyses are explained in detail in chapter III.

2.5.6 Research scope and limitations

This research examined the impact of various methods and degrees of effectiveness of model usage on the design content of urban design plans in US cities. Different types of tools could be integrated with those models. The scope of this study is limited to models integrated with Internet and relational databases. The study focuses on city models that are established to assist urban designers and planners in planning departments in some US cities. Three limitations exist in this study. First, the sample is limited to US cities that employ 3D models in their planning departments, and that have established a history of urban design practice. The sampling is thus neither random nor heterogeneous. Second, the cases selected are limited to three scales: city, city center, and district scales. Thus, the results could not be generalized to other scales of plans. Third, the study focused on a specific phase of the design process, the generation and testing of design alternatives. Therefore, the results may not be completely generalized to other design phases.

CHAPTER III

DESIGN CONTENT IN URBAN DESIGN PLANS

The previous chapter explained the research problem, variables, and methods used for the assessment of the impact of 3D modeling usage on the design content of urban design plans. In this chapter, I describe the components and method of assessment of the design content in urban design plans and the measurement tool used in this research to assess the design content. I reviewed literature to define design content, content analysis technique, and application of content analysis technique in urban design practice. First, the design content in urban design plans is discussed, defined and analyzed into its main constituent. Further, the plans components and qualities that affect the design content are explained, and a criticism of inadequacies of design content in current urban design practice in US cities is presented. Second, content analysis definition, concepts, techniques, and advantages and limitations of application in urban design plans are explained and justified. Third, approaches to designing the content analysis are reviewed, and the approaches and measures used in this research to insure reliability and validity are explained and justified. Fourth, this chapter explains in detail the structure and content of the coding manual used in this research to assess the design content with comprehensiveness and consistency.

3.1 Definition of the Design Content

The design content of urban design plans is the coverage of the strategic vision, core design issues, and detailed and subject-specific design issues (Carmona, Punter, and Chapman 2002, p.29). The significance of the plan is that it seeks to give form and definition to the full spectrum of forces- cultural, ecological, political, social, and aesthetic- that shape the built environment and the public realm. The design content of urban design plans is an overarching element that bridges across all the constituent urban elements and issues by creating a vision that articulates the shape of the urban environment (CABE 2005, p.6).

The design content of urban design plans is closely related to two key substantive elements: quality of analytical content, and the type of design guidance (Turner 1993, p.23). The first element is the quality of the analytical content and the extent to which it extends beyond the site to include the character of the broader context. Relevant analytical content is imperative to underpin design policies and to define the key design aspects of a locality to be developed into a policy (Punter and Carmona 1997 p.173). Theoretically, as important as the analytical content is the process of translating it into design concepts, strategies and alternatives. The quality of the design solution is correlated with, and is a function of, the analytical content, design concepts, and alternative solutions generated at the conceptual phase.

The second key element of urban design plans is the type of design guidance. Design guidelines, which are the operational definitions of design objectives, are often classified into two main modes or styles: prescriptive-oriented and performance-oriented. The prescriptive-oriented style is restrictive and is oriented towards the concrete end product of a design plan by describing the characteristics of the physical environment to be achieved. The performance-oriented style focuses on the performance required by the end product rather than its concrete physical characteristics (Steino 2001, p.3). The prescriptive-oriented style is often described as being negative, restrictive, and unimaginative as it eliminates most possible solutions and focuses on one or a few solutions. The performance-oriented style, which is favored by most commentators, is considered to be more flexible because it does not prescribe solutions or particular built form, but sets principles or performance criteria, leaving the designer free to use his/her creativity to solve the design solution (Punter 1999 p.203). Therefore, it fosters the full usage of urban designers' skills and allows different design solutions to evolve which may enhance the quality of the design product (Steino 2001, p.3; Turner 1993, P.17). Urban design practice usually makes use of both approaches for various aspects of the plan (Stein 2001 p.8).

The adoption of either approach depends on the degree of control urban design plans are intended to exert over urban development. Selecting the appropriate level of prescription in design plans remains a key factor that significantly affects the design content of urban design plans.

3.2 Constituents of the Content of Urban Design Plans

The research depends upon the existence of a clear and comprehensive way of measuring and assessing the content of urban design plans. Various authorities have attempted to define the desirable content of urban design plans. In this section, I will review some prominent theories and synthesize them into a working theory.

The design content embraces three interrelated tiers of substantive elements of urban design plans: design considerations, design policies, and design aspects. The first tier, design considerations, expresses the qualities that urban design, as a process, seeks to achieve. Design plans should set out what constitutes the full range of design considerations, recognizing that they have different weights in different areas and sites. The second tier, design policies, identifies the key factors and considerations that designers should take into account. The third tier, design aspects, includes the aspects addressed or covered in the policies and the degree of emphasis on each design aspect.

Experts tend to approach those considerations from different perspectives. Shirvani (1985) for instance, attempted to compare and synthesize the various criteria used in urban design theory and practice. He suggested that there are three basic types of design criteria: measurable, non-measurable, and generic design criteria. He also suggests that the urban design process should incorporate both measurable and non-measurable criteria and work within the framework of generic criteria (Shirvani 1985, p. 122-123). Measurable criteria are those that can be measured quantitatively. They include two groups: environmental-natural criteria; and form-criteria that address the measurement of three-dimensional urban form, such as building form, massing, and intensity. These criteria can be measured by both conventional and innovative types of measurement (Shirvani 1985, p.133). Non-measurable criteria emphasize the visual qualities of the urban environment such as amenity, clarity and convenience, harmony, scale and pattern, principle views, visual interest, etc. These criteria require using innovative methods of measurement which underscore the significance of using digital technology and modeling in their measurement.

These criteria are concerned with two major design considerations: the visual aspects and the functional aspects of the physical spatial form (Shirvani 1985, pp.128-129). A major difficulty in this rather narrow set is the extent to which visual and functional criteria overlapped. With that respect, Shirvani (1985) highlighted the transition from aesthetic approaches, which consider the city as an artifact, to the functional approaches that evaluate urban environments in terms of cultural, social, and psychological dimensions as well as visual ones (Shirvani 1985 p.129).

Rowley (1994) suggested a broader array of categories that identify visual, functional, environmental, and urban experience design considerations (Rowley 1994, p.5/15-184).Visual considerations range from the design and siting of a single object in space or a concern for buildings seen in their immediate context to a city-wide concern for skylines and the siting of high buildings or other landmarks. Functional considerations traditionally include matters such as road layout and capacity and car parking provision. They should lead to increased understanding of how environments are used as well as how the diversity of users and their differing needs can be incorporated. Hence, they may involve the notion that design of urban spaces should respond to patterns of use and movement, or that vehicular movement should be given priority. Environmental considerations are pertinent to micro-climate issues and ecological impacts of urban design such as energy-efficiency, wildlife support and nature conservation, pollution and waste control, and sustainability.

However, a successful urban design plan must treat more than the physical attributes of the subject area. Urban experience embraces the attributes of places. It includes pubic perceptions, associations and meanings, and the history and genius loci of urban environments (Rowley 1994, pp 4-5/15-184). Collectively, this array represents a basic framework that encompasses most of the factors urban designers should take into account.

These considerations arise over a spectrum of spatial scales from the local to the metropolitan scale of urban form and city image. It is essential that urban design plans should create a set of design considerations that translates into a design framework and includes a list of design principles that permeates all scales of urban environment within the planning system. Yet, there are various approaches with which design policies and principles cover the set of design considerations. They will be discussed briefly in the following section.

The second tier of substantive elements, design policies of the urban design plan, identifies the key factors and considerations that design team should take into account. Experts have different approaches to outlining the full range of key design policies in urban design plans. Among the related literature, four authors' views of urban design policies are reviewed because they cover broad urban design issues and elements. Barnett (1982) for instance, viewed these policies from a strategic point of view at a city-wide scale. He identified six major elements of a design and development strategy as a means to design a city without designing its buildings (Barnett 1982, p.155). These policies are: land-use strategies; public open-space policy; standards for street furniture, lighting and signs; transportation and urban design policy, and public investment strategy.

Conversely, Hedman and Jaszewsk (1984) discussed the fundamentals of urban design from an architectural point of view and pointed out that architecture and urban design are inseparable. They suggested that urban design concern includes: context and contrast; preservation, spatial definition; and urban form and building form (Hong 1997, pp 16-18).

Shirvani (1985) reflected his broader viewpoint regarding this issue when he pinpointed the confusion and difficulty of defining urban design policies and elements. He defined them as physical elements and grouped the elements of urban physical form into categories that ensemble natural environment and social aspects. Those categories are: land-use; building form and massing; circulation and parking; open space; pedestrian ways; activity support; signage; and preservation (Hong 1997, pp 18-19).

Punter and Carmona (1996) suggested four broad areas of policy: public perception, townscape, urban form, and public realm. Design policies are developed then for urban design, architecture, landscaping, and urban conservation. They also suggest that policy recommendations be given a strong sustainability dimension. They emphasized that policies must be well articulated and that they set out as clearly and logically as possible what constitutes the full range of design considerations. With that respect, they also emphasized that not all policies will have equal or similar weight across areas and sites (Punter and Carmona 1996, pp. 201-203).

The third tier of substantive elements includes the design aspects addressed or covered in the policies and the degree of emphasis on each design aspect. These design aspects and their constituent design elements and issues, result from disaggregating the urban design policies into individual design components and elements. They are characterized by a great diversity across geographical areas and cities (Punter and Carmona 1996 p.201-203).

In this research, the design aspects were classified according to their design conceptualization, goals, and scope of concern into 2D and 3D aspects and into local or urban-wide scale (see Table 3.1). This classification, which was based on relevant literature and previous research such as (Carmona, Punter, and Chapman 2002) and (UTF 1999), is meant to examine any possible relation between the extent of coverage of those types of design aspects and the types of plans, computational vs. conventional.

Studies such as that of the Urban Task Force (UTF, 1999), Llewelyn-Davis and Alan Baxter & Associates (2002), (Cowan 2002), and Carmona, Punter, and Chapman (2002) attempted to build an agenda comprising the fundamental design concerns that should be reflected in a core design strategy. The agenda of RTPI, which is an advanced form of the work of Punter and Carmona (1994, 1996, and 1997 a and b) addresses the multiple disciplines of the urban environment and hence includes: townscape, urban form, public realm, mixed-use and tenure, connections and movements, conservation areas, and sustainable urban design (Carmona, Punter, and Chapman, 2002). It must be noted here that conservation areas refer to areas, districts, or neighborhood that are subject to historic preservation and/ or they are identified with special architectural and urban character.

The significance of RTPI’s study, besides the suggested broad agenda of urban design aspects, was its emphasis on the systematic coverage of its constituents and on relating them to the locality. Yet, the move through the intermediate scale of landscape and urban design considerations to the detailed issues of architecture and urban management requires a change in emphasis and degrees of detail. This notion highlights the significance of using new design methods and tools that may assist designers in considering the visual aspects at multiple scales of the spatial structure.

Table 3.1. Classification of the main design aspects according to their conceptualization, goals, and concerns (Southworth 1989, Carmona, Punter, and Chapman 2002)

No	Design Aspects	Design Conceptualization	Design Goal and Scope of Concern (constituent elements)	2D vs. 3D	Urban vs. Local
1	**Sustainable urban design**	• Adaptability • Maintenance • Sustainability	• Sustainable development should be a principal goal of urban design at all scales-buildings, spaces, quarters, and settlements	**2D/3D**	**Urban/ Local**
2	**Townscape**	• Context • Scale • Character	• Visual relationships of a development to its site and its wider setting • Provision of visually interesting public space and buildings • Provision of high quality hard landscape • Protection of both local and strategic views	**Predominantly 3D**	**Urban**
3	**Urban form**	• Continuity and enclosures • Optimizing land-use and density	• Appropriate scale of development • Density , height, and massing • Enclosure of public spaces • Diversity and pattern of urban grain • Block and plot sizes		
4	**Mixed use and diversity**	• Mixing activities • Mixing tenures	• Mixing of uses and tenures to create sustainable communities • Provision of adequate and attractive private amenity spaces and public open spaces	**Predominantly 2D**	**Local**
5	**Connections and movement network**	• Movement • Layout • Accessibility	• Visual and physical permeability • Energy-efficient movement network • Prioritizing safe, easy, and direct pedestrian movement • Prioritizing attractive and well-connected network of public space		
6	**Public realm**	• Quality of the public realm • Legibility	• Encouraging legible, comfortable, stimulating, and safe streets • Incorporating public perceptions of the identity and quality of the built environment into the design strategies • Design against crime • Functional concerns (parking, servicing)	**Predominantly 3D**	**Urban**
7	**Architectural character**	• Architectural form • Elevations and details	• Building massing and spacing • Building form, height, and scale • Style, richness, and visual interest • Materials and details		**Local**
8	**Conservation areas and/or areas of special character**	• Site and Setting • Enrich the existing	• Conservation of urban form and townscape • Architectural form, grain, and morphology • Materials and details • Landmark and listed buildings		
9	**Landscape architecture**	• Strategic landscape considerations • Local landscape considerations	• Soft landscape improvements • Water, trees, and greenery • Landscape layout • Buffers • Street furniture and lighting • Hard landscape layout and planning	**2D**	

3.3 Qualities and Components of Plans That Affect Design Content

Turner (1994) attempted to define and map the relation between the factors arising from the planning process that affect design content. She suggested that most urban design plans share four common key factors: statement of purpose, policy background, survey and analysis, and design guidance. Consequently, she sketched a model for the relationship between those factors, and argued that the internal logic should drive the progression from purpose to policy background to analysis on to guidance. According to that model, the plan's statement of purpose is the main primary factor that drives the progression because it establishes a strong emphasis on design as the main item of enhancement sought for preparing the plans. It is the overarching element that affects other secondary factors such as the preparation time, role of the urban design plan in its relation with other levels of design control, and the analytical content (Turner 1994, pp. 304-306). Consequently, all those factors may collectively have a significant impact on the design content of the urban design plan.

However, this model did not address other essential plan-related factors that should be involved in that progression. Punter and Carmona (1994) define certain primary and secondary factors that may affect the design content of urban design plans. Besides the plan's statement of purpose, goals, and objectives, there are three primary factors:

1. The approach of design control
2. The context of the urban design plan
3. The scale and the type of plans and /or developments.

Secondary factors include degrees of design control and prescriptive content, the levels of survey and analysis and quality of the analytical content, and levels of detail and degrees of abstraction of the plans. The variety in the primary factors may affect the design content directly and translate to a variety of secondary factors that will ultimately affect the quality of the design product, particularly the design content.

In the first primary factor, literature suggests that there are two main approaches with which urban design policies cover the basic design considerations (Punter and Carmona 1996, p. 203). In the first approach, design considerations are covered in a single comprehensive urban design policy where subsequent policies can elaborate each of those considerations with detailed policies. These policies might vary the level of design control according to the quality and coherence of the development area. The second approach, strategic urban design, is seen as a macro-scale urban design which functions as part of the link between overall plan strategy and detailed design policies. It is concerned with the capital web which is the pattern of existing infrastructure and planned investment that is likely to play a dominant role in attracting new development. This approach has been followed in the City of Portland by developing design frameworks for its downtown and progressively extending this strategy into other areas (Punter and Carmona 1996, pp. 203-205). Design frameworks, as such, may enhance the design content by providing a way of linking the more detailed urban form, townscape, and public realm considerations with the general matters of legibility and public perceptions.

In the second primary factor, plans' contexts, urban design plans are meant to ensure that development responds appropriately to its setting. Plans often feature different levels of control for different design contexts, and tend to consider their application on areas of varying coherence and quality. The constituent policies, as such, state the key design principles appropriate to different context. They tailor the policies to a variety of environments such as countryside, greenbelts, town centers and downtowns, and areas of townscapes characters. City center design policies, for instance, deal with public spaces, pedestrian links, and setting of key urban elements and buildings, whereas waterways policies include policies on visual enclosure, riverside uses and ecological protection (Punter and Carmona 1996, pp.222-228). Therefore, elaborate and comprehensive urban design plans develop different levels of control for different contexts. They should include a set of general design parameters for application to areas of varying coherence and quality.

Third primary factor, scale, is not widely used to define particular types of a policy, yet some of the most sophisticated plans incorporate scale considerations. Design principles are directly related to the development scale (Punter and Carmona 1996, p.229). They help identify the characteristics that must be addressed by a particular form of development. More importantly, different development scales may affect the plan's development process, such as its design methodology, approach of design aspects coverage, the degree of control on the urban environment, and degree of abstraction of the design product (Steino p.8). Hence, as the scale development gets smaller, it is likely to increase and emphasize the importance of smaller scale contextual characteristics to which the development should respond.

Urban design plans often aim at fitting their constituent design policies to commonly occurring types of developments. The most common development types are new housing, employment areas, and shopping areas. The policies in a plan identify the more common problems encountered in each type of development and address them directly. For instance, the urban design plan of a new housing project in England aimed to reduce monotony through housing mix policy and through comprehensive series of special housing policies. In employment areas in London, the office design policy aimed to provide flexible and adaptable office space and a mix of uses (Punter and Carmona 1996, p.229).

Different contexts and localities may set different priorities according to their functional and visual characteristics, their socio-economic conditions, and the plan's political background and pressures. Relating urban design plans and /or particular constituent design policies to specific context, type, or scale could be considered a significant design and development approach that may affect the design content in various ways. First, it fosters the effective usage of designers' knowledge and skills to analyze the urban context and then to tailor the design policies to the characteristics of the locality. Second, it may yield a design product that is responsive to its context and thus potentially rich in design content.

3.4 Design Content in Current Urban Design Plans in US Cities

Urban design is essentially a three-dimensional process that draws together the many strands of place-making, environmental responsibilities, social equity and economic viability. It deals with the complex relation between the elements of the built and unbuilt space. Urban design is derived from yet transcends related matters such as planning and transportation policy, architectural design, development economics, landscape and engineering (Lang 2005 p.6). Urban design, as such, is concerned with the effects of new development in the existing city form, and deals with non-visual aspects of the environment (Gosling and Gosling 2003 p.7). An urban design plan is the most essential of all the products of urban design such as design policies, development briefs, design guidelines, and programs. It is a three dimensional depiction of urban design policies, and thus it should be developed within the framework of a set of policies (Shirvani 1985, p.144).

In current practice in US cities, however, there was a discrepancy between what the urban design should be and what it is. An extensive review of the design policies and guidance in five west coast US cities conducted by Punter (1999) revealed that there were problems with that process, its efficiency, and its effectiveness (Punter 1999, p.195). Little consideration is given to three-dimensional aspects of design. Most design and planning applications have been considered within the framework of two-dimensional land-use and rigid zoning codes. In much of the US, zoning ordinance remains the critical document for regulating land uses and shaping the physical form of the urban environment (Punter 1999, p.12). Few plans portrayed an explicit spatial strategy and very few exhibited spatial design strategies relating major development projects, patterns of infrastructure investment, and changes to the desired urban structure within a coherent framework. More importantly, the plans that are developed lack adequate coverage of essential design aspects that would normally be considered to be central to the role of urban design plans in controlling design (Gosling and Gosling 2003, p.8, p.16, p.173; Lang 1994, p.442; Southworth 1989, pp.374-375). These findings suggest investigating the aspects comprising the design content of urban design plans, to what extent they were addressed in these plans, and why they may not have been addressed comprehensively.

The contemporary urban design control in US cities is embedded in a hierarchy of guidance that functions in two ways. First, such control is expressed in terms of goals, objectives, principles, guidelines, and quantitative standards. Second, the plan encompasses several levels and scales such as sub-regional to city-wide, district and neighborhood levels to the individual site (Poerbo 2001, pp.80-81).

Urban design guidelines in US cities accommodate the aspirations of the private sector which dominates the development in city centers (Poerbo 2001 p.965). Guidelines typically reflect the dominance of 2D land-use zoning controls over considerations of 3D urban form (Punter and Carmona 1996, p.203). Because private developers are essentially concerned with individual developments rather than creation of places or integrating the development with the public realm (Carmona et al. 2003, p.232), such development may yield a fragmented, incoherent urban form. This outcome underscores the need to prioritize the quality of city-wide urban design as a means to control the 3D characteristics of the urban form and spatial structure.

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 to design spatial structures (Gosling and Gosling 2003, Lang, 1994, Bourdakis 2001). Designers, as such, have rarely been able to utilize the growing volume of 3D and spatial information to generate sound and well-spaced design concepts and strategies.

Two empirical researches that involved thorough evaluation of several urban design policies in various cities in Britain and US have investigated these issues. The researchers found that “poor” analytical content in development plans has lead to failure to express strategic design considerations, and failure to relate design to differing scales of development and also to avoiding detailed coverage of design issues (Southworth 1989 p.401; Punter and Carmona 1994, p.206). Punter (1999) examined urban design practice in five west coast US cities. He found that one of the key characteristics of the best American urban design plans is that they are based upon thoroughgoing analysis of the character of the locality (Punter 1999, p.200). Similarly, other researchers, such as Turner (1993) found that the very best examples of design plans in US were based upon a very clear and detailed analysis of the area's characteristics and elements. These characteristics include existing scene, the distinctive qualities of each district, local characteristics, architectural features, incidental landmarks, and the mix of uses and types of businesses that generate its character (Turner 1993 p.16).

To generate from these several studies, most analyses were found to be selective and cursory, to blur the distinction between objective findings and subjective creative leaps (Southworth 1989 pp. 374-375). Accordingly, the analytical content is likely to be incompatible and inadequate to underpin effectively the resulting urban design strategies, and the urban design process rarely produces alternatives that might actually form the basis of public debate and political choice.

Therefore, the analytical content is of vital importance to the success of the urban design plan and thus to the quality of the design outcome. Poor analytical content, cognitive problems, and communication problems may lead to failure to express strategic design considerations, failure to relate design to differing scales of development, and failure to achieve detailed coverage of design issues. This may explain, in part, why current design plans do not address the key design aspects comprehensively.

Literature suggests that design thinking has recently come back to permeate planning at all scales of urban design practice in US cities, particularly at the metropolitan, district, and neighborhood scales (Punter 1999, pp. 204). Urban designers pay more respect now to the content of the design rather than the intermediate artifacts such as 3D renderings (Poerbo 2001, p.111). These shifts in design practice underscore the necessity to follow a comprehensive approach to urban design. They emphasize the need to prioritize design in urban design plans and highlight it as an overarching concern of relevance across all scales and types of development. They suggest developing new design methods that use other design tools and techniques to allow designers and professionals to save, communicate, exchange, and import relevant information and knowledge.

3.5 Content Analysis Applied to Urban Design Plans

For this research, content analysis has been used to identify and clarify the design content of a sample of urban design plans. This section explains the methods used for analyzing the selected plans. It discusses the content analysis technique from the following aspects:

1. Definition of content analysis: its concepts and techniques.
2. Advantages and shortcomings associated with the usage of content analysis.

3. Designing the content analysis for urban design plans. It includes content analysis design approach, structure and development of coding scheme, reliability and validity, and selecting samples of case studies.

3.5.1 Definition of content analysis: its concepts and techniques

Content analysis is a technique for systematically describing written, spoken, or visual communication. The analysis can emphasize either the content of the material, which refers to its specific topics and themes, or it can emphasize its structure, which refers to the form of the material (Sommer & Sommer 2002, p.178). Although the basis of content analysis is quantification, it allows for the simultaneous application of quantification and qualitative techniques. In this research, I have applied content analysis to urban design plans to extract, document, assess and thus quantify topics and themes relevant to the research questions and variables.

According to Krippendorff (2004, p.29), the framework of content analysis consists of a number of conceptual components. These elements are:

1. A body of text and a research question that the analyst seeks to answer through studying the text.
2. A context of the analyst’s choice within which to make sense of the body of the text.
3. An analytical construct that operationalizes what the analyst knows about the context.
4. Inferences that are intended to answer the research questions and constitute the basic accomplishment of content analysis.
5. Validating evidence.

A central idea in content analysis is that many words of the text are classified into much fewer content categories. Each category may consist of one, several, or many words. Units of texts classified in the same category are presumed to have similar meanings. Hence, it is important to use a consistent and thus reliable classification procedure to generate variables that are valid and to draw valid inferences from the text (Weber 1985, p.12).

3.5.2 Advantages and limitations associated with the use of content analysis

Despite its significance as a means of data collection, the use of content analysis as a means of measuring design content and policy coverage in urban design plans has certain advantages and limitations. Content analysis has the key advantage that the plan’s content is all important because the plan is a statutory document and must contain the policies that are considered essential to design and development control. On the other hand, the technique has two limitations. The first limitation is that the presence or absence of a particular design consideration may or may not be significant because some policies may implicitly cover certain design considerations without explicitly mentioning them. Hence, gaps in policy coverage might be effectively covered in other policies. The second limitation is that quantifying the design considerations coverage does not give an accurate indicator about the quality, depth, and effectiveness with which they were covered, nor does it mean that the plan has resulted from extensive analysis and experience (Punter and Carmona, 1994, p.200).

To counter these limitations, it has been essential to couple the quantification of design considerations and policy coverage with their qualitative analysis. This would limit the number of plans that could be qualitatively analyzed with detailed conventional content analysis. Yet, using both computational and manual modes of analysis allows the researcher not only to overcome this limitation, but also to attain advantages of both modes of analysis.

Reliability and validity problems should be considered in content analysis research. Reliability problems usually grow out of the ambiguity of either word meanings, category definitions, or other coding rules. In order to draw valid inferences from the text, it is important that the classification procedure be consistent and thus reliable. A much more difficult set of problems concerns the validity of variables based on content classification. Validity problems grow out of the ambiguity of word meanings and category or variable definitions (Weber 1985, p.15). Validity in content analysis, according to Krippendorff (2004) is classified into three types: criterion validity, content validity, and construct validity (Krippendorff 2004, p.319).

To counter reliability and validity problems in this study, I relied on the code structure and development, content analysis design approach, the usage of manual and computational analyses, and various criteria to analyze the findings and draw inferences. These measures will be discussed later.

3.5.3 Designing the content analysis

This section summarizes the approach used and the factors considered in designing the content analysis that guide the handling of data and make the research reproducible and critically examinable. It discusses two important factors: content analysis design approach and techniques, and coding structure and development that include code and categories classifications.

3.5.3.1 Content analysis design approach

The content analysis design followed the methods described by Krippendorff (2004) and involved two design efforts. The first design effort was design preparatory to content analysis which aims at establishing the analytical construct. It involved two steps:

1. Operationalizing and articulating knowledge into an inference mechanism using available theory and literature.
2. Testing the analytical constructs as hypotheses of correlations between text and extratextual features.

The second design effort was design succeeding content analysis which was tailored to allow testing hypotheses concerning how content analysis results, particularly design content, relate to other variables (Krippendorff 2004, pp.90-93). This design allowed me to assess the correlation between the dependent variable, design content of the selected plans, and the independent variable, usage of 3D digital modeling tools and technologies.

Literature suggests that researchers may enter content analysis from three different starting points: text-driven, problem-driven, and method-driven content analysis. In text-driven starting point, content analyses are motivated by the availability of texts rich enough to stimulate the analysts' interest in them. In problem-driven starting point, analysts start from research questions and proceed to find analytical paths from the choice of suitable texts to their answers. In method-driven starting point, content analyses are motivated by the analysts' desire to apply known analytical procedures to areas previously explored by other means (Krippendorff 2004, p.340).

I have adopted the method-driven starting point to design the content analysis for the following reasons.

1. This approach is motivated by desire to apply known analytical procedures to areas previously explored by other means.
2. It helps to address the limitations of content analysis and thus to expand areas of application of research results.
3. It requires less preparation steps and it faces fewer design issues than do other approaches because selecting the methods limit the analytical options.
4. It can consistently produce interpretable results which may increase reliability and validity (Kripendorff 2004, pp. 355-357).

A key step in research design was to ascertain a reliable, stable, and certain network of correlations to answer research questions. The intent was to create a well substantiated path that connects available text to the needed answers to research questions (Kripendorff 2004,

p. 346). To achieve that goal, the research utilized three sources of knowledge pertinent to the design content of urban design plans:

1. Literature on the theoretical propositions and contextual knowledge to understand the context and conditions under which those correlations are considered stable, such as Krippendorff (2004), Neuendorf (2002), Weber (1985), Devillis (1991) and Boyatzis (1998).
2. Past empirical research that examined the relationship between research variables, such as Punter and Carmona (1994 and 1997 a and b) and Southworth (1989).
3. Available theories and conceptual models that address the research questions and variables, such as Turner (1993 and 1994).

Therefore, content analysis must keep track of the conditions under which such correlation is warranted and when it becomes reliable. These conditions include: the statement of purpose, goals and objectives, analytical content, type of design guidance, hierarchy of policies, and techniques of plans' presentation and expression.

In this study, the content analysis incorporated two techniques: tabulation and cross-tabulation techniques. Tabulation produced two types of tables:

1. Absolute frequencies such as the degrees of emphasis in each design element and issue.
2. Relative frequencies such as the percentages expressed relative to the sample size, proportions to sample size, and contribution to total.

Cross-tabulation was used to test the relation, association or correlation, between the values of the research variables. It produced two types of tables:

1. Cross-tabulation of values of variables within the result of content analysis such as degree of coverage of design aspects across computational and conventional cases, and level of coverage of computational and conventional cases across design aspects.
2. Cross-tabulation of values of research variables that resulted from content analysis, such as level of coverage of computational plans, to values of research variables obtained from questionnaires.

3.5.3.2 Structure and development of coding scheme

Literature suggests that there are two approaches to develop a useful and meaningful code structure: a theory-driven or a prior research-driven approach (Boyatzis 1998 pp. 33-37). In this study, I followed the prior research-driven code development approach which lends itself to axial-coding to address clustering and reconfiguring categories identified or developed by others. As a point of departure, I modified and adopted the recording instructions of research on content analysis with similar aims that have been conducted and published by others, namely Punter and Carmona (1994 and 1997 a and b) and that have proven to be productive. The adoption of such approach has lead to three advantages. The first advantage is that there was no need to develop a new code since the existing one has proven to be productive. The second advantage is that the reliability of recording was greatly enhanced because I relied on a familiar conceptual model (Krippendiorff 2004, p. 132). The third advantage was that driving categories from established theories and conceptualizations of design content in urban design plans has allowed me to avoid simplistic formulations and to tap into established conceptualization. Therefore, I was able to effectively draw on and contribute to existing knowledge.

In coding the text into categories, literature emphasizes that categories should fulfill two essential requirements: they should be exhaustive and they should be mutually exclusive because of the syntactical requirements of subsequent recording and/or computation and for semantic concerns. These requirements assure that the resulting records represent texts completely and unambiguously (Krippendiorff 2004, p. 132). The usage of prior research-driven approach and familiar conceptual models obtained from literature helped fulfill these requirements. In addition, the coding scheme included verbal designations and extensional lists to which I adhered in coding the plans' content.

Therefore, no design elements and issues were excluded because of lack of descriptive terms, and no design elements and issues have fallen between two categories of design aspects or have been represented by two distinct data points. This has helped achieve reliability and consistency in recording the content's categories.

The content analysis involved a scoring and scaling procedure that included four scoring types that were applied depending on their relevance to the variables, themes, and categories as follows:

1. Nominal scoring which generated nominal data.
2. Presence or absence which generated ordinal and nominal data depending upon concepts in the theme.
3. Frequency based on a preliminary presence or absence scoring, which generated ordinal data.
4. Frequency which generated ordinal and interval data depending on the technique of counting the frequency and concepts in the theme.

3.5.3.3 Reliability

Literature suggests that three types of reliability are pertinent to content analysis:

1. Stability: Refers to the extent to which the results of content classification are invariant over time. Inconsistencies may stem from a variety of factors such as ambiguities in the coding rules and in the text, cognitive changes within the coder, and simple errors.
2. Reproducibility: Refers to the extent to which content classification produces the same results when the same text is coded by more than one coder. High reproducibility is a minimum standard for content analysis. This is because stability measures the intraobserver consistency and consistency of private understandings, whereas reproducibility measures the consistency of shared understanding or meanings.
3. Accuracy: Refers to the extent to which the classification of text corresponds to a standard or norm. It is the strongest form of reliability because it is an insurance against intraobserver inconsistency, intraobserver disagreement, and deviations from a standard (Weber 1985 pp. 16-17).

To ensure a higher reliability and validity in this study, content analysis has involved the following steps and measures (see Table 3.2):

1. Using multiple items (Redundancy): Literature suggests that redundancy is not a bad thing when developing a scale and that reliability varies as a function of the number of items in the scale (Devillis 1991 p. 56; Sommer & Sommer 2002 p.160). Hence, as a form of insurance against poor internal consistency, the scale included a number of items larger than the prior research model.
2. Approach of code development: The coding scheme, which adopted a prior research-driven approach in its development, was modified from a coding scheme that has been used in a previous research. This allowed me to create an exhaustive and mutually exclusive coding scheme. According to Weber (1985), this may help the classification scheme to be reliable and consistent (Weber 1985, p. 12).
3. Single-concept coding scheme: Literature suggests that a single-concept coding scheme often has high validity and reliability (Weber 1985, p. 25). The single concept upon which the code is structured was design aspects' coverage. Other concepts such as the modes of presentations are meant to obtain contextual data to record the conditions under which the variables correlate.
4. Using common methods for testing reliability: The study involved using three common methods for testing the reliability of the attitude scale. These methods,

which rest on comparison between two sets of scores, are the following: test-retest, split half (or test-test) and/or equivalent forms. These methods help determine the respective types of reliability: stability, reproducibility, and accuracy (Sommer & Sommer 2002 p. 164; Krippendorff 2004, p.215). With the *test-retest* method, I used the scale at two occasions and the results were compared. The *split half* method involved dividing the scale into two halves which were then compared. The *equivalent forms* method involved constructing two different scales and using them in two forms, and the results were compared.

3.5.3.4 Validity

Validity concerns whether the variable is the underlying cause for item variation. It is inferred from the manner a scale was constructed, its ability to predict events, and its relationships to the measures of other constructs (Devillis 1991, p.43). Therefore, it refers to the correspondence of the categories to the conclusions, and the generalizability of results to theory.

There are three essential types of validity that correspond to these operations (Krippendorff 2004 pp. 18-320):

1. <u>Content validity</u>: Concerns the degree to which analytical categories accurately describe meanings and uses in the chosen text. It includes two subtypes of validity:
    a. Sampling validity which concerns the degree to which a sample of texts accurately represents the population of phenomena in whose place it is analyzed
    b. Semantic validity which ascertains the extent to which the categories of an analysis of texts correspond to the meanings these texts have within the chosen context.
2. <u>Criterion- related validity</u>: Concerns evidence that justifies the results, or whether a content analysis contributes answers to the research questions of other researchers.
3. <u>Construct validity</u>: Concerns the validity of the analytical construct. It provides evidence that justifies the inferences that a content analysis is making. It includes two subtypes of validity:
    a. Structural validity which concerns the degree to which the analytical construct models the network of stable relations in the chosen text.
    b. Functional validity which concerns the degree to which the analytical construct is substantiated (or justified against denial) in use.

Construct validity is directly concerned with the theoretical relationship of the research variable, which in this case is the design content, to the other independent variable(s). It is the extent to which the measurement tool performs the way that the construct it measures should perform (Devillis 1991 p. 46).

To ensure a higher validity in this study, content analysis has involved the following steps and measures (see Table 3.2):

1. Approach to code development: This study has adopted a prior research-driven approach to develop the coding scheme by modifying and adopting the coding scheme of a published research with similar aims and that has proven to yield valid inferences. Yet, I modified it to add further urban design elements and issues to create an exhaustive and mutually exclusive coding scheme that fits the research variables and context. This approach has lead to a reliable and consistent classification scheme. The validity of categories was achieved by using three sources of knowledge: literature, theory, and prior research to arrive at an agreed upon definition of each category of urban design aspects. They have allowed me to avoid simplistic formulations and to tap into established conceptualizations.
2. Single-concept coding scheme: The single concept upon which the code was structured was design aspects' coverage. Other concepts such as the modes of presentations are meant to obtain contextual data to record the conditions under which the variables correlate.
3. Content analysis design approach: The research design involved key steps to ascertain a reliable, stable, and certain network of correlations to answer research questions. The goal was to create a network of propositions which contains a path that connects text to answers to research questions. To achieve this goal, the research utilized three sources of knowledge pertinent to the design content of urban design plans, particularly categories from pervious research in this area with similar aims, and established theories of the context of that analysis.
4. Quantitative and qualitative analysis: Content analysis did not rely only on quantification of design aspects and their constituent elements and issues. It also involved a qualitative analysis to help assess the degree of emphasis with which plans addressed and covered each design aspect. This helped generate nominal and ordinal datasets that were tabulated, cross tabulated, and clustered at various degrees of abstraction to create substantive amount of quantitative data which helped draw inferences and reasonable conclusions.

Table 3.2. Summary of the measures adopted to increase content analysis reliability and validity

No.	Measures	Reliability issues	Validity issues
1	Using multiple items (Redundancy)	Stability	Content validity
		Reproducibility	Construct validity (Structural and functional validity)
		Accuracy	
2	Approach of code development	Reproducibility	Content validity
		Accuracy	Criterion validity
			Construct validity (Structural and functional validity)
3	Single-concept coding scheme		Criterion validity
			Construct validity (Structural validity)
4	Using common methods for testing reliability:		
4.1	Test-retest	Stability	
4.2	Test-test (split half)	Reproducibility	
4.3	Equivalent forms	Accuracy	
5	Content analysis design approach		Content validity
			Construct validity (Structural validity)
6	Quantitative and qualitative analysis of case studies		Content validity
			Criterion validity
7	Strategy of samples selection		Content validity
			Construct validity (Structural and functional validity)

3.5.3.5 Selecting a sample of case studies

The process of determining the sample of cases to be included in the content analysis involved two stages to select a purposive sample of cities or cases that may help investigate the relation between the research variables.

In the first stage, I selected a purposive sample of six US cities, each of which should fulfill two basic conditions. The first condition is that a city employs 3D digital urban modeling in the planning department. The second is that the city is known with established history of urban design and planning practice and /or houses academic or research institutions pertinent to urban design practice and /or 3D modeling in urban design practice. This condition is important for two reasons. The first reason is that it may insure that the selected cities are of high and comparable levels of traditions in urban design and planning based on expertise of their professional staff, previous design and planning products, and participation of academic institutions and/or modeling firms in planning practice in those cities. Such high and comparable levels may reduce the effect of the confounding variables, namely the firm/department culture, political factors affecting the decision-making process, and participants' profile and experience. Second, it would insure that the planning department has already established a culture and a sound level of professional expertise in developing conventional plans. The comparison of such conventional plans with computational plans may allow examination of the impact of using 3D digital modeling and IT tools on the quality of the design plan, and thus to ensure achieving internal validity. In some cases, such as Chicago, the computational plan of its central area was based on a previous conventional plan developed on 1983.

The sampling frame from which the cases were selected was the result of surveys conducted by the Center of Advanced Spatial Analysis (CASA) at the University College London for cities of greater than 1 million population that developed 3D urban models (Batty et al 2000; Shiode 2001). The cities selected as case studies were Philadelphia (PA), Pittsburgh (PA), Chicago (IL), New York (NY), Milwaukee (WI), and Boston (MA). These cities, according to Gosling and Gosling (2003), Punter (1999), and Batty et al (2000) employ the best urban design practice and the most advanced 3D digital modeling in urban design practice among US cities.

In the second stage, we selected from each of the afore-mentioned cities a purposive sample of two or three urban design plans, one (or two) of which was developed using digital tools and specifically 3D digital modeling, and one developed using conventional tools. A selected plan should fulfill two main conditions. The first condition is that it should be recently developed (after 1998), and second condition is that it should be either at a scale of a district, downtown, or city center. These conditions were explained in detail in section 2.5.2.1. They are meant to reduce the impact of the control variable, and to ensure that all the design aspects that the cases should configure are of comparable level (see Table 2.3). All those plans are available on the Web, and were downloaded from the websites of the departments concerned with urban planning, design, and development in their respective cities. A list of those plans and their host cities is included in Appendix B.

The sample size is small enough to subject it to content analysis to examine its design content without requiring an overwhelming effort. Although choosing a purposive sample limits generalizing from the study's findings, the purposive sample allowed investigation of their design content to produce rich qualitative and quantitative data sets with high reliability that helped assess the impact of 3D modeling usage on their design content.

3.6 The Structure of the Coding Manual Used in This Research

The application of content analysis requires the development of a coding manual to analyze data in the plans documents. This section will outline the goal and structure of the coding manual that was used in this research to analyze the selected cases studies.

The content analysis of the selected cases is meant to document and assess four main issues: the statement of purpose, the extent with which the selected cases have covered and addressed the basic design aspects, the cross-referencing between design policies at various scales of intervention, and presentation modes. The structure of the coding manual was organized into four major sections:

1. General approach: The general approach of each plan embraces the stated purposes for producing the plan, site analysis upon which the design plan was based, structure of the plan, and type of design guidance. The levels of site analysis were classified into four types: explicit, implicit, integral, and no evidence of analysis. The types of design guidance were classified according to their emphasis on prescriptive or performance guidance into one of four categories: highly prescriptive guidance, enabling guidance and neutral /framework guidance, or a combination of two or more of types (Turner 1994, p.297).
2. Design content: The design content embraces three interrelated tiers. The first tier, design considerations, expresses the qualities that urban design, as a process, seeks to achieve. These considerations, according to Turner (1994), are visual, functional, environmental, urban experience, and specific design considerations. The second tier, recommended design policies of the urban design plan, identifies the key factors and considerations that designers should take into account. The third tier includes the design aspects addressed in the policies and the degree of emphasis on each design aspect.
3. Hierarchy of policies: The hierarchy of design policies embraced the scales of intervention (district, city, city region, regional), and the cross-referencing between design policies at various scales of the intervention.
4. Presentation and expression: The content analysis included a brief study and characterization of how the plan was presented. The plan presentation and expression included three major components:
    a. Means of communicating and techniques to convey information such as the availability illustrations and maps and the availability of 3D illustrations and modeling.

b. Approaches of presenting the design strategies such as breaking the key design strategy into numerous maps according to areas or themes, or using the layering and de-layering, and graphic reduction.
c. Techniques of presenting urban design policies such as computer 3D modeling, physical models, 2D maps, perspectives and photographs.

Each of these sections is explained in detail in the coding manual found at appendix C. It explains each major design element and lists the major constituent sub-elements and design aspects examined in the content analysis.

3.6.1 The general approach

The general approach section addressed the following:

1. Purposes of producing the plan
2. Site analysis
3. Structure of the plan
4. Type of design guidance

3.6.1.1 Purposes

The statement of purpose summarizes the plan's main functions and draws attention to design matters to ensure that they are formally acknowledged as valid requirements (Turner, 1994, P.304). The goal was to assess the consistency between the stated purposes and the actual content of the plans, and to assess the emphasis placed on design aspects generally, and 3D design aspects in specific. It involved two questions:

1. What are the main stated purposes of the urban design plans?
2. To what degree has the statement of purpose emphasized any of the following design considerations: visual, functional, environmental, urban experience (public perception), and specific design considerations? Assessment of the second question was tabulated as one of three degrees of emphasis: non-existent, minor emphasis, or significant emphasis.

3.6.1.2 Site analysis

The plans were examined in order to document the frequency with which reference was made to the analysis criteria throughout the plan, and to assess the level or type of site analytical content within each plan. The coding manual was developed using several sources from prior research. Deriving from previous research, three elements were identified a priori as forming the basis for appraisal: analysis of the fabric of the locality, analysis of development pressure leading to particular design problems, or analysis of public concerns (Punter and Carmona 1997 b, p.122). The examination of analytical content however was broadened to include five major analytical elements: land-use and transportation, architecture, streetscape and open space, socio-economics factors, user perception and behavior, natural factors, and history. The code's structure has explained and detailed each major element with a list of their constituent sub-elements and design aspects. This list has adopted and modified the list developed by Southworth (1989) in his research that used content analysis to analyze 70 urban design plans in US cities (Southworth 1989, pp 377-379). Use of southworth's list was meant to establish consistency in analyzing the plans' content to maintain reliability in coding its qualitative data.

For each plan, four levels of analysis were identified: explicit, implicit, integral, and no evidence of analysis. Explicit analysis is one that is evident in the plan and provides a clear analytical basis for policy making. The plans that involve this type of analysis respond directly to local conditions, often tailoring policies specifically to individual localities and often including details of the analysis within the plan. Analysis that is integral to the plan sets future directions for development, although it tends to be largely descriptive, and rarely develops clear design principles. In implicit analysis, plans provide evidence of careful analysis but lack clear statement of the analytical process or conclusions. Some plans show no evidence whatsoever of analysis of the locality, which may be surprising, but has been observed by other researchers (Turner 1994, p.293).

3.6.1.3 Structure of the plan

The plans' were examined to find evidence whether they had been prepared by breaking the key strategy map into numerous sub-area maps. The data was tabulated into three levels of evidence: significant, minor, and no evidence.

3.6.1.4 Type of design guidance

The plans were examined to assess which elements of guidance are more likely to influence the design development on the site, and to note any particular emphasis on either prescriptive or enabling guidance. The coding structure adopted and modified the definitions developed by Turner (1994) which include three broad types of design guidance. The first type, highly prescriptive guidance, contains fixed requirements for mix/density, sets out a road layout, and provides an indicative site layout. The second type, enabling guidance, places most emphasis on design and the relationship between buildings, vehicles, and the landscape, with minimal restriction on layout and access position. The third type, neutral/framework, is neither prescriptive nor enabling but providing guidance and suggests a framework within which the designer might work (Turner 1994, p.297). Data was tabulated into four categories that included the three types of guidance: highly prescriptive, neutral/ framework, enabling, and a combination of two or more types.

3.6.2 Design content

The design content embraces three tiers as follows:

1. The first tier: Design considerations
2. The second tier: Design policies of the urban design plan
3. The third tier: Design aspects addressed (covered) in the policies, and the degree of emphasis on each design aspect.

Following is an explanation of each tier and its constituents.

3.6.2.1Design considerations

Design considerations express the qualities that urban design, as a process, seeks to achieve. Literature suggests that there are five design considerations: visual, functional, environmental, urban experience (public perception), and specific design considerations (Rowley, 1994, p.182). These categories of design considerations form a basic framework which collectively encompasses most of the factors urban designers should consider. To avoid any overlap or mix in data coding, the coding manual defined those considerations and listed a breakdown of their constituent elements. The coding manual involved assessing the degrees of emphasis the plans made on each design consideration. The assessment was tabulated under three degrees of emphasis: no emphasis, minor emphasis, or significant emphasis. Definitions of these consideration and their constituent elements are given below.

1- Visual considerations

Visual considerations range from design and siting of a single object on a space, to a concern for buildings seen in their immediate context, to city-wide concern for the skylines, to siting of high buildings or other landmarks. They encompass issues such as:

- Aesthetics
- Environmental psychology and perception
- Urban form
- Spatial definition and composition
- Serial vision
- Color, texture, and decoration

- Landscaping

<u>2- Functional considerations</u>

The functional considerations include issues such as:

- Layout and capacity of road network
- Car parking provision
- Refuse collection facilities
- Layout, safety, and convenience of pedestrian network or routes
- Design of open space (in connection with movement and use)
- Mix, intensity, and compactness of activities and uses
- Privacy
- Protection and security against crime

<u>3- Environmental considerations</u>

The environmental considerations include issues related to the ecological impact and “green” considerations of urban design such as:

- Provision of natural light, sun, and shade in spaces;
- Avoiding noise, glare, air pollution, and wind;
- Designing with the micro-climate;
- Energy efficiency;
- Wildlife support and nature conservation;
- Pollution and waste control; and
- Sustainability.

<u>4- The urban experience (public perception)</u>

Issues related to attributes of place rather than physical spaces have been grouped as the urban experience. The keywords are: complexity, diversity, activity, surprise; public perceptions, associations, and meanings, and the history and genius loci of settlements. These issues include:

- Diversity of architecture and other visual stimuli;
- The amenities such as lighting, street furniture and security measures;
- The open spaces for active and passive recreation; and
- Social interaction of diverse people in these spaces.

5- Specific design considerations

In addition to the considerations of the built environment, a range of specific design concerns should infuse the remainder of the plan to ensure that design quality is considered in relation to all policy areas. Such concerns apply over and above the issues already included in design-specific policy. An indicative range of such considerations is listed by policy area below:

- The rural environment;
- Transport and infrastructure;
- Employment and local economy;
- Town centers and retail development;
- Housing; and
- Sports, leisure, and community facilities (Carmona, Punter, and Chapman 2002, p.30)

3.6.2.2 Design policies of the urban design plan

The design policies identify the key factors that designers should take into account. A suggested agenda for urban design policies include the policies explained in sections 2.2.1 through 2.2.9. The coding manual included instructions for documenting the degrees with which each plan emphasized the design elements and issues that constitute each urban design aspect.

1- Sustainable urban design

Sustainable development should be a principal goal of urban design at all scales such as buildings, spaces, quarters, and settlements (Carmona, Punter, and Chapman 2002, p.60).

2- Townscape (visual composition of space)

Townscape policies are meant to embrace a concern with four main design issues:

1. The visual relationships of a development to its site and wider setting
2. Defining the appropriate townscape role of a development including its relationship to and provision of visually interesting public spaces and buildings
3. The protection of both local and strategic views, particularly where topographic or historic factors have combined to create particular assets of the skyline or the natural setting of a settlement (Carmona, Punter, and Chapman 2002, p.60).
4. Enhancing the streetscape in new development and provision of high quality hard landscape (Carmona, Punter, and Chapman 2002, p.60; Punter and Carmona 1997, p.156)

<u>3- Urban form (three-dimensional built volume)</u>

Urban form policies should include and emphasize four design considerations:

1. Appropriate scale of development through control of building envelope incorporating density, height, and massing concerns, but emphasizing the creation of human scale consistent with the context.
2. Key character-giving elements such as:
    a. relative enclosure of public spaces
    b. continuity of the building line
    c. diversity and pattern of the established urban grain, and block and plot sizes.
3. Tailored density allocation (in existing urban areas) to the existing character of the area and to the relative accessibility, and should not override other key contextual considerations.
4. Considerations of sunlight, daylight, and microclimate to ensure good living and working conditions, comfortable public spaces, and energy conservation.

<u>4- Public realm (the social experience)</u>

Public realm policies emanating from social perspectives can complement townscape and urban form policies. They are concerned with the following issues:

1. Encouraging legible, comfortable, stimulating, and safe streets and public spaces (e.g. active frontages at ground level whenever possible).
2. Incorporating public perceptions of the identity and quality of the built environment such as:
    a. Permeability of blocks and neighborhoods
    b. Vitality
    c. Comfort
    d. Environmental quality
    e. Public art (to create visually rich public realm)
3. Embracing design-against-crime (safety) principles including:
    a. Consideration of the defensible space
    b. Surveillance
    c. Visibility
    d. Lighting
    e. Other security measures
4. Functional concerns such as:
    a. Parking

b. Servicing
c. Disabled access considerations
d. Relationship between public and private spaces

5- Mixed use and tenure

The mixing of uses should be a fundamental policy objective in order to create more sustainable living and movement patterns, and more vital and viable urban centers. It would also aim at the provision of adequate and attractive amenity spaces in residential developments.

6- Connections and movement

Accessibility considerations will be important to the detailed design of public spaces. Policies should seek to achieve the following:

1. Promote walking and cycling (as the most sustainable modes of transport)
2. Ensure the quality of walking and cycling (frontage controls and enhancements)
3. Maximizing the local autonomy of residents
4. Structuring the development around energy-efficient movement networks
5. Prioritizing safe, easy, and direct pedestrian movement
6. Creating a network of attractive and well-connected public space.

7- Architectural character

The architectural character includes three hierarchical levels of design considerations:

1. Coverage of architectural form considerations which include building spacing, bulk, design character, form, height, massing, scale and size.
2. Coverage of elevational considerations which include contemporary design, design vocabulary, relation of design vocabulary with surrounding environment, style, and richness and visual interest
3. Coverage of elevational detail considerations which include materials, roofscape, proportions, fenestrations, detailing, color, rhythm, silhouette/profile, vertical/horizontal emphasis and texture.

8- Landscape architecture

The landscape architecture character includes three hierarchical levels of design considerations:

1. Coverage of strategic landscape considerations which include boundaries, existing vegetation, landscape survey, open space, topography and urban edge
2. Coverage of soft (green) landscape considerations which include soft landscape, trees, species, buffers, water, and landscape layout
3. Coverage of hard landscape considerations which include floorscape, hard landscape layout and planning, street furniture and lighting.

9- Conservation areas and listed buildings

Content analysis of the design content includes documenting and assessing the design aspects of special areas and/or areas that are visually, functionally, physically, or historically significant. It also includes documenting and assessing the design aspects of the proposed development within these areas. These design aspect include the following characteristics:

1. Townscape and urban form characteristics which include building line, density, character, grain, morphology, urban space, landmarks, authentic setting, skyline, topography, and views.
2. Architectural form and detail of the development in conservation areas and/ or areas of visual interest. These, in turn, address the following secondary characteristics:
    a. Architectural form, grain, and morphology aspects
    b. Elevational considerations
    c. Detailed elevational considerations
    d. Coverage of listed building policies such as rehabilitation, preservation/ conservation, extensions, adaptive re-use, infill development, renovations.

3.6.3 Hierarchy of policies

The hierarchy of design policies includes two components:

1. The scales (or levels) of intervention. The coding manual included three scales or levels of design intervention:
    a. Level 1: Strategic urban design at the city/conurbation level
    b. Level 2: Strategic urban design at the city/district level
    c. Level 3: Urban design at the level of individual spaces or groups of spaces.

The levels of intervention coding manual were determined according to two factors: issues addressed at each design level, and scope of intervention of each design level (Frey 1999, p.21).

2. The cross-referencing of design policies across the multiple scales or levels of design intervention, or the link between the overall design strategy and detailed design policy.

The availability and emphasis on cross referencing of design policies in plans' documents are organized as: no emphasis, minor emphasis, or significant emphasis.

3.6.4 Plan presentation and expression

The content analysis should include a brief general analysis of plan presentation with the design or design-related sections of the plan. The plan presentation and expression embraces three major components:

1. Means of communicating and techniques to convey information such as:
    a. Availability of illustrations and maps
    b. Availability of 3D illustrations and modeling
2. Approach of presenting the design strategies
3. Their contribution towards comprehensive, readable, lively, and attractive documents.

The availability and extent of usage of illustrations in plans' documents are organized under three levels of usage: unavailable, minor usage, and significant usage. The code's structure documents and assesses the following issues of illustrations' usage:

1. Reference to illustrations in the text
2. Explicating the analytical content
3. Explicating the purpose of the plan
4. Using illustrations to portray any specific design policy such as :
    a. The spatial design strategy
    b. The location of conservation areas
    c. The areas of townscape differentiation
    d. View corridors
5. Providing a source of contextual information to the reader

3.6.4.1 Approach of presenting the design strategies

The content analysis assesses the availability and emphasis of the following presentation approaches. The assessment will be organized under three levels: unavailable, minor emphasis, and significant emphasis:

1. Breaking the key strategy map into numerous sub-area maps

2. Superimposing the suggested design alternative (s) as a (2D) map on the study area map
3. Superimposing the suggested design alternative(s) as a (3D) model on the study area (3D) model
4. Breaking the key strategy plan into numerous themes or categories according to certain criteria
5. Using the layering and de-layering techniques
6. Combining design policies in one overall design map.

3.6.4.2 Techniques of presenting urban design policies

The content analysis documents and assesses the extent to which various computational and conventional presentation techniques were used to analyze and represent the constituent urban design policies of the plan.

CHAPTER IV

USING 3D DIGITAL URBAN MODELING AND INFORMATION TECHNOLOGY IN URBAN DESIGN PRACTICE

The previous chapter discussed the constituents of design content in urban design plans and explained the usage of content analysis to measure it. It presented a view that the design content of plans in much of current urban design practice in US cities lacks the coverage of basic design aspects of the built environment. The hypothesis of this research is that an urban design process that incorporates 3D modeling can increase the quality and comprehensiveness of the design content of the plan. This chapter discusses how 3D modeling can support urban designers in the design process. It aims to construct a theoretical proposition for the relation between 3D modeling usage and the design content of urban design plans. Thus, I present a literature review that investigated 3D modeling usage and its role in supporting designers in the design process. This chapter describes the purpose of usage and types of 3D digital models, and outlines the methods and functionalities of 3D modeling. It outlines the potential barriers to widespread application in the field and the emerging capabilities in 3D modeling arena. This chapter explains the main 3D modeling techniques to visualize and configure urban design elements and issues. Finally, the chapter outlines a theoretical proposition to illustrate the possible causal relation between 3D modeling usage and the design content.

4.1 Introduction

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. Consequently, potential adopters hesitate 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. 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. Therefore, there is 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.

4.2 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. This section provides a review of the techniques and commentary that attempts to explain the impact, or lack of impact, of 3D modeling in urban design. This research applies a novel perspective of examining both the methods of urban design, specifically the use of 3D modeling, and the quality of urban design to attempt to reveal a correlation or causal relation.

Literature suggests that a methodological framework underlying the usage of 3D models in urban design practice is required. Pietsch (2000), for instance, suggests that their effective usage requires a framework balancing abstraction, accuracy, and realism (Pietsch 2000, p. 525). This framework did not consider how models' types affect modeling methods and applications. Such a framework could outline types of 3D models, the range of purposes for 3D models, and the operations or actions available with specific models. Therefore, I approached 3D modeling with respect to two aspects: first, the roles and types for which models were designed, and second, the key techniques used to implement and deliver various visualization styles.

4.2.1-Role and types of using 3D models in urban design practice

There have been some limited approaches to define the role of 3D digital models in urban design practice. Shiode (2001) for instance emphasized only their analytical role. He suggests that their role is defined by the degree of their utility and analytical features. He also argues that their potential for extensive and alternative use will be directly reflected where GIS will prove to be powerful (Shiode 2001, p.4). Besides the analytical role, digital modeling may have a more profound role when it shifts designers' emphasis into new directions to gain new insights. It may establish new possibilities for urban analysis that involve innovative ideas such as the " city experimental labs" which are specifically for morphological analysis of spatial volumes (Dokonal, 2002 a, p.418) Such a shift becomes a means to rethink the urban design process and particularly the significance of 3D creativity.

It also underscores the importance of a methodological framework underlying their usage in urban design practice.

Batty et al (2004) defined four distinct roles of 3D models: exploration, explanation, engagement, and education. A model and its visualization may stress these four roles in different ways, with one purpose dominating (Batty et al, 2004, p.9). The first role, exploration, is more geared to investigate how models translate data inputs and outputs. The second, explanation, involves using visualization to confirm or falsify some theory that is embodied in the model. The usual processes of comparing patterns in the input and output data is central to this. Third, engagement is geared towards forecasting for policy-making, 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).

There have been several typologies of urban model. Shiode (2001), for instance, classified 3D digital models according to their degree of realism. The degree of reality is defined as the amount of details captured and reproduced within the model (Shiode 2001, pp.2-3). His typology includes six categories of a variety of geometric content that range from low geometric content such as 2D maps and digital orthography, to high geometric content such as detailed volumetric CAD models that represent the architectural characteristics of a building with detailed geometries (see Figure 4.1). However, it should be noted that the amount of geometric details does not necessarily reflect how much of a sense of reality the model can actually offer. In fact, rapid and inexpensive modeling techniques such as texture mapping and panoramic data capturing prove to be successful with the generic audience (Leavitt 1999, p. 4).

Klassen (2002) classified models into three types according to their relation to reality: concrete, conceptual, and formal. Concrete models, such as urban /architectural three-dimensional models, are composed of empirical identities. They feature spatial dimensions and allow realistic experimenting. Conceptual models, such as design sketches and 2D spatial models, are composed of conceptual identities. They are mental constructions such as theories or sketches referring to the reality and are used as thought images, yet they are rarely used by architects/ urban designers to test their design products. Formal models, such as mathematical models, summarize reality in a series of equations. They are un-interpreted syntactic systems of symbols that correspond to abstract names (Klassen 2002, p.183).

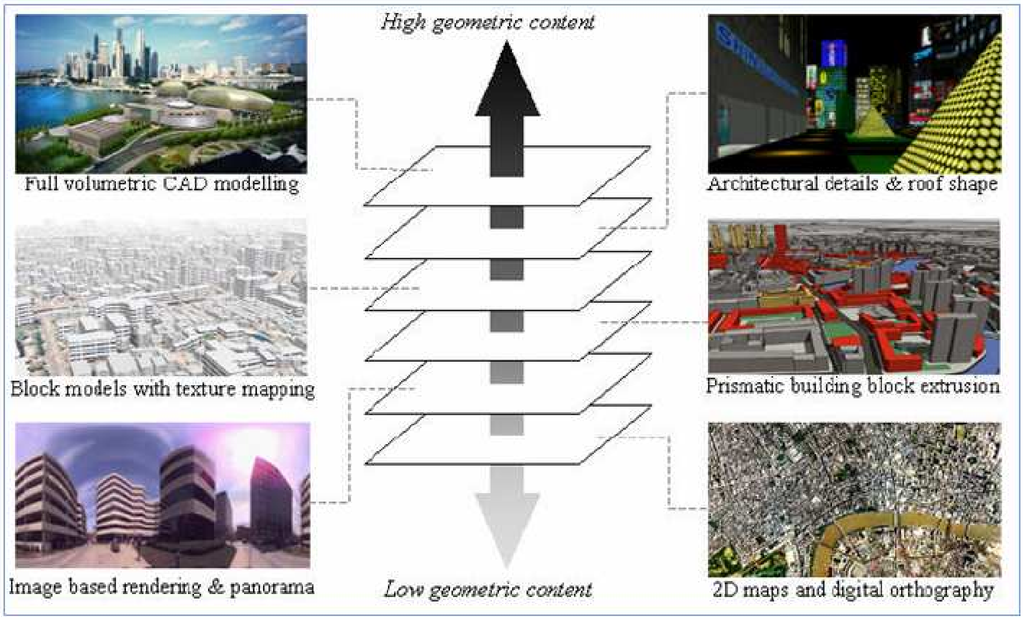


Figure 4.1: A Typology of 3D Urban Models according to Their degree of realism (Shiode 2001, p.3)

The wide variety of classification factors and thus types of models within each factor demonstrates diversity in the current digital modeling arena. One author argues that the decision to select an appropriate type of 3D digital model should be dictated by the needs of a project to fulfill the required levels of realism while keeping the cost down (Kim 2005, 57). He suggests that the interrelationship between realism and data accuracy should be considered. However, the choice of the model's type should consider other essential factors, such as the intention with which reality is approached, data accuracy, personal preferences of designers and model developer, and model's purpose and functions (Klassen 2002, p.186). These factors should determine the model's type, which in turn affects the methods and techniques of its usage. The 3D digital 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 functions, the properties of and the structural and spatial relations between elements of the built environment. The following section explains some of those methods and functions.

4.2.2 Methods and functionalities of 3D modeling

The significance of 3D modeling usage has not been examined yet by any systematic research that may identify the appropriate methods and applications of their usage in urban design practice. There is little systematic research regarding the application of these technological capabilities to the actual theory and practice of urban planning and design (Simpson 2001, p.363).

A few researchers have addressed that support thoroughly, but focused only on the significance of GIS capabilities. Batty et al (1998 a) for instance, identifies how main GIS functions namely thematic mapping, overlay analysis, and structured query, may support the urban design process (Batty et al 1998 a, p.10). Huang et al (2001) and Shiffer (1995) only highlighted the impact of 2D and 3D visualization on the decision-making process in large geographical areas. They ignored the fact that urban design practice may control the urban environment at various interrelated hierarchical scales.

Batty et al (1998 b) suggested a coherent, well-defined framework of four main categories to classify the various modeling methods and functionalities. Each category deals with certain design tasks as follows (Batty et al 1998 b, pp. 9-11):

1. Navigation functionalities: Traversing and exploring the urban environment in the broader sense including exploring the information contained within the virtual environment.
2. Communication functionalities: Interacting with other users and reaching agreement or otherwise over common problems and goals. Interaction involves extracting various abstractions from the urban scene.
3. Analytical functionalities: Grouping, ordering, and transforming information using a variety of formal and informal scientific procedures to abstract, generalize, and distinguish information.
4. Manipulation functionalities: Editing, adding, erasing, and changing information such as in creating or modifying a design alternative.

The definition of each category has created a coherent, well-defined framework which allows classifying the array of modeling functionalities and techniques with minimum overlapping or duplication. The role of these functionalities in the design process is explained in section 4.4.

Some experts have suggested methods by which these functionalities should be used in core design tasks, such as rapid and effective storage and retrieval of information, various visualization techniques to inform survey and analysis, and different strategies for communicating information, design concepts, and plans within and across design teams. Other methods such as rapid exploration of alternative concepts would help stakeholders comprehend and accept those concepts and thus empower their participation in decision-making (El-Araby 2002, p.461, p.457; Klosterman 1997, pp.3-6; Poerbo 2001, pp.113-114; Shiode 2001, p.263). However, these researchers have not formulated any comprehensive framework of applications.

Broader and inclusive framework was suggested by Koshak (2002). He suggested that the urban design applications are:

1. Visualization: Using 3D models to generate 2D and 3D visualizations to represent the study area (see Figures 4.2 and 4.3).
2. Analysis: Integrating geometric and non-geometric information of various entities in an urban setting to facilitate both spatial and statistical analysis that help the analyst to discover and understand its characteristics (see Figures 4.3, 4.4 and 4.5).
3. Simulation: Simulating pedestrian and vehicular movement in an urban environment (see Figures 4.6 and 4.11).
4. Decision-support: Testing the effects of certain important decisions on urban environments (see Figures 4.7, 4.8 and 4.9).
5. Collaboration: Visualizing and discussing urban design proposals by multiple stakeholders to foster their participation in judging future developments of urban environments (see Figure 4.10) (Koshak 2002, pp. 76-80).

However, the main difficulty in this framework lies in the fact that classifying the array of modeling methods and applications involves a certain extent of overlap and duplication.

Some researchers have expressed their faith in the applications and potential impact of 3D modeling functionalities on urban design (El-Araby 2002, p. 457; Langendorf 2001, p.335; Laurini 2001, p.192). Peng et al (2002), for instance, provided in detail a well-defined methodological framework of the functions of Sheffield City Model (SUCoD). He made the case that SUCoD can evolve into an integrative dynamic urban modeling platform to support collaborative multi-disciplinary urban design and research (Peng et al 2002, pp. 87-89, p.102). However, it lacked the analytical tools, such as the GIS, that are required to effectively support the urban design process or urban environment performance analysis. This has confined its utility to storage and retrieval of historical datasets to inform historical reconstruction of Sheffield (see Figure 4.12). Shiode (2001) emphasized digital 3D visualization methods and focused on their relative merits over their traditional counterparts. He argues that the combination of diverse modeling methods and functions may lead to the emergence of a wide range of visualization efforts that facilitate understanding the urban structure, mechanism of urban growth, spatial analysis, and planning in the wider context (Shiode 2001, p.264). Their usage would help visualize urban and built environments and provide the option of delivering relevant information in an intuitively comprehensive form.

The importance of 3D digital modeling functionalities and methods lies in the potential improvement of the quality of the decision-making process. These tools may help establish greater certainty and objectivity which may translate into greater confidence in decisions made by various design participants.

Figure 4.2. 3D digital model of Boston, MA representing the urban form and townscape and their relation with their urban context (EarthData Solution 2005).

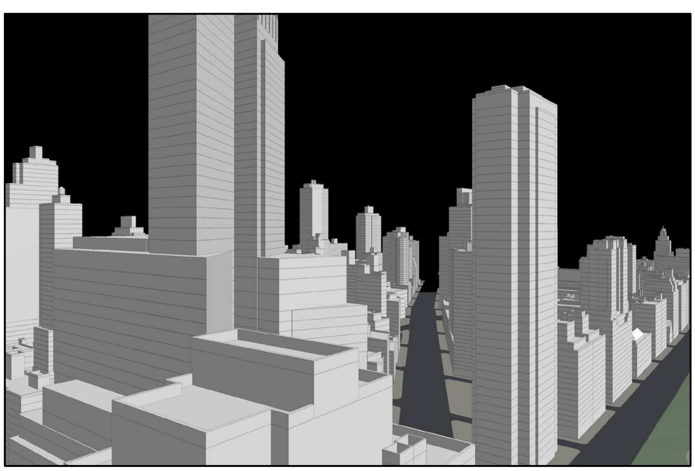
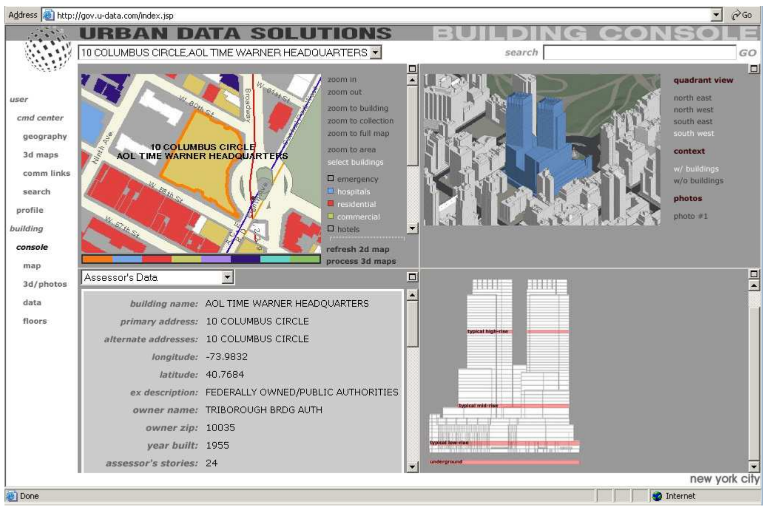


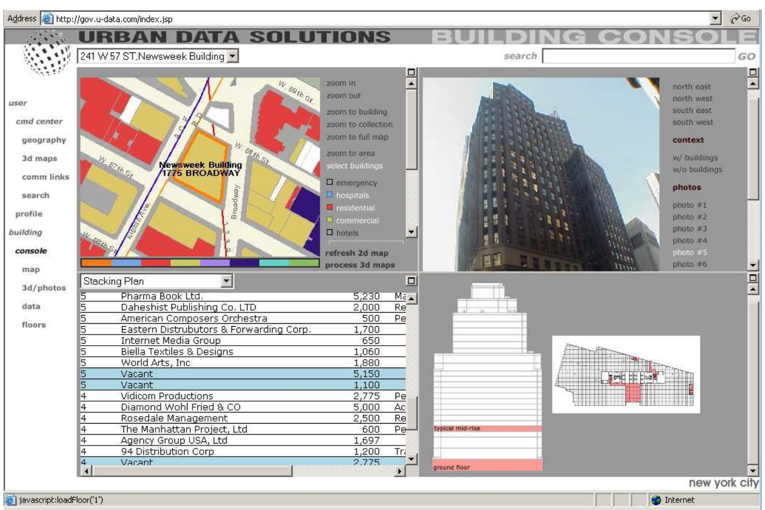
Figure 4.3. Positioning the viewer virtually anywhere to navigate the study area and analyze the characteristics of and relations between its urban elements and issues (EarthData Solution 2005)

Figure 4.4. Integrating multiple types of spatial data and representing it with various levels of representation (EarthData Solutions 2005).

In this modeling system, analytic results can be posted or linked to geographic features in the database and visualized. The system is interoperable with a myriad of other systems and existing analysis platforms.



Here, Time Warner Headquarters, in the lower left reveals tabular assessor's data that is linked to the building.



The power of third party databases can be leveraged through this modeling system (SIMmetry) to produce information rich displays. For example, here is a stacking plan that reveals tenant data in a building.

Figure 4.5. SIMmetry a 3D modeling system that allows designers to retrieve, display and manipulate spatial and non-spatial data to facilitate visualization and analytical applications (EarthData Solutions 2005).

Figure 4.6. 3D modeling to simulate the visual experience and impact of the East River Park proposed in East River Waterfront Study in New York City, NY (East River Waterfront Study, 2005, p.57)

Figure 4.7. Visualizing, testing, and assessing the impact of alternative design strategy proposed in Manhattan, New York City (EarthData 2005).

Figure 4.8. Thematic mapping and selecting groups of building according to certain criteria such as land-use, height, and ownership, etc.(EarthData 2005).

Figure 4.9. Visual Impact analysis of a design proposal in Chicago Central Area on its urban context (SOM 2005).

In May 2000, plans for the development to the City Council were unveiled by showing a video walk-though of the real-time model on a large-screen projection system. By situating the proposed development in the context of downtown, the model allowed for both broad discussion of urban planning issues and specific design questions such as the District's impact on the Figueroa corridor.

Figure 4.10. Virtual Reality Models and Visual Impact Study of urban design proposals in Los Angeles, CA (UST, Jepson and Friedman 2000).

Figure 4.11. Downtown Los Angeles (Jepson and Friedman, 1998)

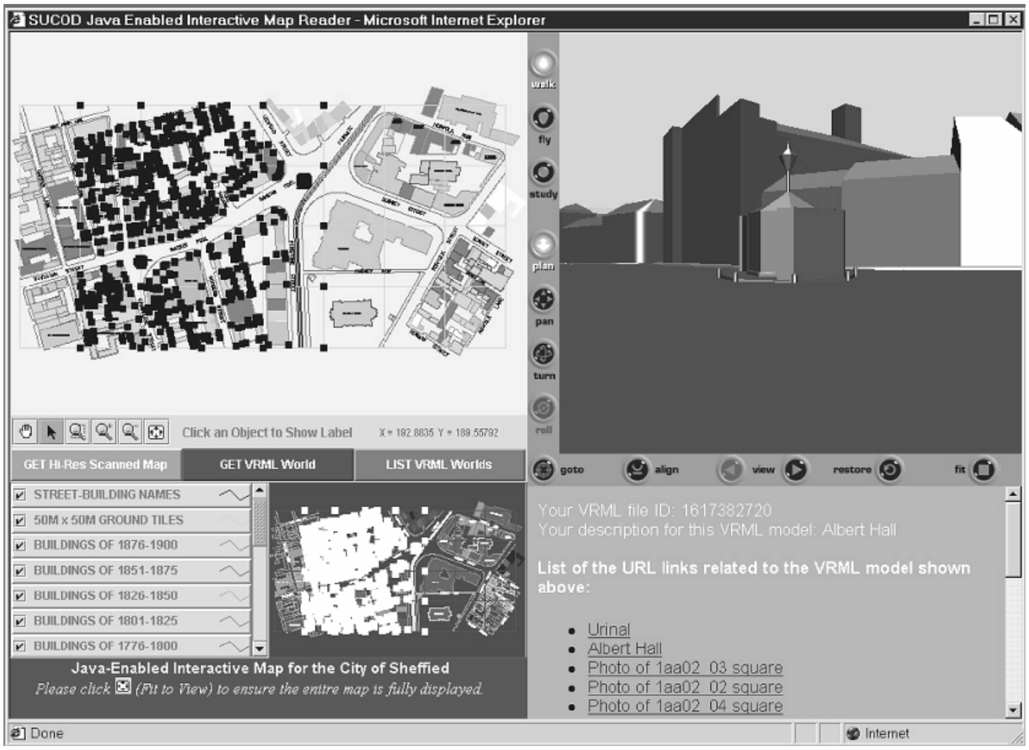


Figure 4.12. Spatial-oriented retrieval of hypermedia documents in SUCoD,, a three-tier modeling project for the historical district of Sheffield, UK. The overall Goal of this project was building an urban information system that may enable information retrieval according to users' needs. Dynamic listing of URL links shown on the right lower frame according to the spatial selection made on the Java map on the left upper frame.

4.3 Limitations and Emerging Capabilities

There are many potential barriers to widespread practical usage of models in the field. Failure to use models effectively in actual practice may result primarily from three factors: first, inadequate support for design within the current generation of applications; second, limited understanding of the proper role these tools should play; and third, little consensus on the methods by which they should be used.

In the first factor, literature suggests that many current 3D models are closer to iconic than to symbolic models that are built around mathematically-simulated urban processes (Batty et al 2000, p.2). They may be defined as static spatial models that focus on spatial rather than spatial-temporal dimensions and relations of the urban elements (Klassen 2003, p.65). This no longer suffices for two major reasons. Urban designers pay more attention now to the content of the design rather than the intermediate artifacts such as 3D renderings (Poerbo 2001, p. 111). Second, most 3D models have not been developed from the perspectives of spatial databases technologies and associated analytical functionalities (Batty et al 2000, p.24). Accordingly, they lack the capabilities to perform the multiple interactive and dynamic functions for which 3D modeling is required. Therefore, their modeling functions, types, and techniques do not support effectively the design of 3D aspects.

In the second factor, the confusion about their role and usage is due, in part, to their problematic type of relationship with the built environment (Fraser and Bjornsson, 2004, p.178). Klassen (2000) coined the term *model overextension* to refer to the situations when designers are not sufficiently conscious of the fact that they are working with only models of reality. For urban designers, these situations may appear as insufficient insight into the relation between model and reality, in spatial and temporal confusion of scale, or in confusion of stand points from which observations are made (Klassen 2002, p.188).

The third factor is unsophisticated and inappropriate use of models for design (Whyte 2002, p. 93). The availability of computational power and 3D modeling is not matched by a methodological framework underlying their usage in actual practice. Most computing applications in architecture and planning are sporadic transfers of technology that may resolve isolated problems but do little to relate the solutions they provide to their wider context. Their current usage is meant to improve efficiency and productivity rather than to invent or apply new forms of expression (Koutamanis 2002, p. 231).

Ineffective usage of digital models may stem also from the fact that there is little systematic research regarding the application of their capabilities to the actual theory and practice of urban planning and design. Much of the literature investigating these functions is either descriptive or addresses their usage in isolated site-specific rather than city-wide or district-scale projects. It ignores the fact that urban design practice may control the urban environment at various hierarchical scales and thus requires integrating and managing a rich hybrid of geometric, geographic, and annotative information and datasets. A few researchers addressed that usage thoroughly but focused only on the significance and usage of certain functions such as GIS analytical and representational functions (Batty et al 1998 b, p.10). These functions would not help visualize the area in its full 3D spatial context within a comprehensive methodological framework.

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). Patterns and processes of the urban complexity can be better explored and explained through visualizing the data, the simulations, and the outcomes that such models generate (Batty et al 2004, p.1). Therefore advanced computational tools such as the recent developments in scientific and dynamic visualization should be effectively used in the design process. In scientific visualization, the close correlation of photorealistic and analytical representations clarifies and demystifies designers' insights and intuitions. Similarly, 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). Scientific and dynamic visualizations may lead to the emergence of a wide variety of modeling functions 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 may interact in unanticipated ways.

Although an integrated urban design support system is still considered utopian (Poerbo 2001, p. 141), there have been very few efforts that seek to combine 3D modeling, GIS, Internet, and VR to create a platform for urban design decision-making process. Their combination may offer functions that are particularly powerful in visualizing the urban environment and in supporting designers at various design phases. Three samples of these tools, Venue, Geo V&A, and SIMmetry and, are briefly explained below. (Refer to Koshak 2002 and Poerbo 2001 for further details and an exhaustive list of other tools).

Virtual Environments for Urban Environments (Venue), a research project developed at the Center of Advanced Spatial Analysis (CASA) at the University College, London, focuses on adding 3D visualization capabilities and space syntax as an analytical tool to GIS. The research developed three core inter-related components:

1. Innovative sketch planning capability in desktop GIS.
2. Purpose built space syntax functionality within desktop GIS.
3. 3D modeling for urban designers within desktop GIS.

The additions allow one to perform morphological and configurational analysis of urban environments (Koshak 2002, pp 25-26). Similarly, Huang et al (2001) suggested the Geo V&A, a system that fully integrates GIS, VR, and the Internet for visualization, analysis, and exploration of spatial data and for setting up a platform for distributed spatial decision-making. The four interconnected modules of the system provide an integrated environment for spatial data visualization, analysis, and interaction in 2D and 3D media (Huang et al 2001, pp. 441-447). SIMmetry, developed by EarthData, is a spatial information management platform combining GIS, CAD, and database technologies. The platform is Web-based and delivered through standard Internet browser technologies. The platform is designed to have 4 major screens or portals to organize and deliver various types of spatial information. Communication links to geo-spatial portals or other temporal data can be established (see Figures 4.4 and 4.5). These systems may provide urban designers with substantial support through their array of functionalities, yet the system's functions are more relevant to projects on city-wide or city region-wide scales.

4.4 Techniques of Visualizing Urban Design Elements and Issues

A variety of techniques of and issues in visualization have been identified as important to urban design. This section will define and explain the utility of some of these techniques.

Because some of the interdisciplinary character of urban design, a project usually requires multiple types and levels of representations. 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). The usage of DBMS, CAD, GIS, and VRML tools may provide an integrated environment for spatial data visualization, analysis, and interaction in 2D and 3D (see Figure 4.5). GIS provides powerful spatial analytical and visualization tools in 2D digital maps. Three-dimensional visualization tools allow for the generation of 3D perspectives and representations by extruding spatial features in 2D GIS (see Figure 4.4). Surface and 3D analytical functions such as slope and aspect calculations, volumetric calculations, contouring, and visibility analysis are efficient ways to comprehend the spatial structure of the urban environment (see Figure 4.3) (Huang et al 2001, p.447). These visualizations and analyses can be used to generate VRML models to communicate the experiential nature of urban settings and to navigate and explore the virtual world (see Figure 4.10). They may increase designers' imaginations by visualizing their hidden intentions and thoughts, and facilitate comprehending design concepts and alternatives (Poerbo 2001, pp. 113-114; Al-Kodmany 2002, pp. 197-199). (Refer to Al-Kodmany, 2002; Koshak, 2002; and Simpson 2001 for an exhaustive list of these tools and their potential applications in urban design and planning).

Some flexible and interactive models are equipped with multiple levels of details to allow quick viewing in various zoom scales. They allow an interactive switch between multiple levels of details which facilitates increasing levels of detail of a view as the user approaches and switching between variable levels of details (Fraser and Bjornsson 2004, p.190). Designers, as such can shift their focus on designing urban elements and configurations relevant to the scale of design intervention. 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).

Urban simulation, which integrates CAD and GIS with real-time visual simulation, is a powerful decision-making support tool (see Figure 4.11). It facilitates modeling, displaying, assessing visual impact of design proposals, evaluating proposed design guidelines, and visualizing urban areas as they currently exist or as they are proposed (Koshak 2002, p.23). Urban simulation enables designers and planners to view the configurations and components of the spatial structure in accelerated time from a fixed point of view, which may collectively improve designers' understanding of the spatial behavior (Gosling and Gosling 2003, p.249). For computer simulations to be useful, they must be systematically validated during their creation and presented along with sufficient supporting information to the end users to allow an accurate assessment of their value (Decker 1994, p.421).

The prospects of using urban simulation in the evaluation of design guidelines in urban areas was illustrated in the by a project produces by Peter Bosselman and others at the center of Environmental Design Research at the University of California at Berkeley in association with the Architecture and Urban Design Division of the City of Toronto. This project involved using conventional modeling and mechanical simulation processes, such as wind tunnel testing in combination with computer techniques to establish bulk and height limits for buildings governing the microclimates these limits would create (Decker 1994, p.423). This project was exemplary because it cited the prospects of using urban simulation to measure, analyze and assess the impacts of urban design guidelines on the physical environment (Bosselman, et al 1992, p.97) The work of Urban Simulation Team (UST) at the University of California Lost Angeles is another example of urban simulation that involved constructing organized large scale 3D models and databases (Ligget and Jepson, 1995). The work involved building a photo realistic model of the entire Los Angeles basin, an area of several hundred square miles.

Virtual Reality (VR) provides real interactive simulations of the visual features of the urban environments. It supports the design process in several ways, enabling team members to analyze and navigate through the urban elements and spaces interactively (see Figures 4.3, 4.6, and 11), provide input into a simultaneous discussion of a proposal from the earliest stages onwards (see Figure 4.7), and explain design proposals to a far wider audience than has been possible hitherto (Fraser and Bjornsson 2004, p.191). The major advantage of its usage as an analysis /design tool is increasing the engagement in and experience of the spatial configuration of the built environment. Consequently, it minimizes the probability of misconceptions that may result from conventional representations (Gottig, Newton, and Kaufman 2004, p.109).

Literature suggests that the ideal computer model is one that can be continuously updated to include real change as it occurs in the design process (Gosling and Gosling 2003, p.251). It should provide designers with precise instant feedback as they make initial design decisions (Fraser and Bjornsson 2004, p.191). This requires integrating these tools with interactive databases that are directly linked to any change made in the attributes of and relationship between urban elements (see Figure 4.13). The significance of integrating these tools is explained in detail in chapter V.

Integrating these tools is important to the urban design process for three main reasons (see Figure 4.14). First, literature suggests that the development of computational assistance to designers greatly depends on assumptions about preferred representations of design knowledge and reasoning (Oxman 2001, p.108). A specific representation may be appropriate only during a particular stage or context of use before it is replaced by another representation (Batty et al 2000, p.1; Dave 2001, pp.3-4). Various design stages, as such, require using a number of representations of various degrees of abstractions and levels of details to represent, analyze, and propose information and solutions. Second, complex and multiple datasets in urban design often require both spatial and non-spatial descriptors which suggest presentations and manipulation of operations for both the graphic and non-graphic data items (Dave and Schmitt 1994, p. 88). Third, the collaborative and multi-disciplinary nature of urban design requires communicating the outcome of its various stages to a wide variety of affected parties. This trend underscores the strong influence of presentation modes and techniques on how designers perceive and communicate their concepts with other designers.

The effective application of these integrated tools and functions in the design process may improve the quality of decision-making through improving and supporting designers' capabilities in performing core design tasks as outlined in the following section.

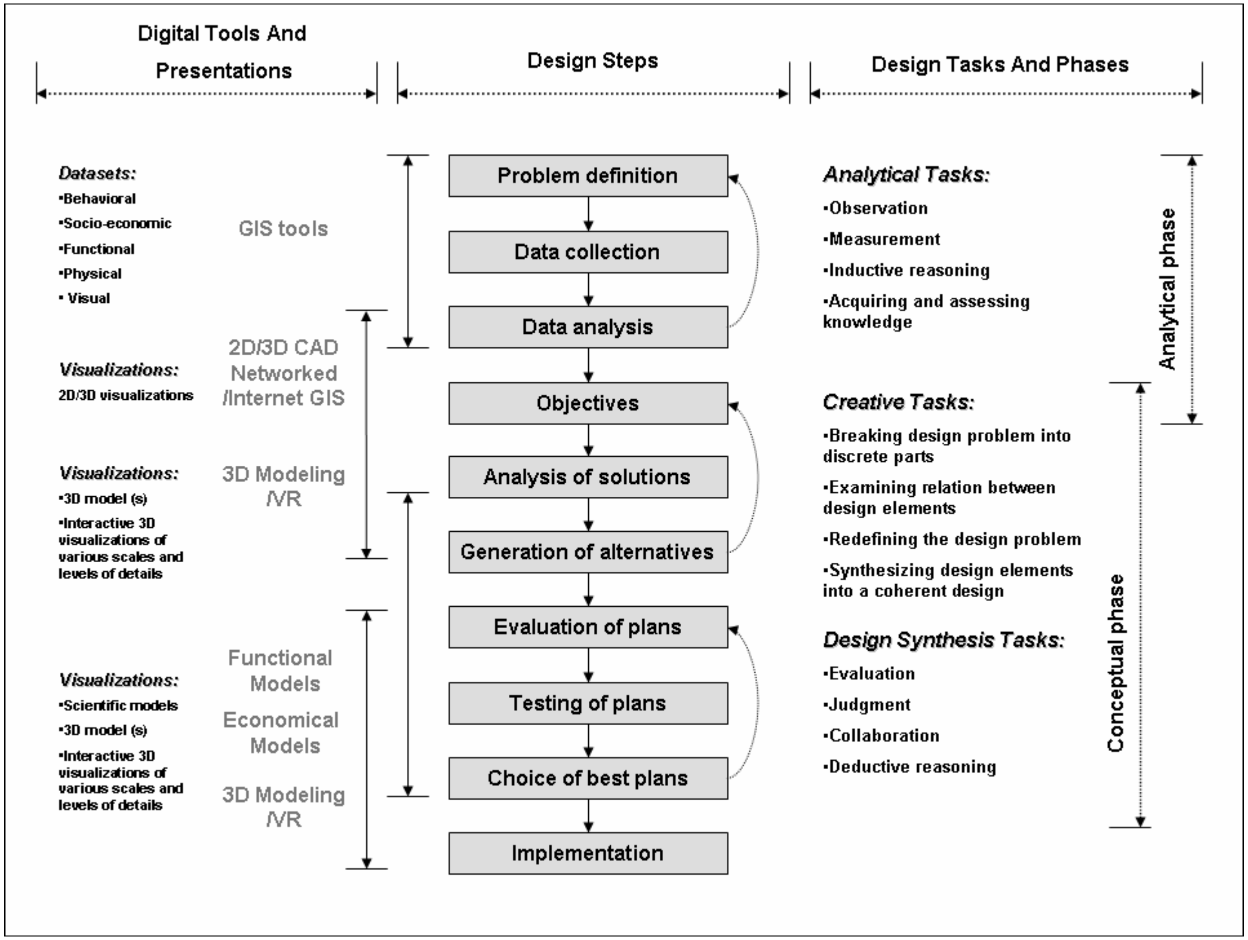


Figure 4.13. Integrating a variety of digital tools to support various design stages and tasks.

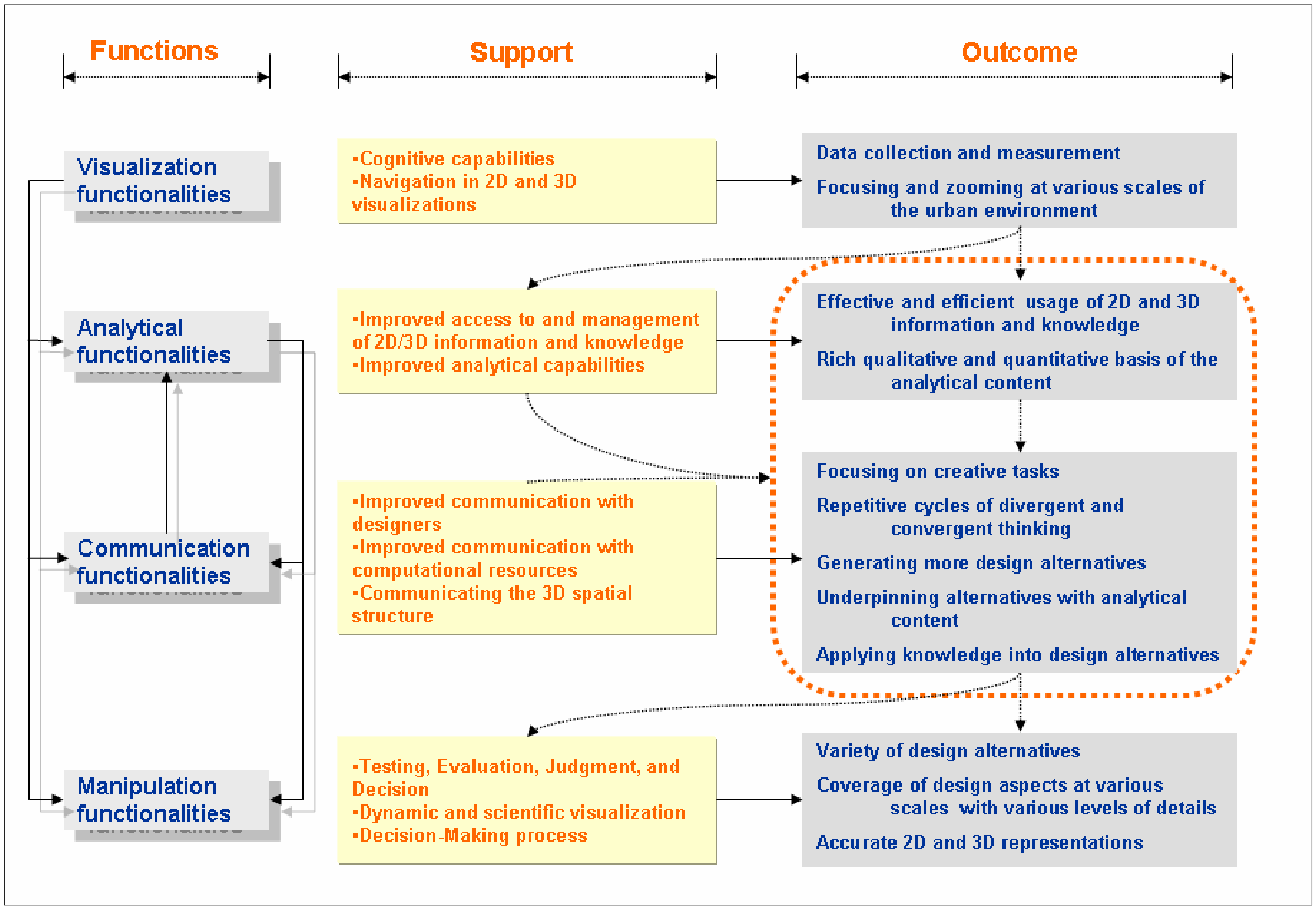


Figure 4.14. The anticipated support and outcome of the various modeling and information systems functionalities to fulfill designers' demands at various design phases.

4.5 The Relation between 3D Digital Modeling Usage and 3D Design Aspects: A Theoretical Proposition

This section outlines a theoretical proposition that tracks the causal relation between using visualization and modeling tools and quality of the design outcome. This proposition outlines the mechanism of support that these tools provide at each design stage and predicts its anticipated impacts on the design process and product (see Figure 4.15). It indicates that the consistent utility of tools' capabilities throughout various design stages has three impacts on the design process. The combined effects of these impacts may lead to the emergence of new skills, applications, and methods of usage and provides a source of inductive power. Use of these tools could facilitate strategic design decision, which may collectively translate to improvements in the form, appearance and content of the design product.

The effective and efficient usage of the capabilities of information technology and visualization tools may lead to three significant impacts that are illustrated in the theoretical proposition in three tracks (see Figure 4.15). The first impact, illustrated in track 1, is reinforcing the knowledge of the tools' development, methods of their usage, and skills of their users. The second impact, illustrated in track 2, is changing the relationship between the actions made on representations. The third impact, illustrated in track 3, is the stimulation of and improvements to designers' cognitive abilities.

In the first impact, literature suggests that the design process involves two main types of representation: *external* and *internal*. *External representation* refers to the process of communicating the evolving design to other design participants for formal evaluation and development. *Internal representation* refers to the process of creating and transforming design alternatives and concepts through reflection and action (Kalay 2004 p.190). It involves the generation, evaluation, and revival of mental models with the aid of overt conceptualization and memory aids (Kalay 2004, p.190; Mendivil 1995, p.93). Both types of representations involve reiterations whereby the representational tool feedback loops help inform and empower designers. Within the context of continuous data-processing systems, powerful feedback loops exist throughout the design process. Such loops may affect the relationship between the representational tools' application, potential development, and methods of usage and the designers' skills and design product (see Figure 4.16). Hence, directly experiencing, reflecting, and acting on the representations made with visualization and representation tools can also be seen as reinforcing the knowledge of the tools' known and unknown potential. This knowledge can ultimately determine and affect the form, performance, and appearance of the design product (Woolley 2004, p.188).

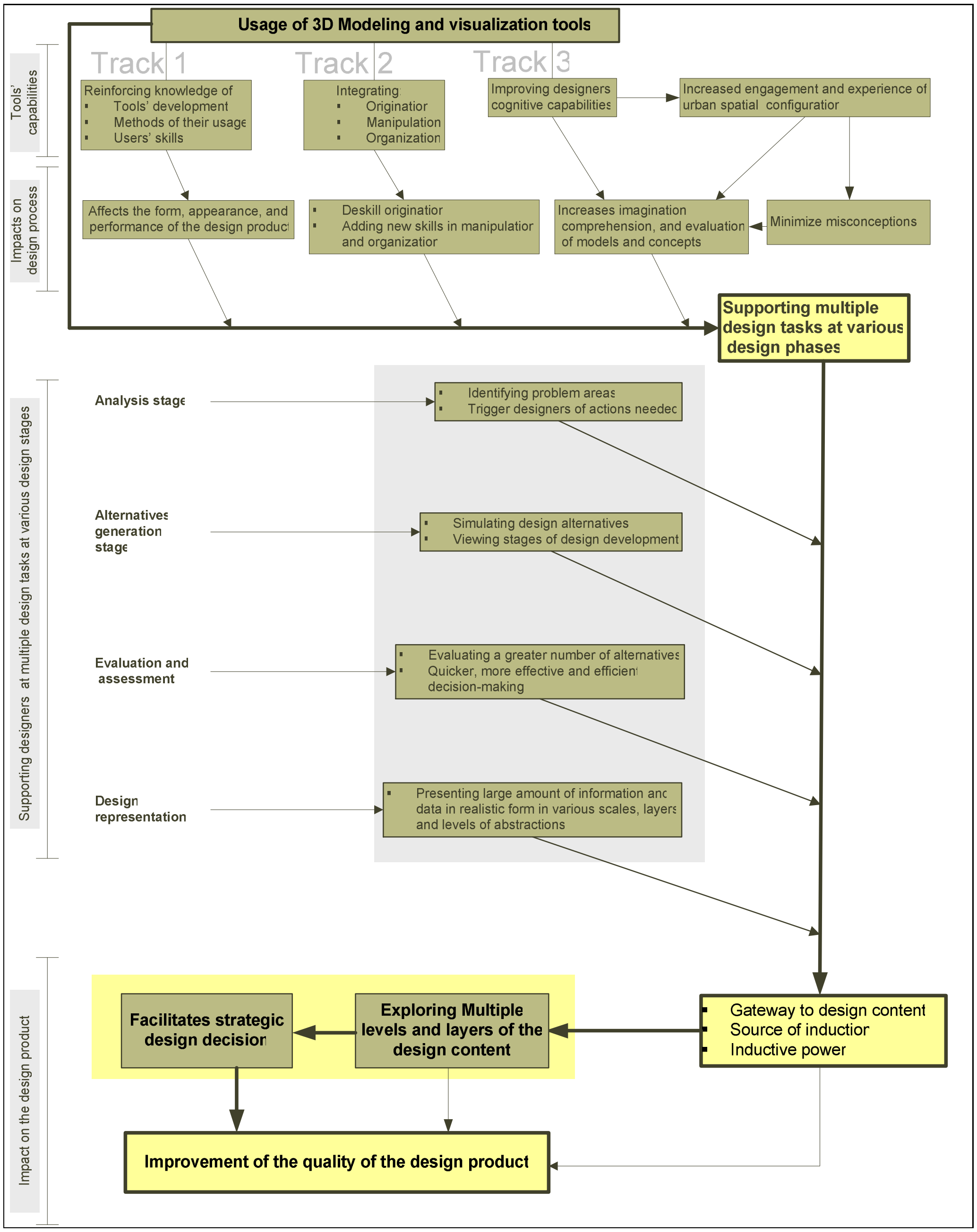


Figure 4.15. *Schematic flow chart of the theoretical proposition outlining the potential impact of using 3D modeling tools on the quality of the design product.*

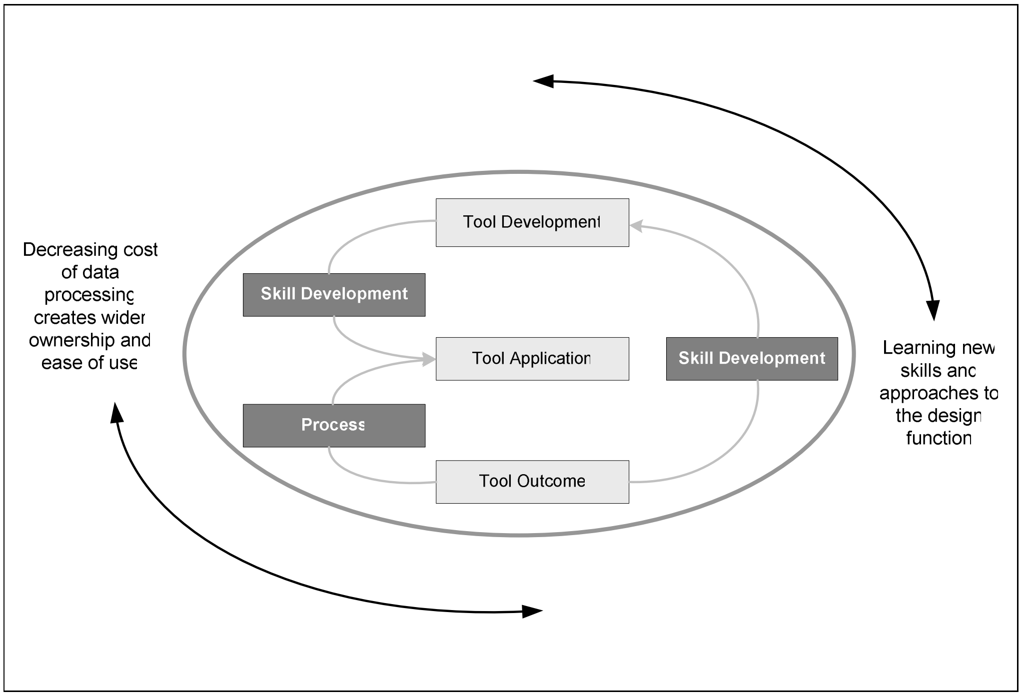


Figure 4.16. Reiteration-representational tool feedback loops inform and empower designers) (After Wooley 2004, p.188)

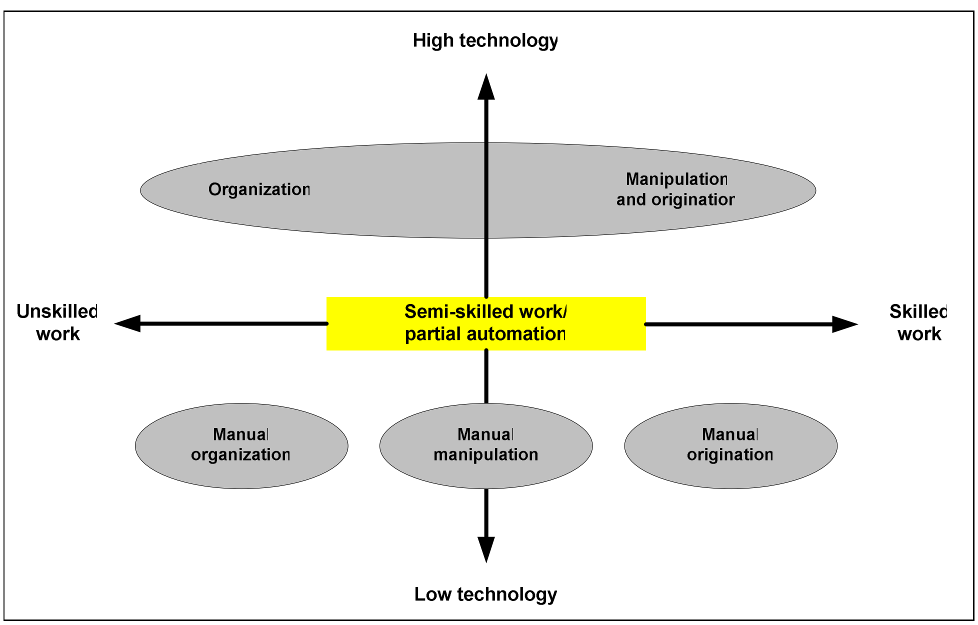


Figure 4.17. The positioning of skills in relation to representational technologies (After Woolley, 2004, p.198)

In the second impact, the usage of digital technology may change the relationship between the main types of actions made on representations: origination, manipulation, and organization. Origination is the creation of representations; manipulation is alteration of pre-existing representations; organization is the processing, management, and structuring of completed representations. Digital technology has integrated all types of actions and has closely engaged origination with manipulation (see Figure 4.17). Such integration has lead, to a certain extent, to deskill origination and triggered new skills to evolve in relation to the manipulation or representations. In addition, both manipulation and origination are supported by integrated, highly automated organizational capabilities (Woolley 2004, p.198).

In the third impact, the usage of digital modeling and visualization tools is likely to improve designers' cognitive capabilities. It provides a highly informative view of the urban structure strengthened by the interaction with the simulations which facilitates conceptualizing structural and visual relationships between the elements of urban form (Gottig, Newton, and Kaufman 2004, p.101). Such view may enhance the imagination, comprehension, and evaluation of models and concepts and minimizes the probability of misconceptions of conventional representations.

These capabilities can support designers in performing multiple design tasks at all design stages. In analysis, 3D visualizations give a better impression of the urban context than 2D maps. They help identify problem areas and trigger the design team to identify the action(s) that should be taken. In the alternatives generation phase, they establish an interactive planning environment that helps the design team simulate, view and compare design alternatives within their urban context. In evaluation and assessment, they facilitate comparing and assessing the impact of a greater number of design alternatives within their urban context which makes the decision-making process quicker, more effective, and efficient (Ranzinger and Gleixner, 1997, p. 164). In design presentation, the various presentations help visualize large amount of data and information in a rather realistic form (Huang et al 2001, p.442). Their various types, degrees of abstraction, and levels of detail respond to the variety of design representations and analyses required during various design tasks and stages.

The support which digital 3D visualizations provide allows designers to establish a focus of attention. This creates a gateway to the content of the design product or to the potential design product that may trigger the designers' natural ability to recognize a design opportunity. Their dynamic nature allows designers to penetrate further within the design product and thus to explore which design elements need to be specified in further detail, and/ or which design elements offer the best potential for further development. As dynamic entities, they represent the most important source of induction to facilitate design development. Therefore, their inductive power entitles them to become a means to make strategic design decision and thus to affect the quality of the design product (Mendivil 1995, pp. 85-86). This framework of how digital 3D urban visualization could affect urban design practice serves as a working hypothesis to the investigation of real world cases.

CHAPTER V

THE RELATION BETWEEN 3D DIGITAL MODELS USAGE AND DESIGN CONTENT: A THEORETICAL MODEL

This chapter describes the mechanism of the digital modeling and IT tools' support in the urban design process. It outlines the logical argument that explains how that usage may improve designers' capabilities and skills in performing design tasks and thus improve the quality of the design outcome, particularly the design content. This chapter employs published literature to portray theory of urban design process. This theory will then be used to support development of a causal model to explain how 3D urban models and IT tools can impact urban design. To pursue that goal, the chapter covered the following topics:

1. The concepts generation phase: its goals, significance, relation with the analysis phase, intellectual tasks, and role in determining the quality of the design outcome.
2. The problems that urban designers encounter in both analysis and concept generation phases and the consequent procedural gaps that may affect the quality of the design outcome.
3. The hypothetical role of IT and 3D modeling in providing a solution to those problems and in filling the procedural gaps.
4. Explanation of the mechanism and causal relation between the design quality and the usage of information management, communication, and representational tools.

The chapter presents the variety of design skills and capabilities needed to conduct the intellectual tasks of the conceptual phase and explains the causes of the procedural gaps and flaws in that phase. Evidence has been obtained from literature, logic, and qualitative field data that supports and corroborates the hypotheses that the usage of a variety of digital modeling tools and IT systems is likely to reduce those problems and help bridge those procedural gaps. It explains how their combined support affects the quality of the design outcome. It then explains the impact each type of support is likely to provide. The significance of using a variety of tools was explained with respect to the requirement of the urban design process and the designers' needs through the conceptual phase.

5.1 The Concepts Generation Phases

This section addresses the concepts generation phases. It discusses the significance of that phase, its relation with the analysis phase intellectual tasks, and its role in determining the quality of the design outcome. This section includes the following subtopics:

1. Goals and significance of the concepts generation phase.
2. Sub-phases comprising the conceptual phase.
3. Factors affecting the quality of the design outcome of the conceptual phase.

5.1.1 Goals and significance of the concepts generation phase

A principal aim of the conceptual phase is to generate a variety of promising well-spaced alternative design strategies. To achieve this aim, it is important to generate, test, evaluate and choose from as many potential solutions as is practically possible (Bayne 1995, p.303; Liu, Bligh, and Chakrabarti 2003, p.341). The generation of design alternatives involves several intellectual tasks structured around a number of key sub-phases and linked with other interrelated phases and sub-phases of the urban design process. It involves a continuous, cyclic, and iterative process to produce solutions that are gradually refined through a series of creative leaps or conceptual shifts (Carmona et al 2003, p.54).

The role of the conceptual phase is vital for the decision making process that lies at the core of the urban design practice. Each alternative should represent a comprehensive plan for the design problem at hand and a unique approach to attain the desired goal and objectives. Literature suggests other analytical and educational roles of design alternatives. Shirvani (1985) suggests using them to challenge or confirm a recommendation, discover, or unify some expected advantage inherent in one particular pattern of development. They may act as a means to provoke public discussion on critical issues, and/or be used to educate the public as to the values of planning (Shirvani, 1985, p.113). Lang (1994) also emphasized their analytical role and suggested considering them as analytical tools that elucidate problems rather than as solutions to be defined (Lang 1994, p.432).

5.1.2 Sub phases and intellectual tasks in the conceptual phase

Experts suggest a variety of ways of subdividing the conceptual phase into sub-phases according to their professional approaches and view points. Lang (1994) and Shirvani (1985) for instance, discussed this phase and its constituent sub-phases driven by and with emphasis on the architectural and design aspects. According to Lang (1994), the conceptual phase includes three sub phases: intelligence, design, and choice sub-phases. The first sub phase, intelligence, overlaps with analysis and involves divergent thinking to generate ideas or design patterns. The second, design, involves convergent thinking to synthesize the generated ideas or patterns and to identify how patterns will function. The goal of the third sub-phase, choice sub-phase, is to evaluate potential designs before they are implemented. It involves a number of intellectual tasks: the prediction of performance of possible solutions, the evaluation of these performances, and the decision that one scheme should be implemented or that none is good enough (Lang, 1994, p.383-393). Similarly, Shirvani (1985) suggests that the conceptual phase involves two main stages: the identification of key organizing principles that constitute the generative idea of each scheme and the definition of a more detailed set of basic attributes for each alternative as a prelude to elaboration (Shirvani 1985, p.113). In his argument, he relied on two premises. The first premise is that the lessons learned from other designers and cities can offer valuable alternatives and insight into issues confronted in the situation at hand. The second premise is that each alternative derived should seek to represent a comprehensive plan for the proposed design.

Bayne (1995) discussed this phase and its constituent sub phases from an urban planning point of view and with emphasis on the rational approach to planning. She suggests that the conceptual phase involves two types of activities: search and design. In the former activity, existing solutions relevant to the current problems are identified. This activity aims to understand how others have handled similar problems, what factors they identified as important, and how the solution form related to the problem being solved. The latter activity, design, depends on innovation and creative response (Bayne 1995, pp.305-308). In their search for pre-existing solutions, designers rely on two main sources of information: internal memories and external memories. The first source represents designers' experience and knowledge. It includes the store of information contained within their cognitive structure by virtue of their particular experience, education, and information storage and retrieval capabilities. The second source represents a range of sources outside the designers' own cognitive structures. It contains all relevant information that could be brought to solve the problem as well as information imported for adaptation or application to the design problem (Bayne 1995 p.310).

Therefore, the variety in types and scales of urban design problems as well as in design approaches or models may lead to various structural relationships between the sub phases and intellectual tasks of the concepts generation phase. This variety would affect the management of the complex datasets, information, and knowledge base of the design problem and its analytical content and may ultimately affect the quality of the design product. Therefore, it is important to address those factors and their impact on the quality of the design outcome of the concepts generation phase.

5.1.3 Factors affecting the quality of design outcome of the conceptual phase

There are three key factors that may significantly affect the outcome of the conceptual phase. The first factor is the sequence of intellectual tasks comprising the conceptual phase.

The second factor is the analytical content. The third is the provision, processing, and management of information and knowledge.

5.1.3.1-Sequence of intellectual tasks in the conceptual phase

According to creativity and design research, design activities in conceptual design contain two basic intellectual tasks: divergent and convergent thinking. Divergent thinking involves generating a range of possible ideas or design patterns (Liu, Bligh, and Chakrabarti 2003, p.341). Urban designers use many methods to enhance divergent thinking such as morphological analysis, metaphorical thinking, and brainstorming. Convergent thinking involves synthesizing, testing, evaluating, and selecting these patterns. It is an intuitive process conducted by trial and error and by conjecture and refutations to evaluate the function and utility of the generated patterns (Lang 1994, p.393).

Theoretically, these intellectual tasks vary according to the design approach. According to Lang (1994), there are two main design approaches: typological (rational) and problem-solving (empirical) approaches. The typological approach relies on the wholes aiming that both wholes and their comprising parts fit the problem. It involves an intuitive leap to define a concept, and then evaluate and redefine it to identify the preferred design solution. The process includes overlaying a series of concepts on the design problem, modifying one or more of them for best fit, and identifying a preference. Conversely, the problem-solving approach is a bottom-up approach that works out the parts to synthesize them into wholes where both wholes and parts meet specific needs. Designers adopting this approach tend to resolve partial problems and functions that are subsequently synthesized into whole solutions or sets of alternative solutions. They break down the design problem into discrete elements, apply information and analytical content to the appropriate elements of the design, and then synthesize them into a coherent whole (Lang 1994, pp. 384-385, pp.392-393; Milburn and Brown 2003 pp. 50-52).

In practice however, urban design usually includes a combination of both approaches, each of which may be seen as applicable to different aspects of the design process. The typological (rational) approach is a design-oriented approach dominated by the provision of forms. Its design outcome, as such, will be based on and is a reflection of the designers' visualization capabilities. The problem-solving (empirical) approach is a planning-oriented approach dominated by the analysis of physical, visual, socio-economic, and behavioral factors. It involves an integrated solution which synthesizes the designers' understanding and available data and information. Its design outcome may represent a more complete understanding of the issue inherent in the design problem (Steino 2001, pp. 6-8). This underscores the impact of the designers' visualization and analytical capabilities on the quality of the design outcome. It emphasizes, as such, the significance of supporting those capabilities as a means to improve the quality of the design outcome.

The application of either approach may vary according to which view has been dominant, design or planning. Application may vary according to plan's type, scale, goals, and degree of control. However, literature suggests that urban design process is a dialectic process of problem solving. Its problems are semi-structured or non-structured problems which can be fully understood only through the process of problem solving, definition, and redefinition (Steino 2001, p. 6). Therefore, the conceptual phase is likely to involve iterative, repetitive cycles of both implicitly and explicitly conducted divergent and convergent thinking. This notion of the urban design process is consistent with the premise that the design process should follow a multiple rather than a single divergent and convergent approach (Liu, Bligh, and Chakrabarti 2003, p.342) (see Figure 5.1).

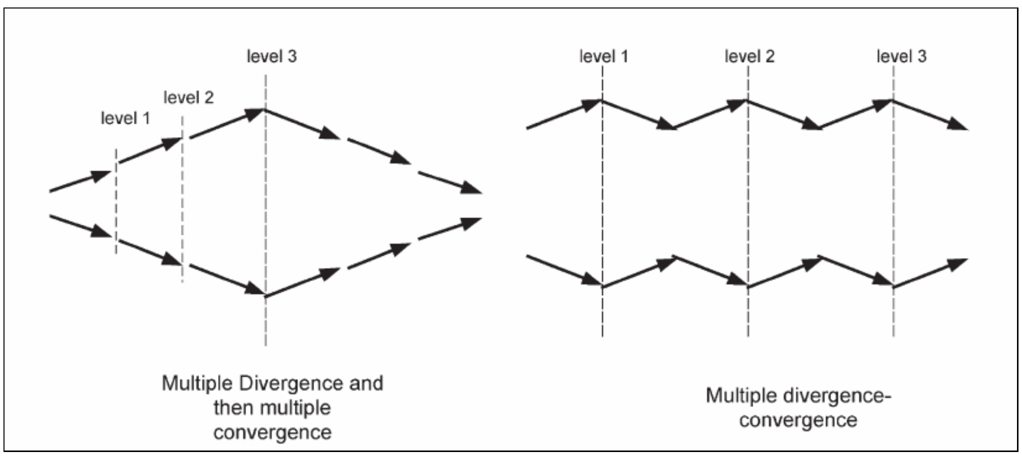


Figure 5.1. Multiple divergence and then multiple convergence vs. multiple divergence-convergence (After Liu, Bligh, and Chakrabarti 2003, p.342).

5.1.3.2-The analytical content

In the second factor, relevant analytical content is imperative to underpin design policies and to define the key design aspects of a locality to be developed into a policy (Punter and Carmona 1997, p.173). Researchers suggested that "poor" analytical content in development plans has lead to failure to express strategic design consideration, failure to relate design to differing scales of development, and also inadequate detail in coverage of design issues

(Southworth 1989, pp.374-375; Punter and Carmona 1994, p.206). Theoretically, just as important as the analytical content is the process of translating it into design concepts, strategies, and alternatives. Hence, analyzing the context of new development and utilizing it to develop design principles is critical to ensure the development of sound design policies (Punter and Carmona 1994, p.208).

The analytical content and methods have to embrace all aspects of the urban environment and be easy to comprehend (Punter and Carmona 1994, p.208). The analytical content at each scale should inform and underpin the relevant design aspects at the respective scale of design. Analysis in urban design practice takes place at three hierarchical levels: the level of town in its landscape setting, the level of the built-up area which is subdivided into various urban areas that share specific homogeneous form characteristics, and the level of urban spaces in each of these urban areas (Gosling 1993, p.216; Skauge 1995, p.427). At each level and context, analysis requires the adoption of its own analytical and assessment techniques and approach to develop alternative concepts based on understanding of the area's distinctive, positive and negative characteristics and patterns (Carmona et al 2003, pp.240-244).

The locally relevant principles of urban design are considered the corner stone to ensure that the analysis phase is closely linked to a comprehensive range of design principles (Punter 1997, p.37). For instance, one of the key characteristics of the best American urban design plans, such as *San Francisco Urban Design Plan 1970*, is that they are based upon thoroughgoing analysis of the character of the locality (Punter 1999, p.200). Therefore, the success of the design solution is correlated with, and is a function of, the analytical content, design concepts, and alternative solutions generated at the conceptual phase.

5.1.3.3- The provision, processing, and management of information and knowledge

Urban designers should be specifically knowledgeable in certain areas, particularly substantive and procedural knowledge. This includes knowledge about and knowledge and understanding of urban design and planning, contextual knowledge, methods and skills of analysis, design, and communication, and judgment and good sense (Alexander 2001, pp.377-378; Ozawa, and Seltzer 1999, p.261). The extent to which designers have command over that knowledge base will determine their abilities to work with and guide the professional team towards a satisfactory design solution (George 1997, p.156). This highlights the significance of improving the communication modes and tools as a means to facilitate generating design alternatives and improve their quality.

Empirical research has proven that knowledge and research are central to the generation of alternative design strategies (Milburn and Brown 2002, p.61). They have two key roles: the first is in the development of criteria for concept evaluation. The second is in the development of general rules for application during design. They are incorporated in the design process at three stages: before design, during design, and after design. Their role before design is both direct through site inventory and analysis, and indirect through case studies and library and database research. Their role during design is twofold: influencing concept generation, and application of the concept. Their role after design involves evaluation and justification of design (Milburn and Brown 2003, p.61).

However, having adequate command over such a diverse knowledge and retrieving information from internal and external memories, particularly in complex urban problems, falls beyond the capabilities of single designers (Arias, Eden, and Fischer 1997, P.1). The effective usage of computational and networking technology such as design repositories, information storage systems, visual databases, and library systems may enhance the designers' capabilities (Poerbo 2001 p. 112). They may support designers in information management, processing, and retrieval and avoid conducting repetitive time- and effort-consuming tasks. Such support may cause the following effects on the design process and product:

1. Organizing the quantitative basis of urban design such as quantitative projections, building intensity, cost aspects, in computer systems (Poerbo 2001, p.111). This may allow designers to focus on and devote more time to the creative tasks which may ensure better accuracy and rich design content in the design product.
2. Facilitating the collection, integration, and interpretation of a much wider variety of descriptive material. This would allow designers to overview the very precise data and facts about the economic, legal, political situation of the design area (Poerbo 2001, p.112). If that support is associated with the usage of 3D modeling, designers may become able to analyze the various layers of the urban constructs and to combine the visual and non-visual aspects of the urban environment.

Literature suggests that design thinking has recently come back to permeate planning at all scales of urban design practice in US cities, particularly at the metropolitan, district and neighborhood scales (Punter 1999, pp. 204). Although no progress in the design process is possible without an image of the potential solution at the beginning (Lang 1994, p.384), urban designers pay more respect now to the content of the design rather than the immediate artifacts such as 3D renderings (Poerbo 2001, p.111). This paradigmatic shift highlights the significance of information and research in current urban design practice. Hence, the quality of the design outcome is increasingly becoming dependent on information analysis and management than on visualization.

The variety in intellectual tasks, design approaches, and structural relationships of sub-phases comprising the conceptual phase requires designers to use a variety of analytical, visualization, and communication skills and capabilities to drive the generation of concepts. In addition, the paradigmatic shifts in design models and the gradual increase in emphasis on design content, knowledge and research in design strategies suggest the significance of supporting designers' capabilities in improving the knowledge base of the design process. Therefore, it is recommended to use various digital tools and techniques to improve urban designers' capabilities in visualization and cognition as well as information analysis and management to improve the quality of the design product. The supporting tools should be selected carefully based on current and future designers' needs to conduct those intellectual tasks throughout various phases of the design process, particularly the conceptual phase. This may help not only in integrating existing tools in the design process, but also in developing new tools and techniques that could fulfill designers' needs and support new design concepts and strategies. Therefore, a range of tools rather than a specific tool might be utilized to bridge the procedural gap in the design process.

5.2 Problems and Procedural Gaps in Analysis and Concepts Generation Phases

This section briefly discusses the following problems:

1. Nature of the design problems and causes of the problems and procedural gaps in analysis and concept generation phases.
2. Information-related and communication-related problems.

5.2.1 Nature and causes of the design problems and gaps

According to some experts, urban design plans adopted in US cities are often developed without being underpinned by relevant analytical content, or are not based on in-depth analysis for the specific problem of the study area (Gosling 2003, p.16, p.173; Lang 1994, p.442; Southworth 1989, pp.374-378). These plans exhibited a lack of coverage of urban design topics which would normally be considered as central to design control. They demonstrate two procedural gaps: one between theory and practice, and the second between analysis and conceptual phases.

Although urban design is essentially a three-dimensional process that focuses on shaping urban elements and their relationship within a coherent functional and visual structure, some experts suggest that few urban design plans adopted in US cities portray that spatial strategy explicitly, while consideration is rarely given to three-dimensional aspects of design (Gosling and Gosling 2003, p.8, p.16, p.173). More importantly, the plans that are developed may lack 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 (Carmona, Punter, and Chapman 2002, p.55; Punter & Carmona 1997, pp.170-173). Many design and planning applications in US cities have been considered within the framework of two-dimensional land-use and rigid zoning codes (Gosling and Gosling 2003, p.8).

Although the conceptual phase should involve developing specification-based and differentiated sound alternatives, designers instead often devote the greatest amount of decision-making resources to developing and defending a single solution (Bayne 1995, pp.304-305). In practice, most analyses were found to be selective and cursory, to blur the distinction between objective findings and subjective creative leaps, and rarely presented alternatives that might actually form the basis of public debate and political choice. Without a diverse range of alternatives, it is impossible to choose a solution that can be demonstrated to be superior. This situation is often coupled with lack of effective analytical content and/or theoretical discourse, which altogether might lead to practical deficiencies and shortcomings (Bayne 1995, p.304; Wang 2002, p.981).

These gaps have led some experts to argue 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 to design spatial structures. The following section explains the causes of those gaps and flaws. It suggests that they may be due to communication-related problems and information-related problems (see Figure 5.2).

5.2.2-Information-related and communication-related problems as drivers of the procedural gaps in analysis and concepts generation phases

Sound communication may affect the design process through two factors:

1. The extent with which professionals successfully interpret the decisions made at this phase by other collaborating professionals.
2. The extent with which all professionals and designers can easily coordinate and combine knowledge at the appropriate time (Rivard et al 2003, p.51).

This led some experts to argue 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 to design spatial structures (Bourdakis 2001, p.404) **(**see Figure 5.2-Track 3**)** . Similarly, the current shift towards collaborative multi-disciplinary design process and distributed knowledge suggest sound coordination between design participants. Therefore, communication-related problems may be due, in part, to the incapability of conventional urban design tools and techniques to meet the needs and requirements of an increasingly multi-disciplinary and distributed design process and knowledge (see Figure 5.2-Track 1).

Information-related problems may be a result of an increasing access to, and overwhelming volume of information and data pertinent to the design problem which lead to poor management of that data and ultimately poor analysis **(**Figure 5.2-Track 2). According to Levin (1984), there are three categories of information processes: derivation of solutions, consistency testing, and comparison and selection. In arriving at decisions, the designers' impediments are twofold. The first is lack of objective information as to what ends are desirable as well as the relationships between ends and means. The second is the designers' own limitations as human beings and the paucity of tools at their command. Hence, the emerging design is likely to be the one that was, or appeared to be, the easiest to produce (Levin 1984, pp.117-119) (Figure 5.2-Track 3).

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 (Figure 5.2-Track 2). Accordingly, 3D information and the analytical content and results are not likely to underpin effectively the resulting urban design strategies. 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.

The growing tendency to collect and use more 3D data and information suggests using techniques for visualizing and interacting with those large and complex datasets effectively (Rivard et al 2003, p.51; Whyte 2002, p.103, 199). Designers and professionals also need tools to save, communicate, exchange, and import relevant information and knowledge. In their interaction, they need to exchange ideas, data, and negotiate their design intents governing concepts generation. Therefore design methods will have to enhance the utility with which design participants interact with each other and with computational resources. In light of these findings, it becomes essential to develop new design methods that use other design tools and techniques.

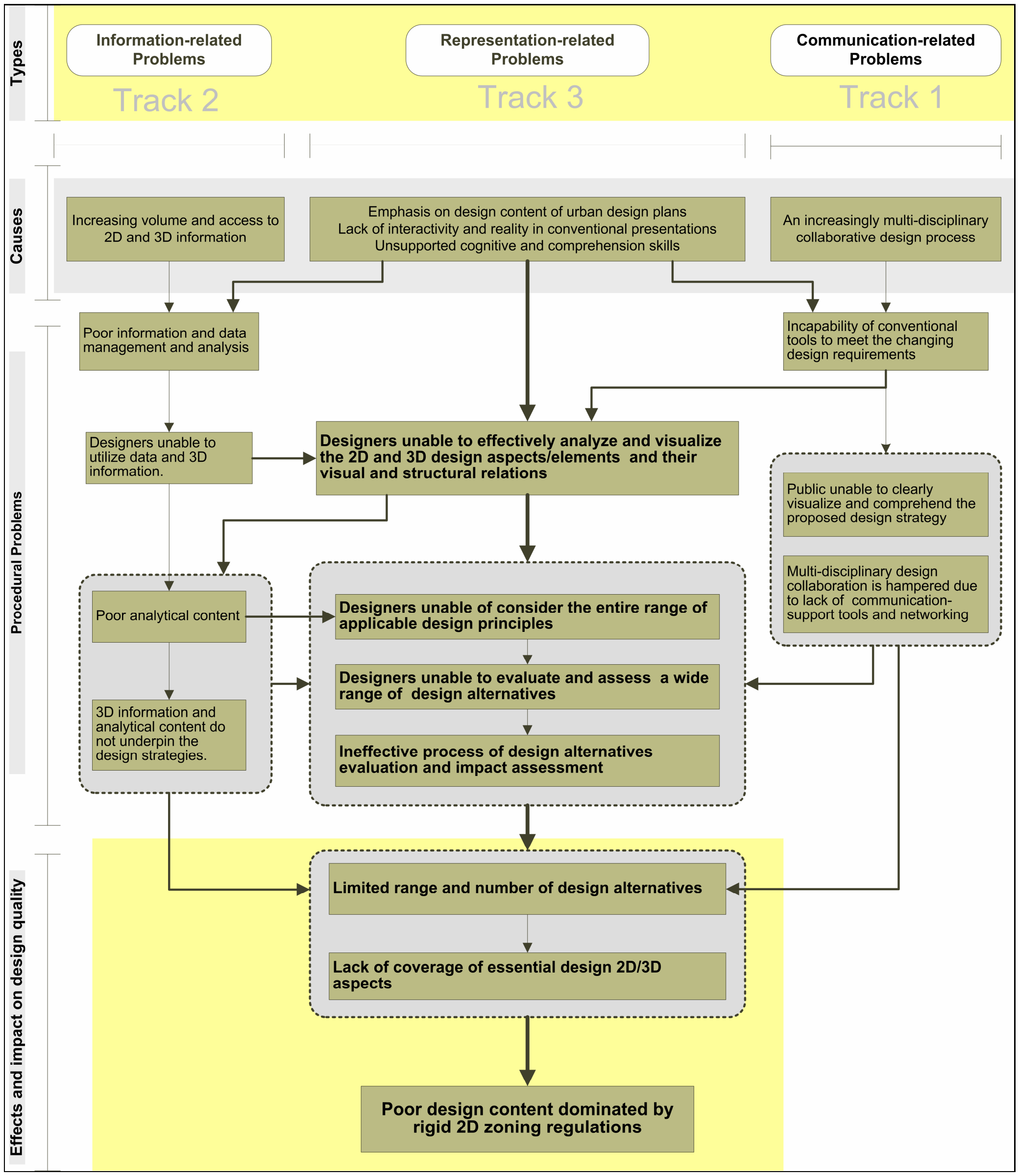


Figure 5.2. Analyzing the causes and effects of problems leading to procedural gaps in the urban design process in US cities

5.3 Role of Information Technology and Modeling Tools in Fulfilling Design Requirements and Bridging the Procedural Gaps

This topic will address how using IT and 3D modeling may affect the design content by using the following logic:

1. Using IT and modeling will allow designers to :
   a. Have better access to information.
   b. Improve their analytical abilities.
   c. Visualize and interact with 3D information.
2. Therefore, they will use information more effectively which will allow them to:
   a. Generate a greater number of design alternatives, and thus a better design solution.
   b. Underpin the resulting plan with the analytical content.
   c. Improve their abilities to comprehend design solutions using 3D media to design and communicate the 3D spatial structure.
   d. Communicate with other design professionals.
3. Therefore, they will be able to cover the entire array of design aspects at all levels of the urban environment and thus achieve better design content.

5.3.1 Design requirements affecting tools' selection and methods of usage

Literature suggests that searching for an appropriate role for computer-based information and methods must begin with a conception of urban design rather than with a particular technology or a set of technologies (Klosterman 1997, p.46). Hence, selecting the supporting tools should be driven by the foundational knowledge of design and the essential factors affecting contemporary urban design practice. This selection should be based on current and future needs and requirements of various phases of the design process. Among others, there are three main design requirements that determine the selection and methods of usage of IT and modeling tools. The first requirement is the multiple representations and degrees of abstractions; second, the complex types of datasets; third, the collaborative and multidisciplinary nature of urban design process.

In the first requirement, various design stages require using a number of representations of various degrees of abstractions and levels of details to represent, analyze, and propose information and solutions. A specific representation may be appropriate only during a particular stage or context of use before it is replaced by another representation (Batty et al 2000, p.1; Dave 2001, pp.3-4). Hence, the design process suggests using progressively detailed graphic representations. This has led some experts to argue that the development of computational assistance to designers greatly depends on assumptions about preferred representations of design knowledge and reasoning (Oxman 2001, p.108). The second requirement is the complex and multiple datasets involved in the urban design process. Data in urban design often requires both spatial and non-spatial descriptors which suggest presentations and manipulation of operations for both the graphic and non-graphic data items (Dave and Schmitt 1994, p. 88). The third requirement is the current paradigmatic shift towards a more complex, collaborative, and multi-disciplinary design process which requires communicating the outcome of its various stages to a wide variety of affected parties (Batty et al, 2000 p.1).

This trend underscores the significance of two issues:

1. The significance of enhancing communication between design participants within and across teams.
2. The strong influence of presentation modes and techniques on how designers perceive and communicate their concepts with other designers (Carmona et al 2003 P.282).

Urban designers have to consider selecting and designing their representation media in order to enhance how professionals and public alike understand the proposed alternatives. Capabilities of digital tools such as VR, computer simulation and animation may enhance understanding and communicating proposals. They may add a temporal dimension to the spatial dimension and graphic representations of design proposals to allow designers to assess the impact of design alternatives on the urban environment dynamically.

Therefore, fulfilling designers' needs in the concepts generation phase requires using a range of tools rather than a specific tool. This usage, in turn, requires not only integrating existing tools but also developing new tools and techniques that could fulfill designers' needs. That integration may foster developing new methods and skills of their usage in order to support new design methodologies and strategies and thus to improve the design content and coverage of urban design plans in US cities. These ideas were diagrammed in Figure 4.13 and were explained in section 4.4.

5.3.2 The hypothetical support and applications of IT and modeling tools

The primary support that 3D modeling and information technology systems provide is in navigation-visualization application. Yet their improvements to designers' visualization capabilities are likely to support analytical and decision-making applications that would ultimately affect the quality of the design outcome. If designers use tools such as CAD, GIS, VR, and Internet, then those tools are likely to encourage experiments with new forms of information management, communication, and visualization to produce more imaginative design solutions that are a better fit to the design problem and a better translation of design and planning goals and objectives (see Figure 5.3).

In navigation applications, those tools may support the design process in two ways: as outputs of some computer applications, and as input visual interfaces in order to access the databases and run applications (Laurini 2001, p.192). This support may improve designers' visualization capabilities and thus enhance the modes with which they communicate with both computational resources and databases, and design participants and the public at large (Figure 5.3-Track 1). They help registering input and output to cognitive processes whereby internal and mental representations are refreshed and reinforced by creating external versions and subsequently internalizing them again through perception (Koutamanis 2002, p.231). Hence, they can provide environments which facilitate task management and integration, searching for relevant data, and collaboration (Langendorf 2001, p.337) **(**Figure 5.3-Track 1**)**. The graphical user interface will improve the intellectual tasks, theoretical thinking, analysis processes, and communication. Therefore, it may be argued that the support those tools provide in navigation-visualization applications becomes the driver of supporting designers in communication and thus analytical applications.

In analytical applications, the improvement in designers' visualization capabilities is likely to affect their communication and thus analytical capabilities in two ways **(**Figure 5.3-Track 2**)**. First, it enhances their analytical capabilities with an improved access to and management of information. It allows designers to retrieve and thus apply information, knowledge, and analytical content to the design problem at various stages of the design process. Designers, as such, may avoid performing tedious, repetitive, time- and effort-consuming tasks. Instead, they may focus on pure creative tasks. Second, it allows designers to effectively and efficiently conduct 2D and 3D analyses of complex and multiple spatial and non-spatial datasets. Thus, they may be able to analyze, in depth and breadth, the characteristics of and the structural and visual relations between the urban design elements and issues at multiple levels of the urban environment.

Accordingly, using digital tools and techniques in such analyses may allow designers to effectively and efficiently use information, particularly 3D information, in the design process. This may significantly improve the quantitative and qualitative basis of the analytical content so as to address multiple levels of the area's specific characteristics and problems.

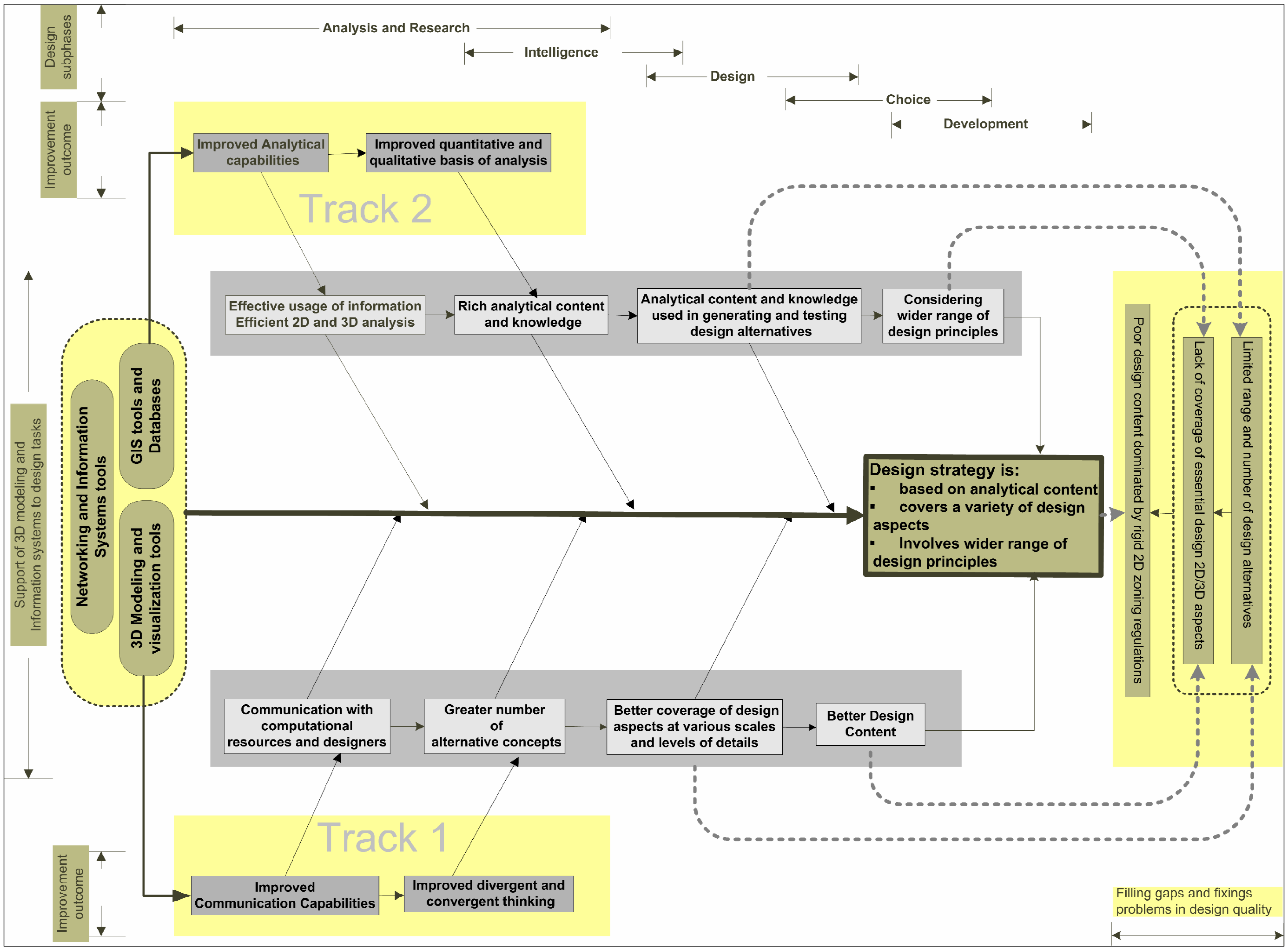


Figure 5.3. Conceptual model outlining the causal relation between the usage of 3D modeling and information systems tools and qualities of the design outcome

Research has proven that content of a design in urban architecture is often built in several design levels, where each level meets its specific design problems (Westrik 2002, p. 434). The analytical content, as such, becomes central not only to concepts' generation and application on the design context, but also to the evaluation and justification of the selected design (Milburn and Brown 2003, pp. 53-55). Therefore, the analytical content is more likely to underpin the design strategies and address the entire array of design aspects of the urban environment.

The combined improvements in designers' visualization capabilities with other improvements in their analytical and communication capabilities will affect the time structure with which designers conduct and control the operation and sequence of design tasks. Creative tasks will involve iterative and repetitive cycles rather than a single cycle of divergent and convergent thinking. Designers, as such, can generate and evaluate a greater number and variety of well-spaced alternative design concepts and strategies. Literature suggests that there is a strong relationship between productivity and creative thinking (Lang 1994, p.393). The usage of dynamic and scientific visualization techniques will allow designers to explore the design alternatives with various degrees of abstraction and details and to simulate and assess their impact on their urban context. Usage of a combination of interactive 2D and 3D views allows designers to zoom at, explore, and communicate multi-dimensional spatial and temporal relations between design elements and issues at various scales of the urban environment. This allows designers to make informed decisions and selections of the preferred design strategy. Therefore, designers are more likely to comprehensively cover and fit together the various levels of 2D and 3D urban-wide and local design aspects into coherent design strategy with rich design content.

The support of 3D modeling and information systems in the conceptual phase emphasizes the analytical and educational roles of alternative design strategies. In the analytical role, it fosters using them as a means to provoke discussions among and across design teams on critical issues to redefine the multiple dimensions of the design problem(s) and to define design solutions. This would help overcome communication problems due to various backgrounds and thus perspectives and visions of design participants. It helps designers educate the public as to the values of planning. In the educational role, it fosters wider and more effective public involvement in the design process and helps reach consensus on the preferred design strategy. This will also translate into greater confidence in decisions made by various design participants which may improve the quality of the decision-making.

5.4 Mechanism of the Causal Relation between the Digital Tools' Support and Qualities of the Design Product

This section provides evidence obtained from literature, logic, and qualitative field data that support and corroborates the hypotheses that the usage of a variety of digital modeling tools and IT systems is likely to fix those problems and help bridge those procedural gaps. It explains the impact each type of support is likely to provide and then explains how their combined support affects the quality of the design outcome.

5.4.1 Communication support

Digital modeling and information technology may not only lead to improved productivity over existing traditional methods of communication but also has the potential to change communication itself. They are likely to encourage experiments with new forms of communication, visualization, and information retrieval that may lead to restructuring the traditional design process. This possibility is grounded in six properties of computing technology: flexibility, interlinking, information management, visualization, intelligence and connectivity (Kalay 2004, p.189) (see Figure 5.4).

The capabilities those properties provide may support designers at two main levels. The first level (Figure 5.4-Track 1) supports exploration and communication between design participants, and in particular, with the citizens. It involves supporting several tasks such as groups' communication, information management, graphic display, and spatial analysis. The second level (Figure 5.4-Track 2) is more dedicated for enhancing analysis and deliberation between actors. It involves supporting several tasks such as the design process model, advanced spatial visualization, decision models, and structured group process (Laurini 2001, p.254) (see Table 5.1).

The effective organization and communication by computers and information technology systems contribute mostly to the effectiveness of decision-making through collaboration process. This process involves consultation, negotiation, decision-making, and reflection (Chiu, 2002, pp. 205-207) (see Figures 5.5 and 5.6). The most important impacts of this process on design will be its transformation from a hierarchical, linear process to a distributed, interleaved process where the sequence of inputs is not predetermined but rather opportunistic. It means acting upon and making the most of opportunities in a timely manner because more design participants and specialists will be able to visualize the design process and products. They, as such, will be able to define tasks and process dependency and to define data dependency (Chiu 2002, p.208; Kalay 2004, p.416). This, in consequence, will affect the design process and thus design product in three ways. The first way is the ability of design participants and specialists to make the best of opportunities in a timely manner. Second, the avoidance of problems and /or the capability of spotting problems at an earlier stage (Kalay 2004, p.416). Third, reducing design time and speeding the design process (Chiu 2002, p.205; Kalay 2004, p.416).

These effects can cause further qualitative and quantitative impacts on the design process. The qualitative impacts include greater satisfaction of all parties involved and reduced errors, oversights, and omissions. Errors due to manual translation from one form of representation to another are eliminated or reduced. Quantitative impacts include more informed design operations and more design cycles. This would allow sharing and incorporating more information and intelligence such as observations, criticism, and proposals into the design alternatives and would also allow generating and communicating more new design ideas and concepts (Den Otter 2000, pp.34-36; Kalay 2004, p.190, pp. 416-417). Designers, as such, are more likely to use information effectively and efficiently and become able to incorporate knowledge and research in the design product in a timely manner.

Table 5.1. Functional capabilities for visualization and other information technology tools used for decision-support and public participation (Adapted from Laurini 2001, p.254)

Level, type, and description of support			**Support tools**
1	**Level one: Exploration and communication support**		
1.1	**Group Communication**	Idea generation and collection through anonymous input, exchange and synthesis, identification of common ideas.	Data/voice transmission, electronic voting, electronic whiteboards, discussion groups, computer conferencing, and public computer screens.
1.2	**Information Management**	Storage, retrieval, and organization of data.	Spatial and attribute database management systems.
1.3	**Graphic Display**	Spatial and attribute data visualization.	Shared and individual computer displays of maps, charts, tables, images, and diagrams
1.4	**Spatial Analysis**	Basic analytical functions	Proximity, buffering, overlay, data analysis, data mining.
2	**Level two: Enhanced analysis/deliberation support**		
2.1	**Process Models**	Descriptive/simulative models of physical and human spatial processes.	GIS-embedded models, specialized models linked to GIS visualization tools, intelligent agents, experts systems, knowledge bases.
2.2	**Advanced Visualization Tools**	Virtual realities, multimedia animations.	
2.3	**Decision Models**	Various decision rules integrating individual and group-derived evaluation criteria with alternatives performance data.	Multi-criteria decision support techniques.
2.4	**Structural Group Process**	Facilitated/structured group interaction, brainstorming	Automated Delphi, nominal group technique, electronic brainstorming.

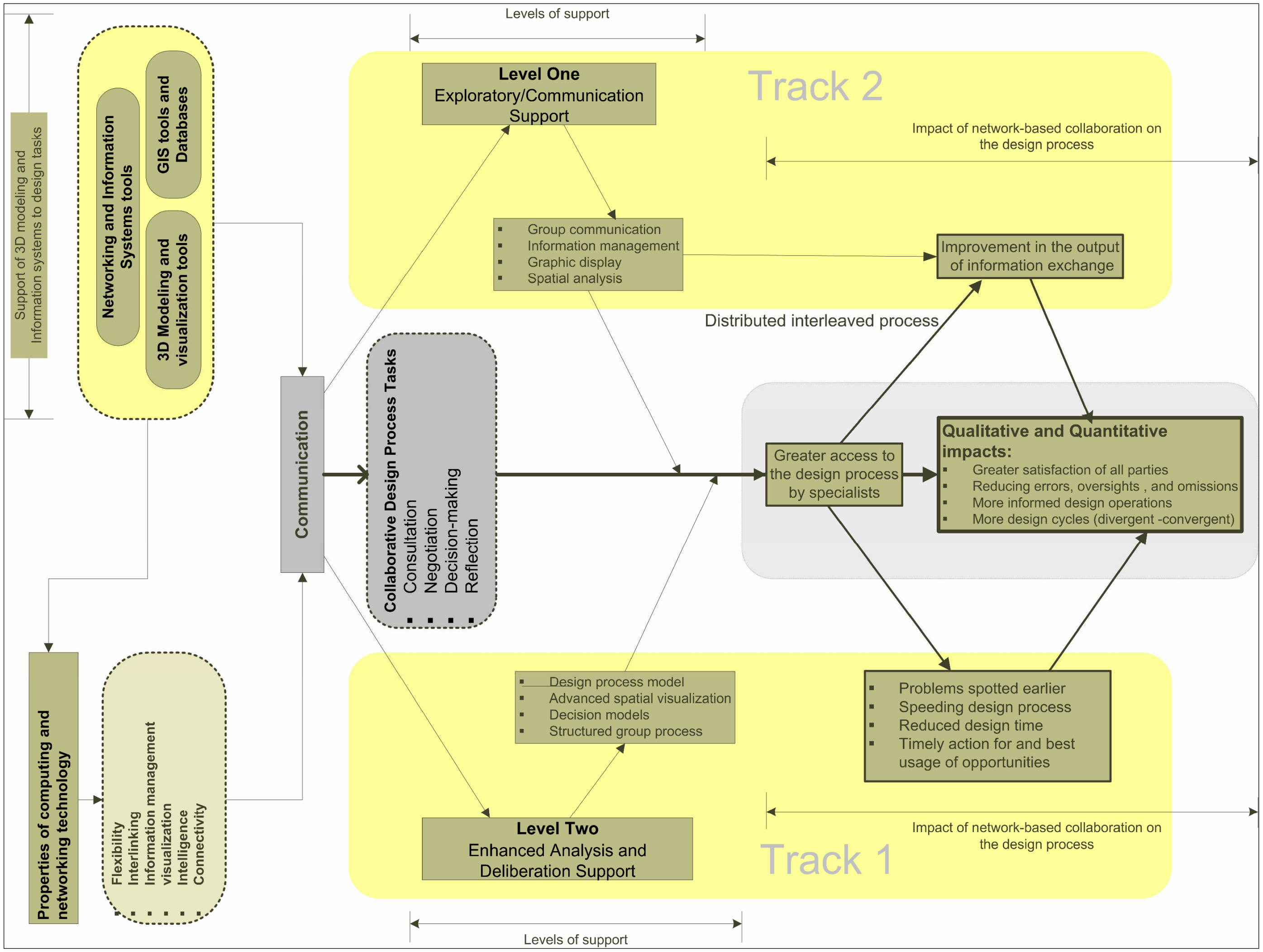


Figure 5.4. Schmeatic flow diagram of the likely impacts of communicatin tools' support on the urban design process

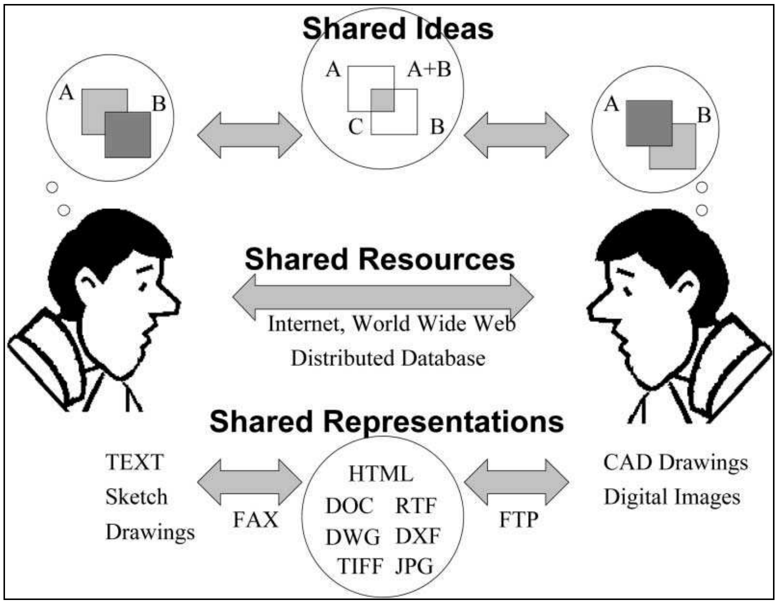


Figure 5.5. Communication conditions among multiple persons (After Chiu 2002, p.189)

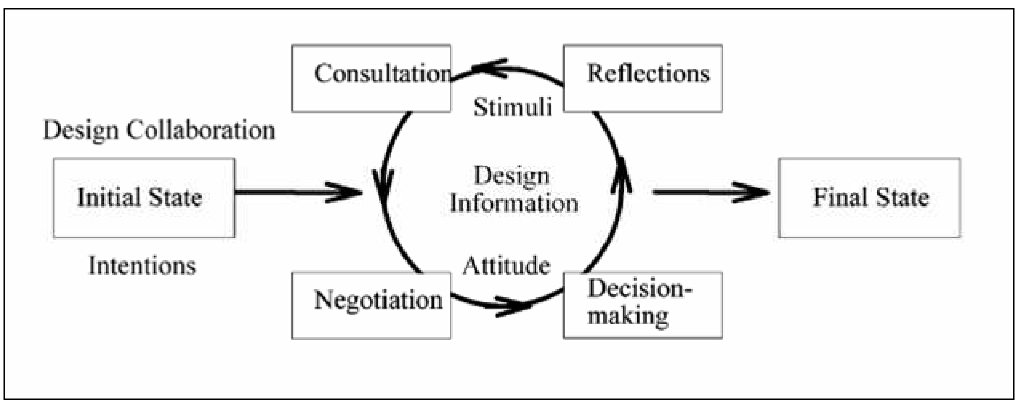


Figure 5.6. A process model of design collaboration (After Chiu 2002, p.206)

It would be hard to isolate the qualitative and quantitative impacts of using communication-support tools on the design process and product from the impacts of using information support tools. Their combined and overlapping impacts can lead to significant improvements in core design tasks such as group communication, information management, and generating and testing alternative design strategies. The next section will outline how the qualitative and quantitative impact of using communication support tools can affect information management and overlap with the support that information management tools provide.

5.4.2 Information management support

The support at the exploratory /communication level (level one) can lead to improvements in two main areas of the design process: information management and group communication (see Figure 5.7). The likely impacts of these improvements are as follows:

1. Facilitating shared understanding of information among design participants.
2. Qualitative and quantitative improvements of the output of electronic information exchange.
3. Effective conflict management and resolution among different professionals to reconcile differently constructed world views or different paradigms (Kalay 2004, pp. 106-109).

The potential improvements in the management of information due to usage of networking and IT-supported communication help designers get better control and steering on information exchange and its output (Figure 5.7-Track 1). These improvements are of increasing importance due to the following reasons:

1. The growing design team due to the higher technical demands and high quality demands.
2. Growing pressure in time due to organizational and real-estate demands.
3. Growing technical complexity of projects.
4. Growing volume of design projects (Den Otter 2000, p.34).

These improvements may lead to similar improvements in the analytical capabilities of the design team that may facilitate effective and efficient usage of information. That usage provides a greater degree of access to relevant and rich data sets and improves the designers' analytical capabilities (Figure 5.7-Track 2). This, in consequence, would improve the qualitative and quantitative basis of analysis with a rich analytical content and knowledge-base that may enrich the design content.

The impacts of the support at the enhanced analysis and deliberation level (level two) can affect the process of generating and testing alternative design strategies in three main areas (aspects). First, designers become able to focus on creative design tasks and thus may generate, explore, evaluate, and modify the widest possible range of concepts. Literature suggests that there is a strong relationship between productivity and creative thinking. To aid creative problem-solving the possibilities have to be based on different design ideas. The comparison helps every one involved to better understand both problems and solutions (Lang 1994, p.393). In conventional practice, designers often consider concepts based on a few principles and thereby ignore a number of concepts based on other principles. Conversely, the computing technology support allows designers to consider a wide variety of design principles and thus concepts which may improve the quality of the final design strategy (Liu, Bligh, and Chakrabarti 2003, p.343).

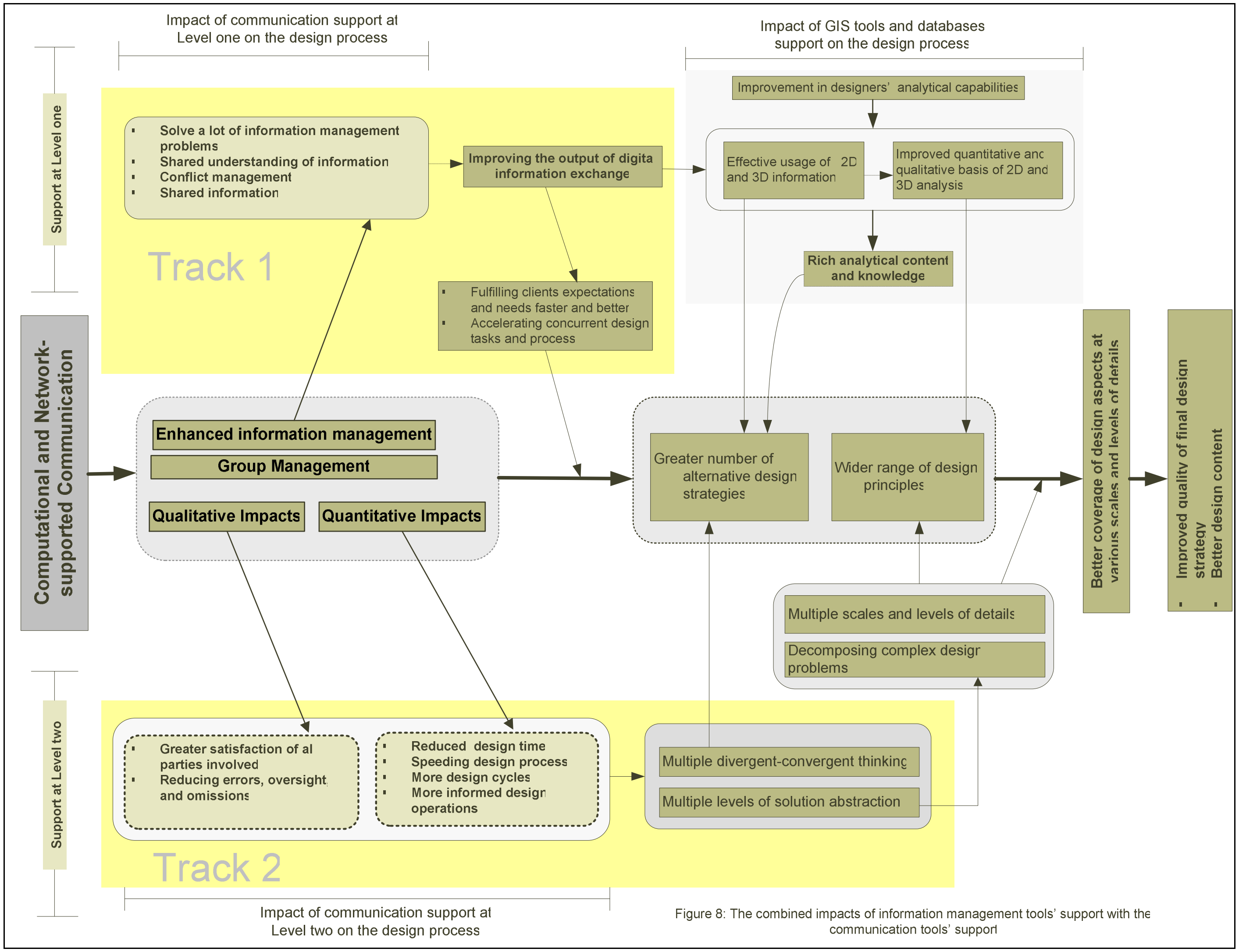


Figure 5.7. The combined impacts of information management tools' support with the communication tools' support.

Second, allowing designers to have multiple levels rather than a single level of solution abstraction which facilitates decomposing and tackling complex urban design problems more effectively (Liu, Bligh, and Chakrabarti 2003, p.344). Third, allowing designers to follow the multiple rather than the single divergence-convergence approach. The multiple approach, according to literature, is considered an ideal approach because it gradually increases the number of solutions for the generation of concepts followed by a divergent and convergent tendency to detail these concepts with an overall decrease in the solutions' number (Liu, Bligh, and Chakrabarti 2003, pp.346-347).

The usage of computing technology can also facilitate comparing and evaluating design alternatives against a wider range of design principles (Pietsch 2000, p.534). This may lead to the consideration of a larger number of design concepts and alternatives developed at multiple levels of abstraction that may ultimately lead to a better coverage of multiple aspects of the built environment at various scales sand levels of details.

In group communication, the communication technology help create a sound group climate that establishes the basis for an open discussion of different design aspects (Badke - Schaub, and Frakenberger 2004, p.125). This highlights the significance of combining the impacts of the representation and visualization tools with those of communication and information management tools in creating a high performance collaborative design team as a means to address various design aspects in the urban design strategy with multiple degrees of details and levels of abstraction.

5.4.3 Representation and visualization support

Literature suggests that the design process involves two main types of representation: external representation and internal representation. Internal representation refers to the process of communicating the evolving design to other design participants for formal evaluation and development. External representation refers to the process of creating and transforming design alternatives and concepts through reflection and action. It involves the generation, evaluation, and revival of mental models with the aid of overt conceptualization and memory aids (Kalay 2004, p.190; Mendivil 1995, p.93). In both representation types, the effective and efficient usage of the capabilities of information technology and visualization tools may lead to three significant impacts. The first impact is reinforcing the knowledge of the tools' development, methods of their usage, and skills of their users. The second impact is changing the relationship between the actions made on representations. The third impact is the improvements to designers' visualization abilities (see Figure 5.8).

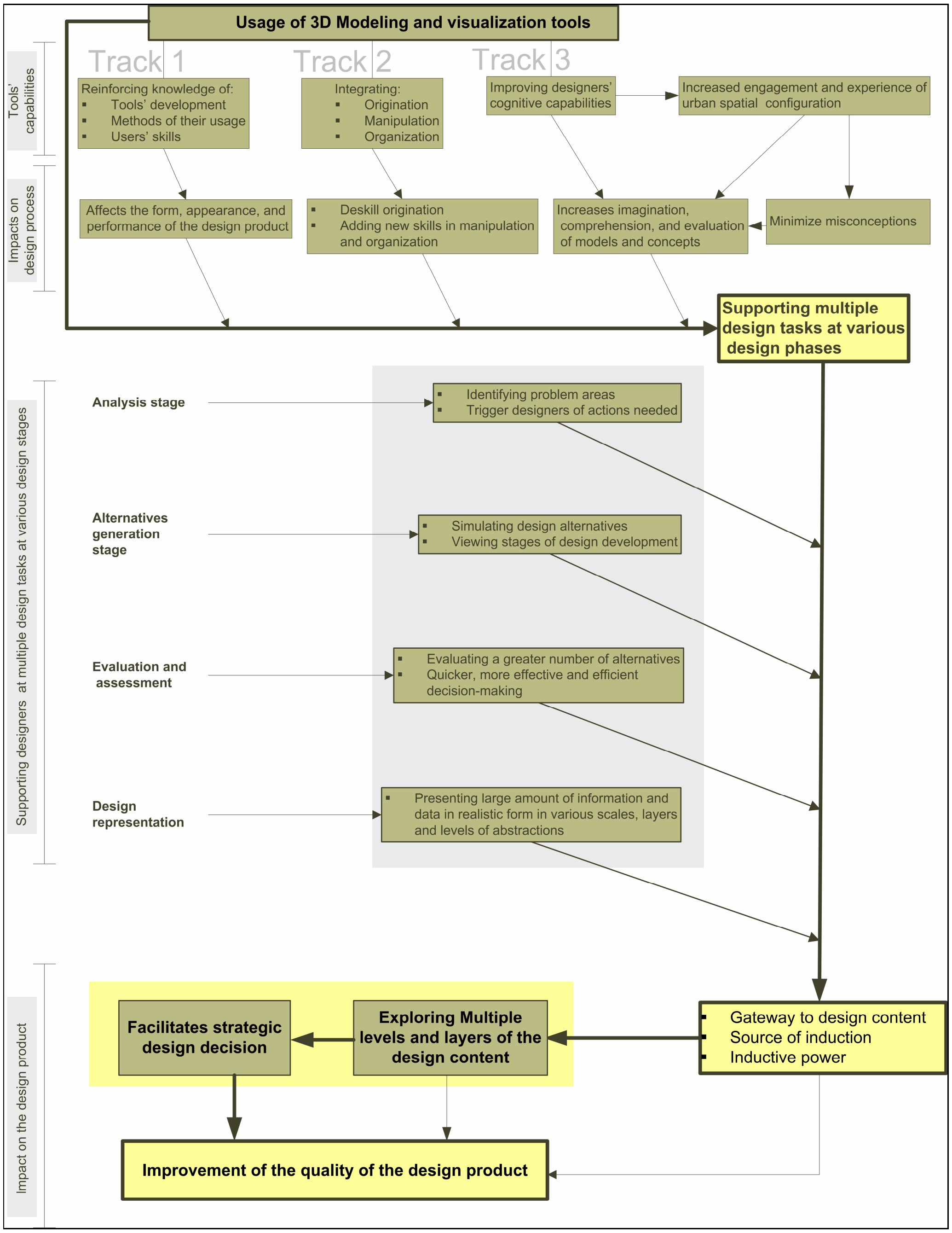


Figure 5.8. Schematic flow chart of the theoretical proposition outlining the potential impact of using 3D modeling tools on the quality of the design product.

In the first impact **(**Figure 5.8-Track 1**)**, both types of representations involve reiterations whereby the representational tool feedback loops help inform and empower designers. Within the context of continuous data-processing systems, powerful feedback loops exist throughout the design process. These loops may affect the relationship between the representational tools' application, potential development, and methods of usage on one hand, and the designers' skills and design product on the other hand. Hence, directly experiencing, reflecting, and acting on the representations made with visualization and representation tools can also be seen as reinforcing the knowledge of the tools' known and unknown potential. This knowledge can ultimately determine and affect the form, performance, and appearance of the design product (Woolley 2004, p.188) (see Figure 4.16).

In the second impact **(**Figure 5.8-Track 2**)**, the usage of digital technology may change the relationship between the main types of actions made on representations: origination, manipulation, and organization. Origination is the creation of representations; manipulation is manipulating pre-existing representations; organization is the process, management, and organization of completed representations. Digital technology has integrated all three, and in particular, has closely engaged origination with manipulation. Such integration has lead, to a certain degree, to deskill origination. Yet, it has lead new skills to evolve in relation to the manipulation or representations. In addition, both manipulation and origination are supported by integrated, highly automated organizational capabilities (Woolley 2004, p.198) (see Figure 4.17).

Therefore, the combined effect of the first and second impacts may lead to the emergence of new skills, applications, and methods of tools' usage in certain tasks that may cause significant impact on the form, appearance, and content of the design product (see Figure 5.9). Those tasks are predominantly performed at the stages of generating, testing, evaluating, and representing design alternatives.

In the third impact **(**Figure 5.8-Track 3**)**, the major advantage of using digital modeling and visualization tools is the improvement of designers' visualization capabilities. Their usage may enhance the imagination, comprehension, and evaluation of models and concepts. They also help provide a highly informative view of the urban structure strengthened by the interaction with the simulations. This, in turn, facilitates the conceptualization of the structural and visual relationships between the constituent elements of urban form (Gotti, Newton, and Kaufman 2004, p.101). In virtual reality visualization technique, the most evident advantage of its usage as an analysis /design tool is the increase of engagement in and experiencing of the spatial configuration of the built environment. It allows a comprehensive exploration of the entire set of elements of urban form and thus minimizes the probability of misconceptions inherent in conventional representations (Gotti, Newton, and Kaufman 2004, p.109).

In the third impact **(**Figure 5.8-Track 3**)**, the major advantage of using digital modeling and visualization tools is the improvement of designers' visualization capabilities. Their usage may enhance the imagination, comprehension, and evaluation of models and concepts. They also help provide a highly informative view of the urban structure strengthened by the interaction with the simulations. This, in turn, facilitates the conceptualization of the structural and visual relationships between the constituent elements of urban form (Gottig, Newton, and Kaufman 2004, p.101). In virtual reality visualization technique, the most evident advantage of its usage as an analysis /design tool is the increase of engagement in and experiencing of the spatial configuration of the built environment. It allows a comprehensive exploration of the entire set of elements of urban form and thus minimizes the probability of misconceptions inherent in conventional representations (Gotti, Newton, and Kaufman 2004, p.109).

Therefore, those capabilities and advantages support designers in performing multiple design tasks at all design stages, namely analysis, generating and testing design alternatives, evaluation and assessment of final design strategy, and design presentation. In analysis, 3D visualizations give a better impression of the urban context than 2D maps. They help identify problem areas and trigger the design team of the action(s) that should be taken. In the alternatives generation phase, they establish an interactive planning environment that help a design team view different stages of the development process. They may be used to simulate the design alternatives in order to compare them with their urban context. Their various types, degrees of abstraction, and levels of detail respond to the various design representations and analyses required during the various design tasks and stages. In evaluation and assessment, they facilitate comparing and assessing the impact of a greater number of design alternatives within their urban context which makes the decision-making process quicker, more effective, and efficient (Ranzinger and Gleixner,1997 p. 164). In design presentation, the various presentations help visualize large amount of data and information in a rather realistic form (Huang et al 2001, p.442).

With the support provided through these advantages, digital 3D representations and visualizations allow designers to establish a focus of attention. They create a gateway to the content of the design product or to the potential design product which may trigger the designers' natural ability to recognize a design opportunity. Their dynamic nature allows designers to penetrate further within the design product and thus allows them to explore which design elements need to be specified in further detail, and/ or which design elements offer the best potential for further development. As dynamic entities, they represent the most important source of induction to facilitate design development. Therefore, their inductive power entitles them to become a means to make strategic design decisions that are likely to enhance the quality of the design product (Mendivil 1995, pp. 85-86).

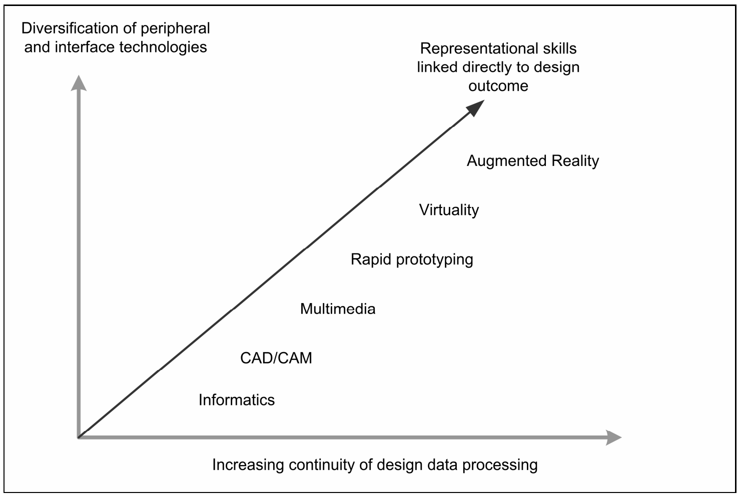


Figure 5.9. The increasing continuity of design processing has facilitated the development of skill based tools (After Woolley 2004, p.194)

5.5 Conclusions

According to some experts, urban design plans adopted in US cities are often developed without being underpinned by relevant analytical content, or are not based on in-depth analysis for the specific problem of the study area. These plans exhibited a lack of coverage of urban design topics which would normally be considered as central to design control. They demonstrate two procedural gaps: one between theory and practice, and the second between analysis and conceptual phases.

The role of conceptual phase is vital for the decision making process that lies at the core of the urban design practice. The generation of design alternatives involves several intellectual tasks structured around a number of key sub phases and linked with other interrelated phases and sub-phases of the urban design process. It involves a continuous, cyclic, and iterative process by which solutions are gradually refined through a series of creative leaps or conceptual shifts. In that process, the procedural gaps may be due to communication-related problems and information-related problems. Communication-related problems may be due, in part, to the incapability of conventional urban design tools and techniques to meet the needs and requirements of an increasingly multi-disciplinary and distributed design process and knowledge. Information-related problems may be a result of an increasing access to, and overwhelming volume of, information and data pertinent to the design problems which leads to poor management of that data and ultimately poor analysis.

Digital modeling and IT tools may help designers visualize and interact with design alternatives, large urban datasets, and 3D information more effectively, thus correcting and bridging these problems and gaps. The primary support those tools provide is in navigation-visualization application. Yet their improvements to designers' visualization capabilities are likely to support their analytical capabilities and to encourage experiments with new forms of information management, communication, and visualization. In addition, communication technology helps create a sound group climate that establishes the basis for an open discussion of different design aspects especially crucial aspects of the design strategy.

Their combined improvements may help bridge those procedural gaps and thus improve the quality of the design product in two ways: supporting designers and improving designers' skills. First, they support designers in performing multiple design tasks at all design stages, and second, they respond to the various types and formats of design representations and analyses required throughout those design tasks and stages. Therefore, they allow designers to produce more imaginative design solutions that are a better fit to the design problem and a better translation of design and planning goals and objectives. Second, their usage may also lead to the emergence of new skills, applications, and methods of tools' usage in certain tasks that may cause significant impact on the form, appearance, and content of the design products. They may create a gateway to the content of the design product which may trigger the designers' abilities to recognize the design opportunity.

The selection of the range of tools and fulfilling designers' needs in the concepts generation phase requires using a range of integrated tools rather than a specific tool as well as developing new tools and techniques that could fulfill designers' needs. This range of a variety of tools is essential to support the entire array of designers' skills and intellectual tasks conducted within a variety of design models, methodologies, and approaches. The tools' integration may foster developing new methods and skills of their usage in order to support new design methodologies and strategies and thus to improve the design content and coverage of urban design plans in US cities.

Therefore, the effective usage of modeling functionalities may improve the quality of the decision-making process through providing certain improvements to designer's capabilities in performing core design tasks. According to the theoretical model illustrated in figure 5.3, the improvements to designers' cognitive capabilities would become the driver to improve designers analytical and communication capabilities. The overall impact of the combined improvements is meant to provide solutions to the information management problems and communication problems that have lead to the gaps in the design content. The following chapter will examine 14 urban design plans to assess the extent to what the usage of digital modeling has affected their design content. The results will also help assess the extent to what digital model supported designers in core design tasks. These results will be compared and contrasted with those illustrated in the theoretical propositions in this chapter. Such a comparison may highlight any discrepancy between theory and practice and help explain the inadequacies that affected the quality of urban design plans. Such a discrepancy may also highlight any design tasks that need further improvements and digital modeling and information tools' support.

CHAPTER VI

CONTENT ANALYSIS OF THE SELECTED URBAN DESIGN PLANS: ASSESSMENT OF THE DESIGN CONTENT OF 14 PLANS

The previous chapters discussed the relation between the usage of 3D modeling and the quality of the design outcome. Chapter III outlined a theoretical proposition of the impact of using 3D digital modeling on the design content of urban design plans. In chapter IV, a causal model to explain theoretically how 3D urban models and IT tools can impact urban design process and product has been suggested and justified. My goal was to test the research hypothesis and to discover empirically whether 3D digital models have an impact on the design content. To pursue that goal, 14 cases have been examined using content analysis. Among those plans, eight plans were developed using design methods supported by 3D digital models and tools (computational plans hereafter) and six plans were developed using conventional design methods (conventional plans hereafter).

This chapter explains the methods used for analyzing the content analysis data and discusses the findings of the selected cases. I first focused on each urban design plan individually to investigate how and to what extent it covered the entire set of design aspects. The first analytical task involved examining each plan to document its general approach, the techniques of analyzing and representing the urban design elements and issues, and the extent with which it has covered the 2D and 3D design elements and issues. The second analytical task focused on each design aspect to investigate the extent with which it was covered across all plans. The second task involved comparing the design content and extent of coverage in both types of plans. In both tasks, the study used the qualitative data collected in content analysis as explained in the chapter III. The data collected in the two analytical tasks are discussed in the following two sections. This evidence is then used to produce findings that are discussed in subsequent sections. Finally, conclusions were derived from a synthesis of all of the evidence and findings.

6.1 Assessment of the Design Content of the Selected Plans

6.1.1 Assessment of the extent of coverage of design aspects, elements and issues

The first analytical task focused on the selected urban design plans to investigate the extents with which they covered the basic 2D and 3D design aspects and their constituent elements and issues. In this task, the content analysis involved two basic steps: assessment and rating.

The first step was documenting the extent with which each urban design plan covered the entire set of design aspects, the general approach, the hierarchy of scales of design control, and the techniques of analyzing and representing the urban design aspects. The extent of coverage was assessed using a scale of three levels: no coverage, minimum coverage, and significant coverage. These coverage levels were represented by three numerical values, 1, 3, and 6 respectively to reflect their relative coverage powers. A sample of the documentation for one computational plan is shown in the appendix (see appendix D). A design element with no coverage indicates that the plan did not cover or address it in its policies to any significant degree. A design element with minimum coverage indicates that the urban design plan has addressed it, yet has not issued a design policy, measure, or guideline to design it and control its design attributes comprehensively. At the third level, a design element with significant coverage indicates that the urban design plan has addressed it efficiently and effectively through design policies, measures, and guidelines to control and design its attributes. Determination of a rating was made after multiple readings of the plans.

Columns A1 through A8 document the assessment of design aspects coverage in eight computational plans (see Table 6.1.A) and columns B1 through B6 document the same in six conventional plans (see Table 6.1.B). In each design aspect, the number of elements addressed at any of the three levels of coverage is listed, and the percentage that each number contributes to the total number of elements in that design aspect is then identified. The number of elements at each coverage level and their percentage to the total are highlighted on the last two rows of each design aspect in the afore-mentioned tables. For example, in the townscape design aspect of NY computational plan, the number of design elements and issues covered with high, minimum, and no coverage levels are: 9, 5, and 3 respectively (see Table 6.1.A). Therefore, the table indicates that 53% and 29% of the total number of elements comprising the townscape design aspect (17 elements) have been addressed with significant and minimum coverage respectively, whereas 18% of those elements were not covered. The table highlights the number of elements at each coverage level and their percentage to the total number of elements. Therefore, this step allowed me to compare the contribution of each coverage level to a total across all categories of coverage levels. In the computational plans, the percentages of elements addressed with significant, minor, or no coverage levels were tabulated and represented in columns A1 through A8 (see Table 6.1.A). In the conventional plans, the percentages of elements addressed with significant, minor, or no coverage levels were tabulated and represented in columns B1 through B6 (see Table 6.1.B).

Table 6.1.A. Percentage of design aspects coverage in computational plans

		COMPUTATIONAL PLANS																							
		A1			A2			A3			A4			A5			A6			A7			A8		
		New York1			Pittsburgh.			Chicago			Philadelphia			Milwaukee			Boston 1			Boston 2			New York2		
No.	Design Aspect	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage
1	**Townscape**	53	29	18	94	6	0	66	17	17	47	47	6	59	29	12	65	12	24	65	6	29	29	53	18
2	**Urban Form**	43	36	21	79	21	0	64	36	0	14	29	57	57	29	14	43	43	14	86	7	7	64	21	15
3	**Architectural Character**	4	32	64	41	45	14	0	0	100	0	0	100	9	18	73	5	27	68	68	9	23	23	4	73
4	**Conservation areas**	34	18	48	66	26	8	34	29	37	0	16	84	5	24	71	24	21	55	18	26	55	24	21	55
5	**Sustainable Urban Design**	8	34	58	34	33	33	33	34	33	17	33	50	25	42	33	33	42	25	66	17	17	8	42	50
6	**Connection and Movement Network**	50	50	0	87	13	0	100	0	0	0	37	63	88	12	0	88	0	12	100	0	0	51	12	37
7	**Land -use (Mixed-use and diversity)**	100	0	0	100	0	0	100	0	0	67	33	0	67	33	0	100	0	0	100	0	0	67	33	0
8	**Public Realm**	100	0	0	88	6	6	66	17	17	17	50	33	66	17	17	66	17	17	67	0	33	67	0	33
9	**Landscape Architecture**	13	13	74	63	31	6	43	19	38	13	13	74	69	25	6	50	31	19	25	44	31	19	31	50
10	**Number of design aspects with high level**	2			6			4			1			4			3			6			2		
11	**Number of design aspects with medium level**	4			3			3			1			2			4			1			2		
12	**Number of design aspects with low level**	3			0			2			7			3			2			2			5		

Table 6.1.B. Percentage of design aspects coverage in conventional plans

		CONVENTIONAL PLANS																	
		B1			B2			B3			B4			B5			B6		
		New York			Pittsburgh			Chicago			Philadelphia			Milwaukee			Boston		
No.	Design Aspect	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage	Significant	Minor	No coverage
1	**Townscape**	13	29	58	18	53	29	46	36	18	47	47	6	47	35	18	35	6	59
2	**Urban Form**	29	42	29	28	36	36	22	64	14	22	43	35	57	29	14	29	29	43
3	**Architectural Character**	0	23	77	18	5	77	0	50	50	23	9	68	55	23	23	45	32	23
4	**Conservation areas**	0	29	71	18	16	66	19	39	42	37	16	47	45	16	39	32	26	42
5	**Sustainable Urban Design**	17	0	83	17	17	66	0	0	100	0	8	92	0	8	92	42	0	58
6	**Connection and Movement Network**	87	0	13	13	37	50	37	37	26	37	38	25	25	25	50	100	0	0
7	**Land -use (Mixed-use and diversity)**	100	0	0	0	100	0	100	0	0	67	33	0	100	0	0	100	0	0
8	**Public Realm**	17	50	33	0	67	33	34	16	50	33	17	50	67	0	33	67	33	0
9	**Landscape Architecture**	0	31	69	13	31	56	6	44	50	25	19	56	19	50	31	44	13	44
10	**Number of design aspects with high level**	2			0			1			1			2			3		
11	**Number of design aspects with medium level**	0			0			3			4			4			4		
12	**Number of design aspects with low level**	7			9			5			4			3			2		

Table 6.2.A. Ranking design aspects according to the percentage of their significant coverage in computational plans

	COMPUTATIONAL PLANS															
	A1		**A2**		**A3**		**A4**		**A5**		**A6**		**A7**		**A8**	
	New York1		**Pittsburgh.**		**Chicago**		**Philadelphia**		**Milwaukee**		**Boston 1**		**Boston 2**		**New York2**	
No.	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage
1	Land -use (Mixed-use and diversity)	100	Land -use (Mixed-use and diversity)	100	Connection and Movement Network	100	Land -use (Mixed-use and diversity)	67	Connection and Movement Network	88	Land -use (Mixed-use and diversity)	100	Connection and Movement Network	100	Land -use (Mixed-use and diversity)	67
2	Public Realm	100	Townscape	94	Land -use (Mixed-use and diversity)	100	Townscape	47	Landscape Architecture	69	Connection and Movement Network	88	Land -use (Mixed-use and diversity)	100	Public Realm	67
3	Townscape	53	Public Realm	88	Townscape	66	Sustainable Urban Design	17	Land -use (Mixed-use and diversity)	67	Public Realm	66	Urban Form	86	Urban Form	64
4	Connection and Movement Network	50	Connection and Movement Network	87	Public Realm	66	Public Realm	17	Public Realm	66	Townscape	65	Architectural Character	68	Connection and Movement Network	51
5	Urban Form	43	Urban Form	79	Urban Form	64	Urban Form	14	Townscape	59	Landscape Architecture	50	Public Realm	67	Townscape	29
6	Conservation areas	34	Conservation areas	66	Landscape Architecture	43	Landscape Architecture	13	Urban Form	57	Urban Form	43	Sustainable Urban Design	66	Conservation areas	24
7	Landscape Architecture	13	Landscape Architecture	63	Conservation areas	34	Architectural Character	0	Sustainable Urban Design	25	Sustainable Urban Design	33	Townscape	65	Architectural Character	23
8	Sustainable Urban Design	8	Architectural Character	41	Sustainable Urban Design	33	Conservation areas	0	Architectural Character	9	Conservation areas	24	Landscape Architecture	25	Landscape Architecture	19
9	Architectural Character	4	Sustainable Urban Design	34	Architectural Character	0	Connection and Movement Network	0	Conservation areas	5	Architectural Character	5	Conservation areas	18	Sustainable Urban Design	8

Table 6.2.B. Ranking design aspects according to the percentage of their significant coverage in conventional plans

CONVENTIONAL PLANS												
	B1		B2		B3		B4		B5		B6	
	New York		Pittsburgh		Chicago		Philadelphia		Milwaukee		Boston	
No.	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage	Design aspects ranked according to their significant coverage	% Significant coverage
1	**Land -use (Mixed-use and diversity)**	100	**Urban Form**	28	**Land -use (Mixed-use and diversity)**	100	**Land -use (Mixed-use and diversity)**	67	**Land -use (Mixed-use and diversity)**	100	**Movement Network**	100
2	**Movement Network**	87	**Townscape**	18	**Townscape**	46	**Townscape**	47	**Public Realm**	67	**Land -use (Mixed-use and diversity)**	100
3	**Urban Form**	29	**Architectural Character**	18	**Movement Network**	37	**Conservation areas**	37	**Urban Form**	57	**Public Realm**	67
4	**Sustainable Urban Design**	17	**Conservation areas**	18	**Public Realm**	34	**Movement Network**	37	**Architectural Character**	55	**Architectural Character**	45
5	**Public Realm**	17	**Sustainable Urban Design**	17	**Urban Form**	22	**Public Realm**	33	**Townscape**	47	**Landscape Architecture**	44
6	**Townscape**	13	**Movement Network**	13	**Conservation areas**	19	**Landscape Architecture**	25	**Conservation areas**	45	**Sustainable Urban Design**	42
7	**Architectural Character**	0	**Landscape Architecture**	13	**Landscape Architecture**	6	**Architectural Character**	23	**Movement Network**	25	**Townscape**	35
8	**Conservation areas**	0	**Land -use (Mixed-use and diversity)**	0	**Architectural Character**	0	**Urban Form**	22	**Landscape Architecture**	19	**Conservation areas**	32
9	**Landscape Architecture**	0	**Public Realm**	0	**Sustainable Urban Design**	0	**Sustainable Urban Design**	0	**Sustainable Urban Design**	0	**Urban Form**	29

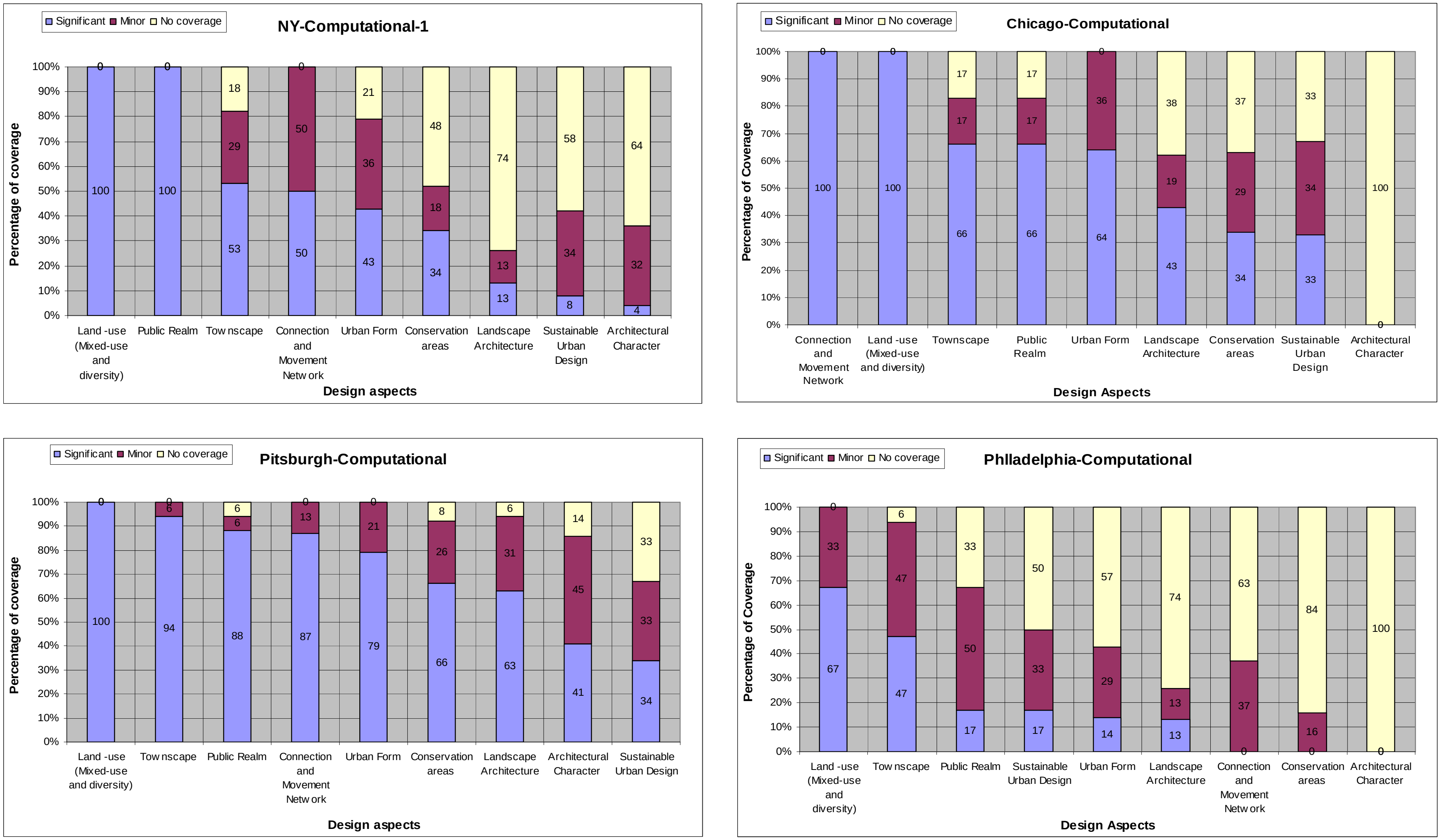
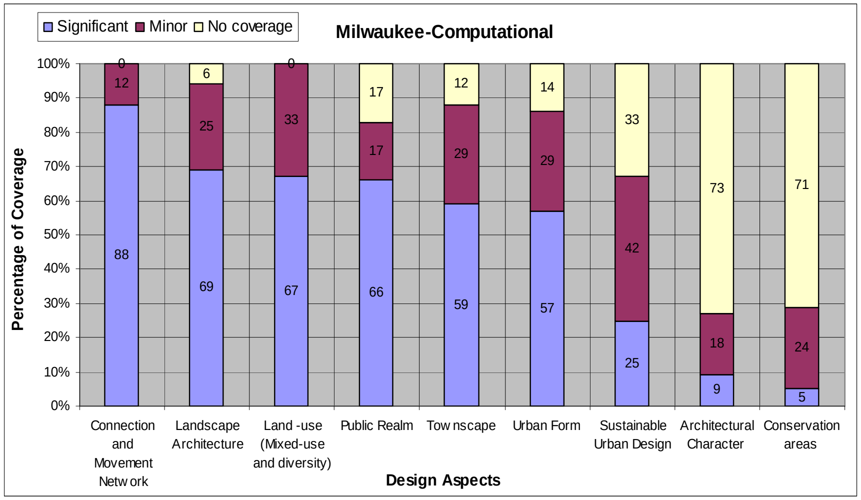
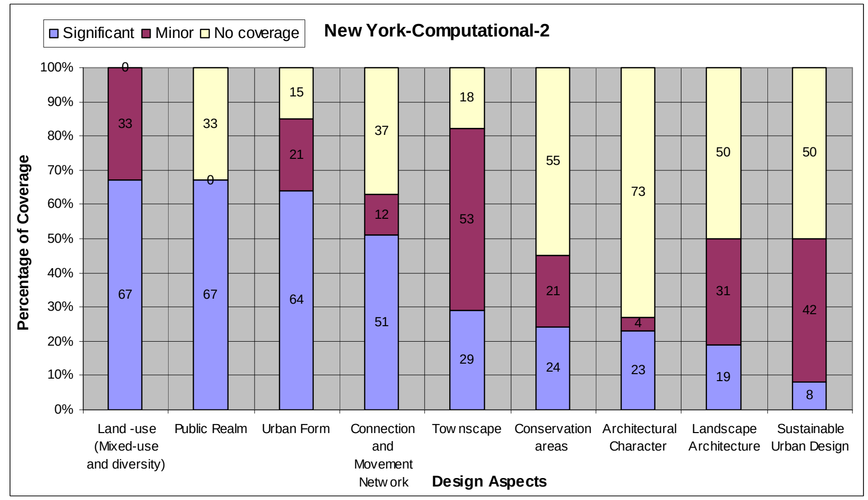
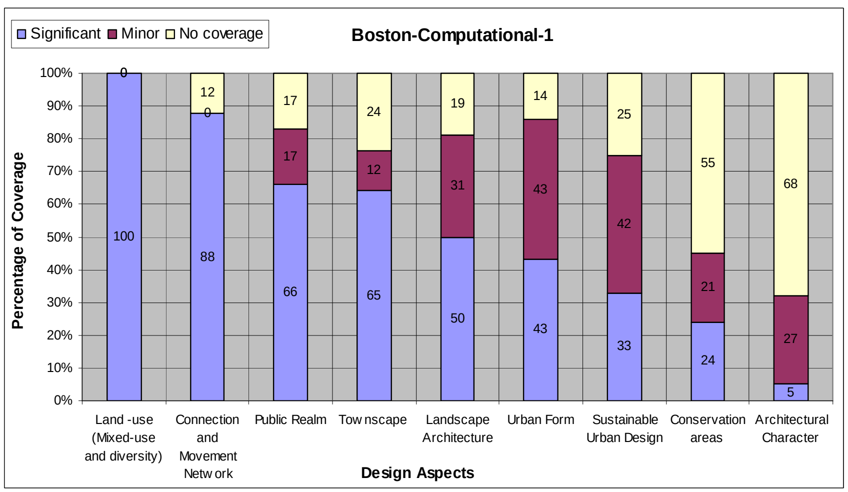


Figure 6.1.A. Percentage of design aspects coverage in computational plans







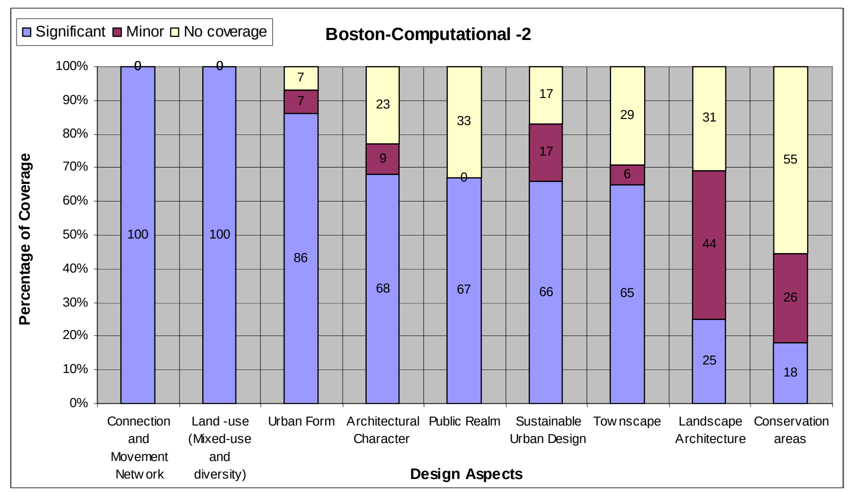


Figure 6.1.A (continued).

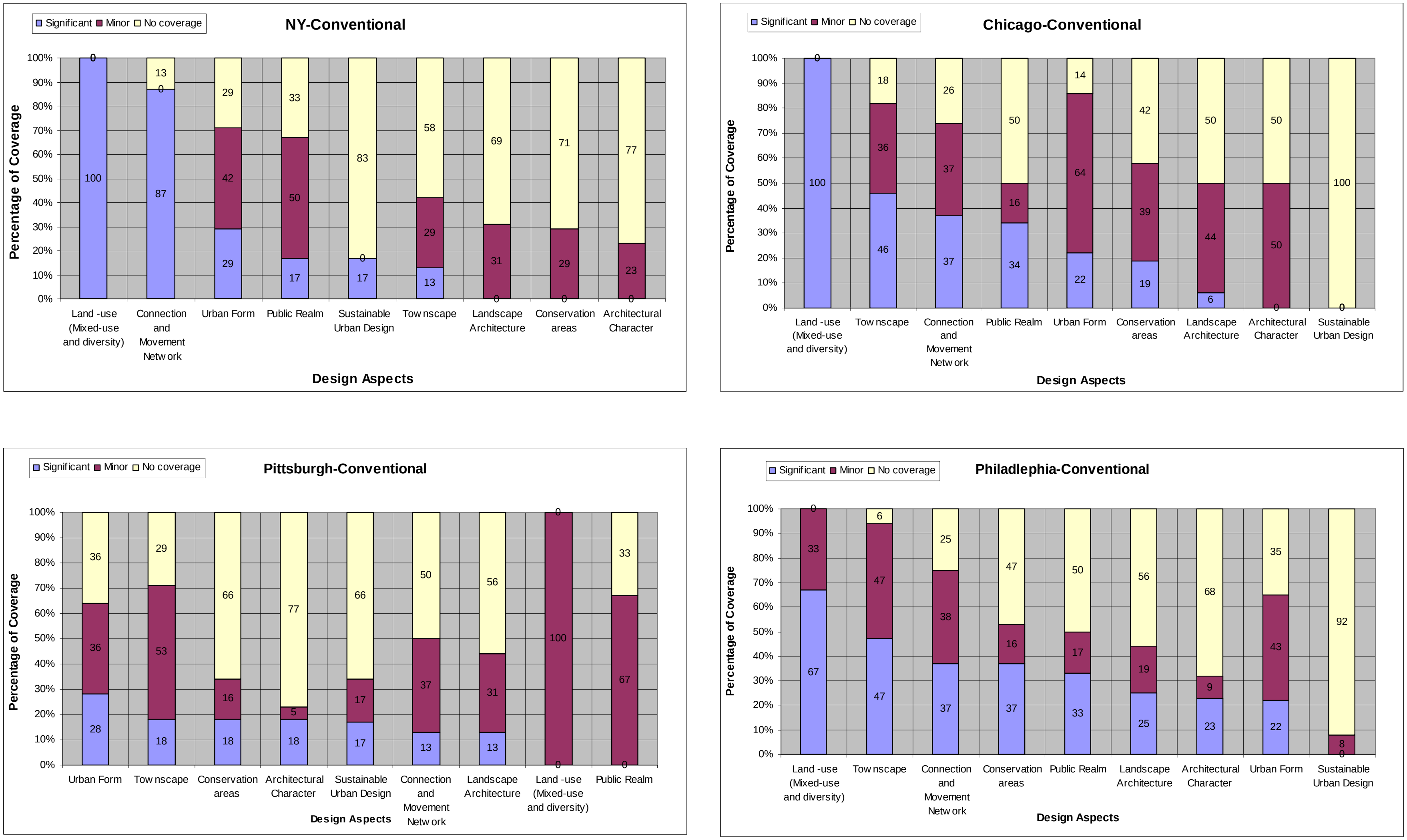
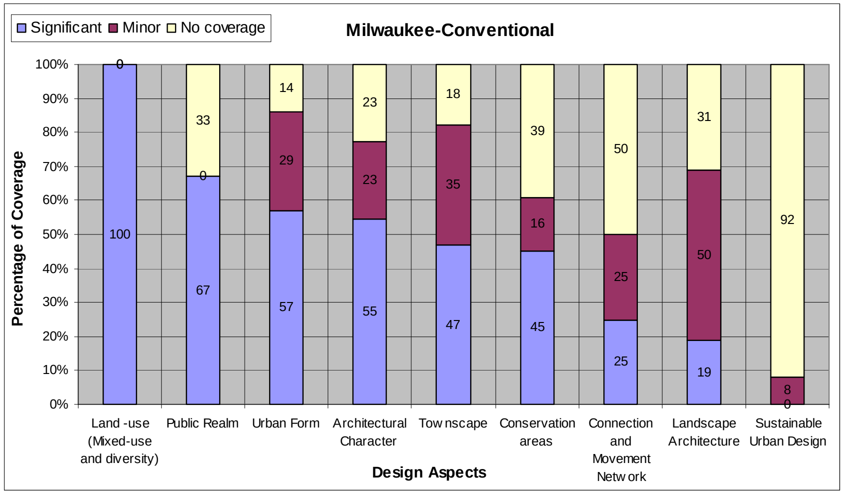


Figure 6.1.B. Percentage of design aspects coverage in conventional plans



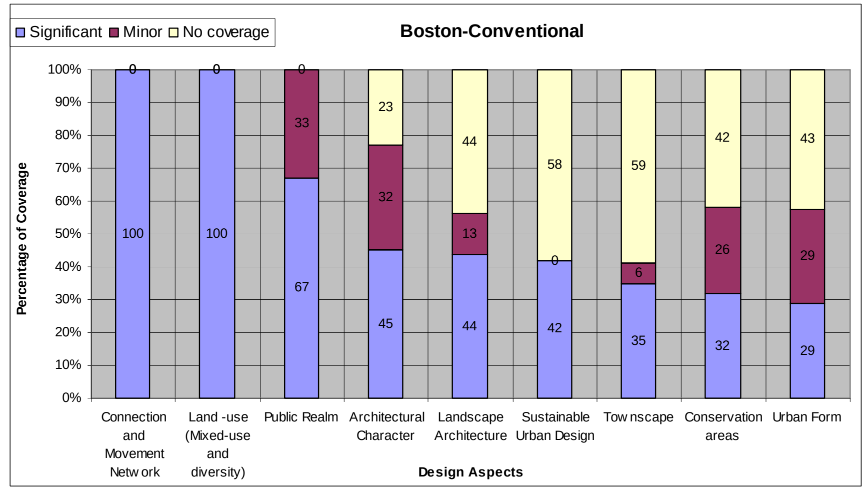


Figure 6.1.B (continued).

The second step in this task involved sorting the design aspects of each plan in descending order according to the percentage of the design elements addressed with significant coverage (see Table 6.2 A and B and Figure 6.1 A and B). This step helped identify any emerging pattern or trend that both types of plans may show in addressing their design aspects. It also allowed comparison of the extent of coverage attained in all plans with the assumption derived from the literature review that urban design practice in US cities display a lack of coverage of 3D design aspects in current urban design plans and emphasize covering 2D design aspects.

6.1.2 The extent of design aspects coverage: computational versus conventional plans

The second analytical task focused on the design aspects to compare the extent with which they were covered across both types of plans: computational and conventional urban design plans. It involved three steps. At the first step, I considered each design aspect individually and used the percentage of its constituent design elements and issues that were addressed with significant coverage to sort the design plans in descending order. Each plan, as such, was assigned a rank that reflects the percentage with which it covered the constituent elements of each design aspect with significant coverage. For example, in urban form, Boston computational-2, Pittsburgh computational, Chicago computational, and N.Y. computational-2 plans ranked (1) through (4) because they addressed 86%, 79%, 64%, 64% of the elements of urban form with significant coverage respectively (see Figure 6.2). This step allowed me to identify the type of plans that cover each design aspect with higher degree of significant coverage.

The second step involved comparing the selected urban design plans in their ranks of covering the entire set of design aspects. Consequently, the plans were ranked in ascending order according to their cumulative rank, which is the sum of their ranks attained throughout the entire set of design aspects (see Figure 6.3). For example, Philadelphia conventional plan ranked 7, 12, 5, 3, 12, 8, 2, 8, and 7 of among the 14 plans in covering the entire set of design aspects, i.e. townscape through landscape architecture respectively, with significant coverage. Therefore, the cumulative rank of this plan was 64 . This step identified which type of plans (computational or conventional) rank higher (i.e. less cumulative rank) in covering the entire set of design aspects, and helped also to identify the design aspects that each type of plan tended to rank higher.

The third step involved calculating the average percentage of elements addressed with significant coverage in both types of plans. For instance, in the townscape design aspect, the percentages of its constituent elements addressed with significant coverage in computational plans were 53%, 94%, 66%, 47%, 59%, 65%, 65%, 29% which yielded an average of 60% (see Table 6.1.A). The percentages of the same elements in conventional plans were 47%, 35%, 18%, and 13% which yielded an average of 34% (see Table 6.1.B). This method allowed me to compare the average of the percentage of elements covered with significant coverage in both computational and conventional plans. It also identified any correlation that may potentially emerge between plans' type and the design aspects with higher average percentage.

6.2 Findings of the Analytical Tasks

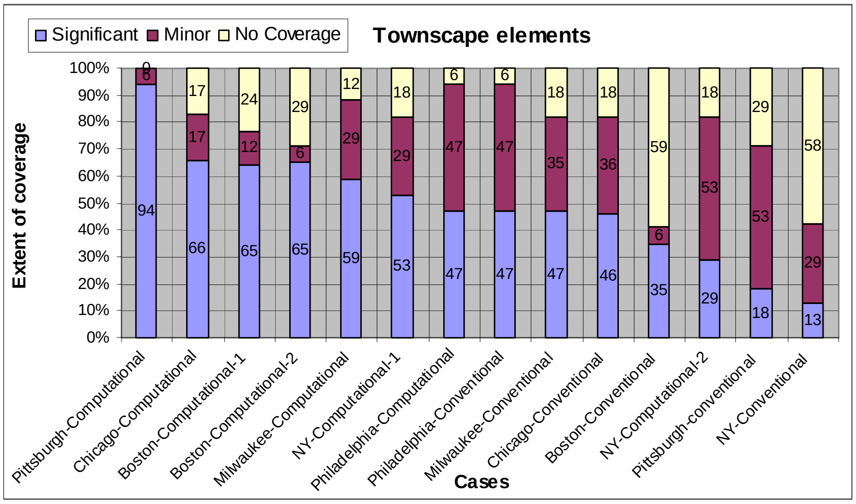
6.2.1 Findings of the first analytical task: analysis of the design aspects

Content analysis revealed various levels of design aspects coverage as well as certain patterns with which the coverage level of each design aspect varies across plans. It was found that the design aspects tend to fall into three distinct groups according to the percentage of their constituent elements addressed with significant coverage (see Table 6.3). The first level, group A, includes the design aspects that plans most focus on and thus address with high coverage level. In those aspects, the percentage of elements addressed with significant coverage range from 66% to 100%. The second level (group B) includes design aspects addressed with an average coverage. In those aspects, the percentage of elements addressed with significant coverage range from 65% to 33%. The third level (C) includes design aspects that receive the least focus, and thus address with low coverage. In those aspects, the percentage of elements addressed with significant coverage range from 32% to 0%. These ranges of design aspects coverage were used as criteria to classify the design aspects of each urban design plan into three specific types or levels: high, average, and low coverage (see Table 6.3). These levels were highlighted in rows (10-12) respectively in Table 6.1 A and 6.1.B.

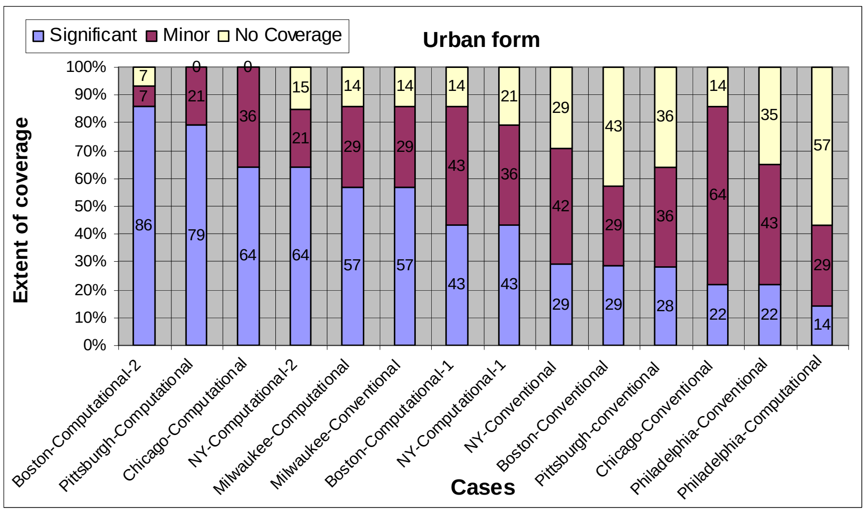
Table 6.3. Maximum and minimum limits of the various coverage levels of design aspects

No.	Group	Criteria		
		Definition	Percentage of elements addressed with significant coverage	
			Minimum	Maximum
1	A	Design aspects addressed with high level of coverage	66	100
2	B	Design aspects addressed with average level of coverage	33	65
3	C	Design aspects addressed with low level of coverage	0	32

2.1



2.2



2.3

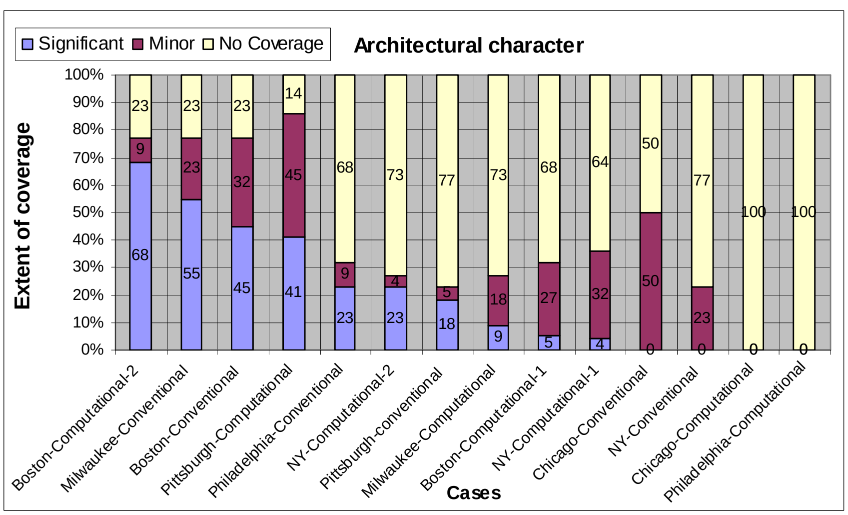
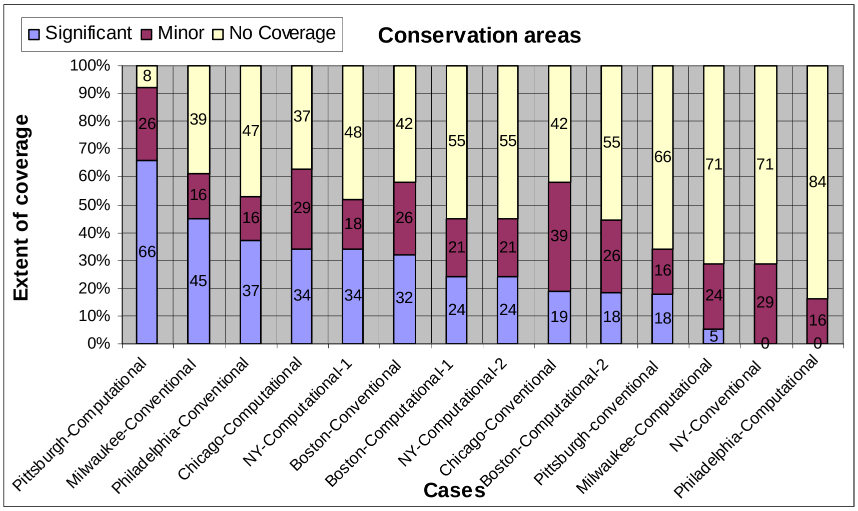
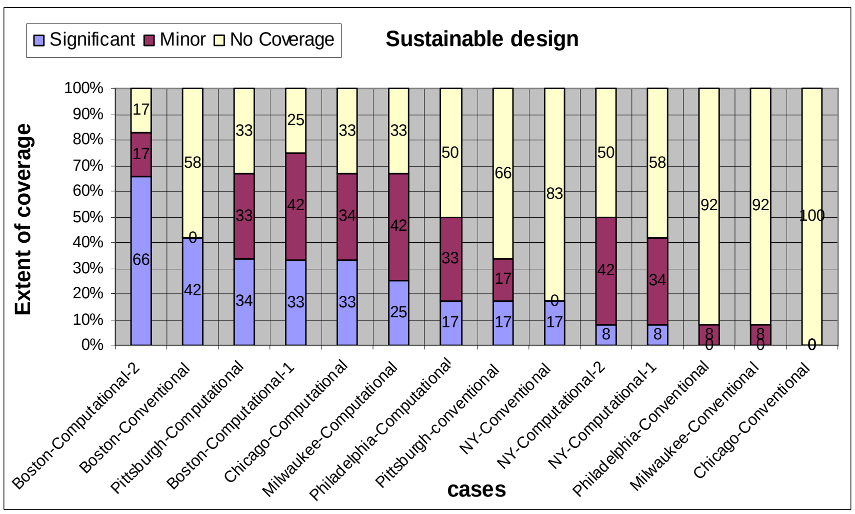


Figure 6.2. Distribution of the percentages of coverage in the entire set of design aspects

2.4



2.5



2.6

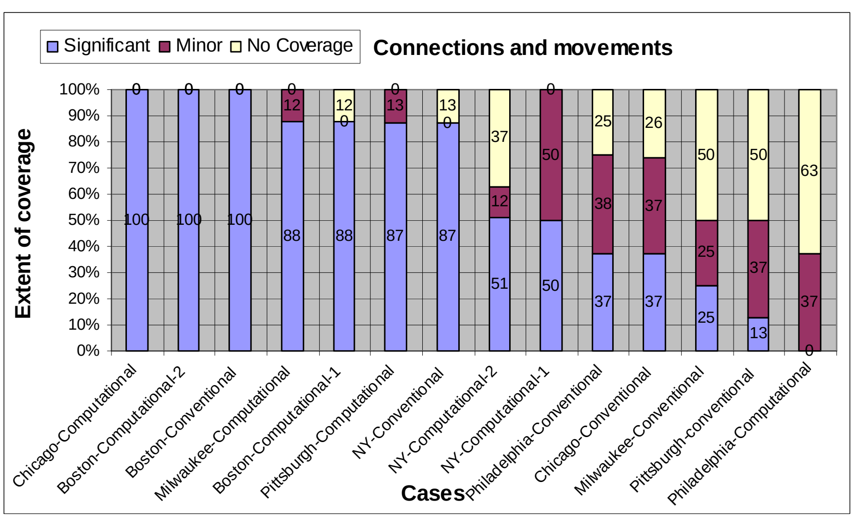


Figure 6.2 (continued).

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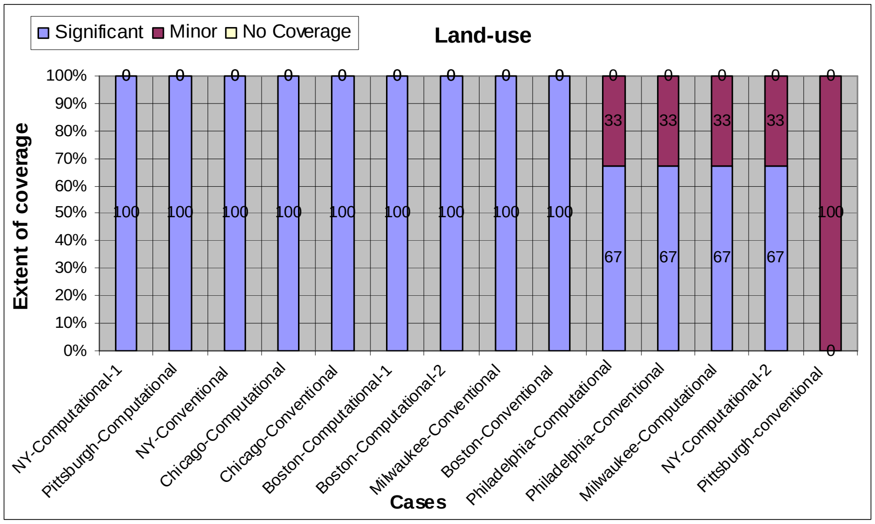

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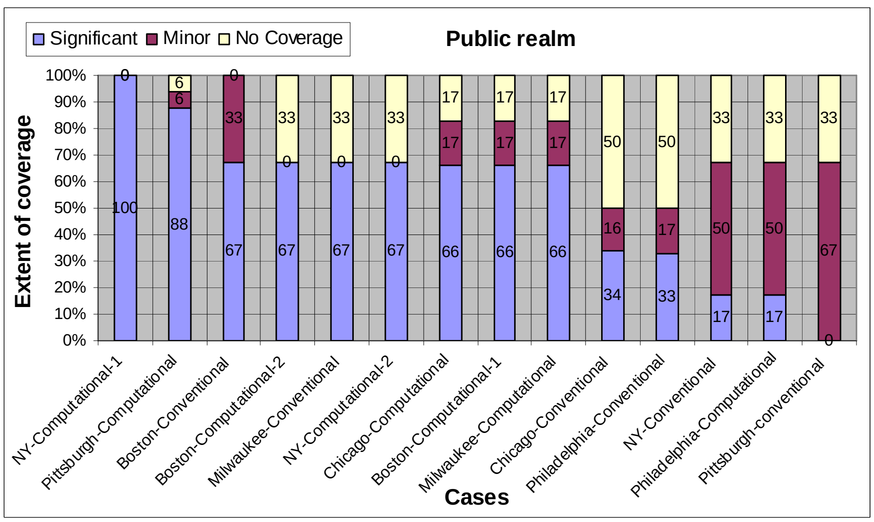

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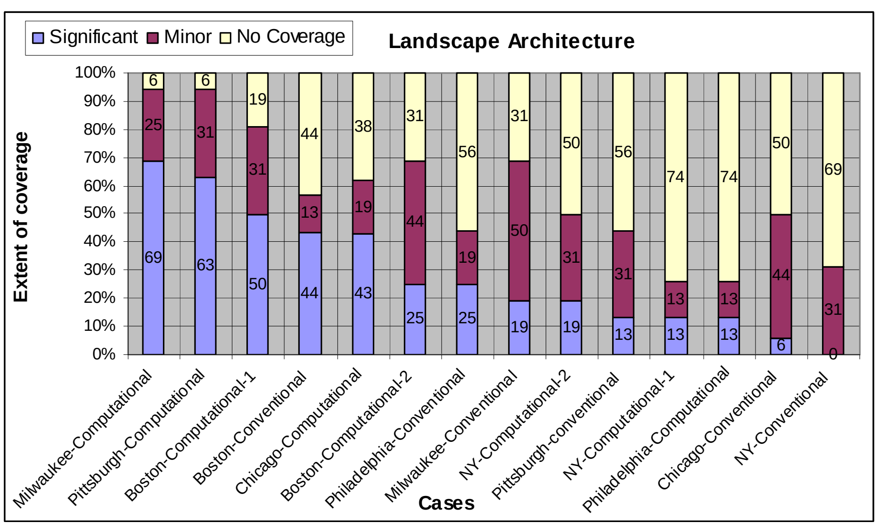

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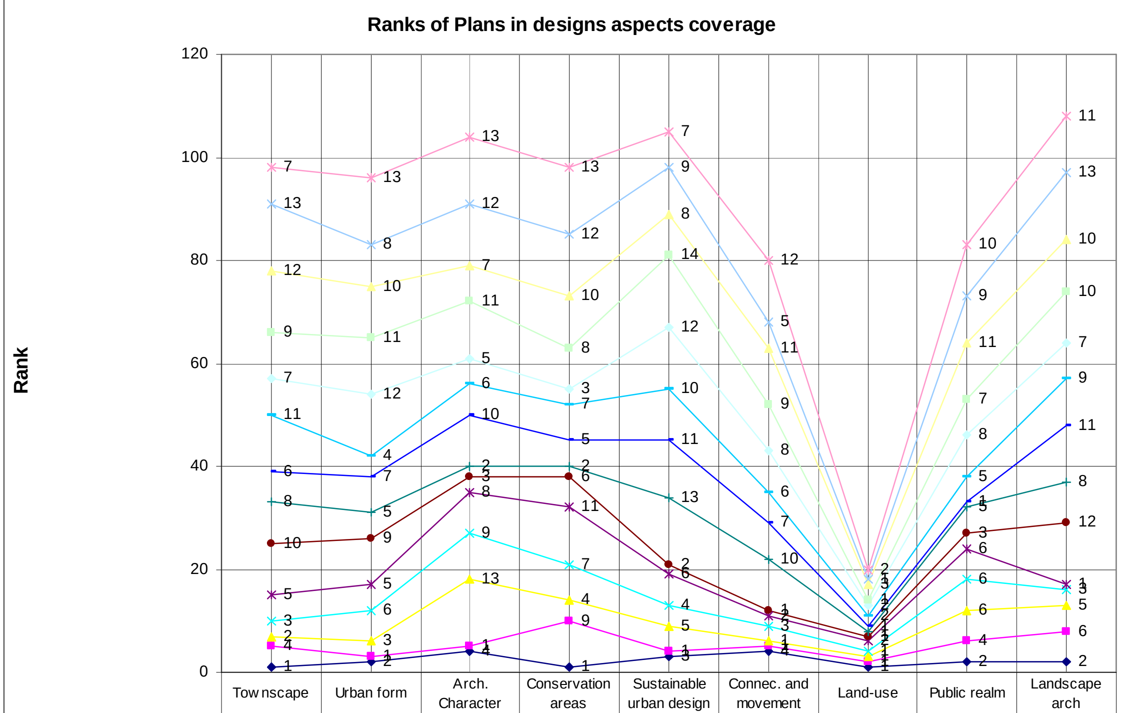


	Townscape	Urban form	Arch. Character	Conservation areas	Sustainable urban design	Connec. and movement	Land-use	Public realm	Landscape arch
Philadelphia-Computational	7	13	13	13	7	12	2	10	11
NY-Conventional	13	8	12	12	9	5	1	9	13
Pittsburgh-conventional	12	10	7	10	8	11	3	11	10
Chicago-Conventional	9	11	11	8	14	9	1	7	10
Philadelphia-Conventional	7	12	5	3	12	8	2	8	7
NY-Computational 2	11	4	6	7	10	6	2	5	9
NY-Computational 1	6	7	10	5	11	7	1	1	11
Milwaukee-Conventional	8	5	2	2	13	10	1	5	8
Boston Conventional	10	9	3	6	2	1	1	3	12
Milwaukee-Computational	5	5	8	11	6	2	2	6	1
Boston-Computational 1	3	6	9	7	4	3	1	6	3
Chicago-Computational	2	3	13	4	5	1	1	6	5
Boston-Computational 2	4	1	1	9	1	1	1	4	6
Pittsburgh-Computational	1	2	4	1	3	4	1	2	2

Design aspects

Figure 6.3. Ranks of design plans according to the percentage of significant coverage for the entire set of design aspects

The number of design aspects in each level varies significantly across plans. In group A, it may range from 0 such as in Pittsburgh conventional plan, which does not include any design aspects that pertain to level (A) or it may include 7 design aspects of level (A) such as in Boston computational plan-2 (see line 10 in Table 6.1.A and 6.1.B and Figure 6.1 A and B). In Pittsburgh conventional plan, no design aspects were found that may meet these rules because the percentages of elements addressed with significant and minimum coverage of design elements comprising the urban form, which is the plan's focus area, are 28% and 36% respectively. In a few plans, such as in Philadelphia computational and Philadelphia conventional plans, the sum of the percentage of elements with significant and minimum coverage is 100%.

The number of design aspects in level (B) varies but less significantly. It may include (4) design aspects such as in Chicago computational plan, may include (4) design aspects such as NY computational, Boston computational-1, Milwaukee conventional, and Philadelphia conventional plans. In three cases, NY-conventional, Boston computational-2, and Pittsburgh conventional plans, this group did not include any design aspect that pertains to this level.

The number of design aspects in level (C) also varies significantly because it includes all those aspects that were not represented in the levels (A) and (B). Some plans, such as Pittsburgh-computational does not include any design aspects of level (C), or may include one design aspect such as Chicago computational plan, or there may include (9) of them such as Pittsburgh conventional plan in which (2) design aspects were with 0% of significant coverage. Pittsburgh conventional plan was a unique case because all its design aspects (9) fall in this group as opposed to the other levels (groups A and B) which were not represented entirely (see Table 6.1-B).

This typology of coverage levels was used as a criterion to assess the overall extent of coverage of the selected plans. The distribution of the numbers of design aspects in each of the above-mentioned groups may indicate the extent with which any plan emphasizes its constituent design aspects (see Table 6.4). From design aspects' coverage standpoint, urban design plans with more design aspects in the first and second groups and less design aspects in the third group are superior to other plans with less design aspects in the first and second groups and more design aspects in the third group. A comparison between the numbers of design aspects in those levels (groups A, B, and C) in two sample cases may help assess the difference in their extent of coverage. For instance, those numbers in Boston computational plan-1 are (3, 4, and 2) whereas they are (1, 3, and 5) in Chicago conventional plan respectively which suggests that the first plan has covered the design aspects more effectively than the second plan. Those levels for each design plan were highlighted in rows 10, 11, and 12 in Tables 6.1.A and 6.1.B.

Therefore, the quantity of design aspects in the three afore-mentioned levels A, B, and C was the criterion used to assess the overall extent of coverage and thus the design content of the selected plans. All plans were classified into three distinct levels of overall coverage: high, medium, and low overall coverage. These levels translate into three levels of design content: rich, average, and poor design content respectively (see Table 6.4). A plan with a greater number of design aspects in levels A and B and less number of design aspects of level C has a high overall coverage level and thus richer design content. Conversely, a plan with less number of design aspects in levels A and B and greater number of design aspects of level C has a low overall coverage level and thus poorer design content.

The high coverage plans should include, at least, 4 design aspects in level A, 2 design aspects in level B, and should not include more than 3 design aspect in level C. The medium coverage plans should include 1 or 2 design aspects in level A, 2 design aspects in level B, and should not include more than 5 design aspect in group C. The low coverage plans should not include more than 1 design aspect in level A, 2 design aspects in level B, and should include more than 7 design aspect in level C. This level, as such, embraces all other plans that did not meet the criteria that entitle them to be in the high- and medium-level of coverage. These criteria are summarized in Table 6.4.

Table 6.4. Criteria for identifying the levels of overall coverage in the urban design plans

No.	Level of overall coverage	No. of design aspects included from each group of design aspects coverage			Plans conforming to the criteria	
		A	B	C	Computational	Conventional
1	High	4(min.)	2 (min.)	3(max.)	Boston 2, Pittsburgh, Chicago	N.A.
2	Medium	1(min.)-2(max.)	2 (max.)	5(max.)	Milwaukee, Boston1, NewYork 1, NewYork 2	Boston, Milwaukee
3	Low	1(max.)	2 (max.)	7(min.) - 9(max.)	Philadelphia.	New York, Philadelphia, Chicago, Pittsburgh,

According to this classification, 4/14 (28%) of the selected plans may be considered plans that had high overall coverage, and thus rich design content. Similarly, 5/14 (36%) of the selected plans had medium overall coverage and thus average design content and 5/14 (36%) of the selected cases are plans with low coverage and thus poor design content. These findings are inconsistent with the argument that most urban design plans in US cities are poor in their design content and that they lack the coverage of basic design issues Instead, this sample of plans exhibits a wide range of design aspects coverage and thus a better content.

The findings revealed a relation between the plans' overall coverage level and the media or methods used. It was found that the group of high overall coverage level includes four computational plans and no conventional plans. In contrast, each of the medium and low overall coverage levels includes a mix of both plan types. The medium overall coverage level includes five plans, three of which are computational plans whereas the low overall coverage level includes five plans one of which only is computational. These findings are consistent with the hypothesis that the usage of 3D modeling enhances the extent of coverage of urban design aspects and issues and thus increases the design content Therefore, further investigation into the coverage of individual design aspects may help focus on the differences in the patterns and the extent of coverage attained in computational and conventional plans.

Content analysis revealed two patterns of design aspects coverage across the cases: the static (or constant) and the changing (variable) coverage. The first pattern, static coverage, includes the design aspects covered at almost the same level (extent) across all the selected cases. Some design aspects such as the land-use were covered across cases with the same high level which ranged from 67% to 100% (see chart 3.7 in Figure 6.2). Other design aspects such as the sustainable design were covered with the same low level of coverage, which ranged from 34% to 0% (see chart 3.8 in Figure 6.2). The second pattern, variable coverage, includes design aspects that were covered with a variety of levels such as the public realm which ranged from 0% to 100% (see chart 3.7 in Figure 6.2).

The static and variable types of coverage indicate that the usage of computational methods and techniques affects the coverage of the design aspects in various extents. Its usage has slightly affected the coverage of certain design aspects which explains the static nature of their coverage across both types: computational and conventional plans. Conversely, its usage has affected the coverage of other design aspects with a significant impact which explains the variable nature of their coverage. Therefore, the usage of computational methods and technique does not affect the design aspects coverage with the same extent or impact. The findings of the second analytical task will demonstrate the variety of impacts that the usage of computational methods have made on the coverage of the entire set of design aspects.

The findings revealed a relation between the overall coverage level of each case and the pattern with which it covers the entire set of the design aspects. It was found that the plans with the same level of overall coverage tend to exhibit the same pattern of design aspects coverage.

Plans with high and low levels of overall coverage are more likely to involve static coverage. They cover the entire array of design aspects with equal percentages of significant and/ or combined significant and minimum coverage. In contrast, plans with medium level of coverage are more likely to involve variable coverage. They tend to cover the entire array of design aspect with a variety of percentages of significant coverage that range between extremes such as 100% and 0% (see Figure 6.1).

Accordingly, it was essential to identify the design aspects that plans have always covered with high, medium, and low levels of coverage across all cases. I adopted the same criterion used and explained earlier in Tables 6.3 and 6.4. This criterion helped classify the entire array of design aspects into three distinctive groups (see Table 6.5). The first group A, includes the design aspects the constituent elements of which were addressed with significant coverage from 66% to 100% in at least three cases. These criteria and their application in other design aspects are summarized in Table 6.6.

Table 6.5. Maximum and minimum limits of the various coverage levels of design aspects

No.	Group	Criteria	
		Percentage of elements addressed with significant coverage	
		Minimum	Maximum
1	A	66	100
2	B	33	65
3	C	0	32

Table 6.6. Criteria of identifying the levels of coverage for the entire set of design aspects

No.	Level of coverage	No. of design aspects included in each group			Design aspects conforming to the criteria
		A	B	C	
1	High	3(min.)	4(min.)	3(max.)	Mixed land-use, Public realm, Connections and movement networks
2	Medium	2(max.)	6(min.)	5(max.)	Urban form, Townscape
3	Low	1(max.)	8(max.)	6 (min.) - 7 (max.)	Sustainable design, Landscape architecture, Architectural character,Conservation areas

The application of this classification reveals a relation between the level of design aspects coverage and their design conceptualization and scope of concern. It suggests that group A, group of high coverage level, includes three design aspects, two of which are related to urban-wide 2D design issues and characteristics of the physical environment (see Table 3.1 for this classification). Among the seven plans that covered these design aspects with the highest coverage, five of which were computational plans (see charts 2.6, 2.7, and 2.8 in Figure 6.2). These findings are consistent with the hypothesis that all design and planning applications are considered within the framework of two dimensional land-use and rigid zoning codes and regulations (Gosling and Gosling 2003, p.8).

In contrast, group B, the group of medium coverage level, includes two design aspects that are related to urban-wide 3D design issues and characteristics of the physical environment (see Table 6.6). It was found that among the seven plans that covered the townscape with the highest coverage, six of which were computational plans (see chart 2.1 in Figure 6.2). It was also found that all the seven plans that covered the urban form with the highest coverage are computational plans (see chart 2.2 in Figure 6.2). These findings are inconsistent with the hypothesis that urban design plans in US cities lack the coverage of 3D design aspects of the urban environment. Most importantly, they provide further evidence that the usage of digital modeling and information systems may enhance the efficiency with which the spatial structure and the three dimensional characteristic of the physical environment are communicated and designed, which ultimately leads to high and medium coverage levels in computational plans.

Group C, the group of low coverage level, includes those design aspects addressed with the lowest coverage level, such as architectural character and landscape architecture. They are concerned with 2D and 3D design elements at the local level. Low coverage levels of those aspects may be due, in part, to the plans' methodological approach that may consider urban design as a process or as a second order in the development process (Steino pp.2-3). This approach emphasizes developing design strategies at a certain level of abstraction and detail to create a sound environment for subsequent detailed architectural design decisions. Therefore, the emphasis of most plans on the structural and visual relationships between urban elements at the strategic and/or urban levels was reflected in focusing on analyzing, designing, and representing the physical environment at an urban-wide abstract level rather than local detailed level. These findings are consistent with the argument of Punter and Carmona (1996) which considers strategic urban design as a predominant approach in recently-developed urban design plans.

The findings highlighted the correlation between the type of media used in analyzing and representing the urban design aspects, and the level of their coverage. Therefore, it may be argued that the variety with which the plans covered the entire array of design aspects is due, in part, to three main factors: the plans' type or media of representing and analyzing design aspects (computational vs. conventional), the plans' scope, goals, and objectives; and the plans' methodological approach

6.2.2 Findings of the second analytical task: comparison of conventional and computational plans

The findings of the first step allowed identification of which design aspects were covered in computational plans more effectively than in conventional plans. To verify this correlation, it would be insufficient and may lead to significant errors if I use the rank of design policies in design aspects' coverage as the only criterion because the percentages of coverage in some high-rank plans are relatively low. For example, 6 plans of the 7 plans that ranked highest in the coverage of sustainable urban design were computational plans, yet the percentages of significant coverage were relatively low and ranged in most of these plans from 42% and 17% (see chart 2.5 in Figure 6.2). Conversely, Chicago conventional plan addressed the townscape with a 46% percentage of significant coverage, yet it ranked 10 of 14 (see chart 2.1 in Figure 6.2). Therefore, it was essential to use two criteria: the rank of design aspects across all plans, and the percentage of design aspects coverage, and thus the levels of coverage, as indicated in Tables 6.5 and 6.6.

The findings revealed a correlation between the level of coverage of each design aspect and the type of plan, i.e. the methods used in developing the plan. This correlation was found upon examining the type and overall coverage level of the plans that ranked highest in addressing each design aspect. This correlation was most obvious in three design aspects: townscape, urban form and public realm. The plans that addressed townscape and urban form with the highest five percentages (i.e. plans that ranked 1 through 5) were entirely computational plans and were either in high or medium overall coverage level (see Tables 6.5 and 6.6). It is also obvious in public realm because it was addressed with high coverage in seven plans, five of which were computational. This correlation was slightly less obvious in connections and movement network and sustainable design whereby among the highest five plans in their coverage, four of which were computational plans and were either in high or medium overall coverage level plans (see Figure 6.2). This correlation was also less evident in land-use because this aspect was covered with invariably high coverage across both types of plans.

In light of these findings, it may be argued that the usage of 3D modeling has affected the extent with which the selected computational plans covered certain design aspects, namely townscape, urban form, and sustainable urban design, all of which are predominantly 3D design aspects at the urban scale, and connections and movement network which is predominantly 2D design aspect at the urban scale. Their usage may have allowed designers to visualize and interact with design alternatives, large urban datasets, and 3D information and characteristics more effectively. These findings bolstered the theoretical assumption made by Punter and Carmona (1997) which suggests that the effective usage of information may allow designers to underpin design plans with relevant analytical content and to define the key design aspects of a locality to be developed into a policy.

The findings of the second step indicate that the selected urban design plans tend to group according to their cumulative rank into three main levels (see Figure 6.4). The median value of all cumulative ranks of the plans (56.6) was used as a guide to distinguish those levels. The first level included five plans of the highest rank in the order of covering the entire array of design aspects (see Figure 6.2). Hence, it included the plans with the lowest cumulative ranks which range from 20 to 46. The second level represented the medium cumulative rank. It included four plans, two of which are the plans with the median value and the other two plans are above and below the median value. The third level included five plans of the lowest rank in the order of covering the entire array of design aspects (see Figure 6.2). Hence, their cumulative ranks are the highest and ranged from 64 to 88 (see Figure 6.4).

The pattern with which the plans were distributed over these three levels of cumulative rank highlights the correlation between the cumulative ranks and the type of plans, i.e. computational vs. conventional. The five plans in the first level, the lowest cumulative rank level, are exclusively computational plans. Conversely, among the five plans in the third level, the highest cumulative rank, four were conventional plans. In addition, the medium coverage level included two computational plans and two conventional plans. This correlation supports the findings of the first step which suggest that levels of design aspects coverage in computational plans are higher than their counterparts in conventional plans. These findings support the research hypotheses that the usage of 3D modeling and information technology may lead to plans that address the design aspects with a higher percentage of significant coverage compared to plans that use conventional design methods in the design and development process.

The gap between the highest (88) and lowest (20) cumulative ranks of computational plans is wider than the gap between the highest (82) and lowest (47) cumulative ranks of conventional plans (see Figure 6.4). This gap also reflects the variety of emphasis with which both plan types cover the entire array of design aspects. The wide gap and variance in the cumulative ranks of computational plans may be due, in part, to two factors:

1. The variety of 3D modeling tools and techniques used for those plans, and the variety of methods with which they were used.
2. The effectiveness and efficiency with which they were used in the design process to address the various statements of purpose, goals, and objectives of both Plan types.

These factors can affect the impact of 3D modeling usage on the quality of urban design plans.

The findings of the third step were based on the average values of the design aspects coverage across all plans. These findings highlighted the following main characteristics of coverage:

1. Both plan types exhibited almost the same trend of prioritizing the coverage of 2D urban-wide design aspects, such as land-use and connections and movement networks, and to a slightly less extent the coverage of 3D urban-wide design aspects, such as public realm, townscape, and urban form (see Figure 6.5). In contrast, local 2D and 3D design aspects were less extensively covered in both types of plans than urban-wide 2D and 3D design aspects.
2. There is a significant difference between the extent of coverage in both plan types across the entire set of design aspects (see Figures 6.4 and 6.5). This difference is not only because their average percentage of coverage in computational plans is within the high and medium coverage level but also because it is markedly higher than in conventional plans. This difference provides further evidence that almost all design aspects are more effectively covered in computational plans than in conventional plans. The greatest difference between both plan types appears in three design aspects, public realm, townscape, and urban form, all of which are predominantly 3D urban-wide design aspects. The difference appears less clearly in connections and movement and landscape architecture, all of which are predominantly 2D urban-wide design aspects. In architectural character, the difference becomes negative (-5) which indicates that its coverage in conventional plans was slightly more effective than in computational plans (see Figures 6.4 and 6.5).

The different levels of coverage in both types of plans may be due in part, to the usage of 3D modeling and information systems. Their usage allowed designers to visualize and interact with the urban-wide 2D and 3D attributes of the spatial structure such as the land-use, public realm, townscape, and urban form. Most importantly, it has enabled designers to make a change in emphasis and degree of detail that is required to cover other design aspects, such as public realm and conservation areas across their intermediate level and through their local level or scale. Yet, the slightly higher level of coverage of architectural character in conventional plans may be due, in part, to the fact that current generations of 3D models lack the interactive capabilities that may allow designers to change the degree of abstractions and level of details. These models do not allow designers to zoom and switch emphasis from urban-wide design aspects to 2D or 3D local design aspects. In chapter VIII, this issue and its impact on the design process will be highlighted and justified in light of evidence collected from interviews with key designers of two selected plans.

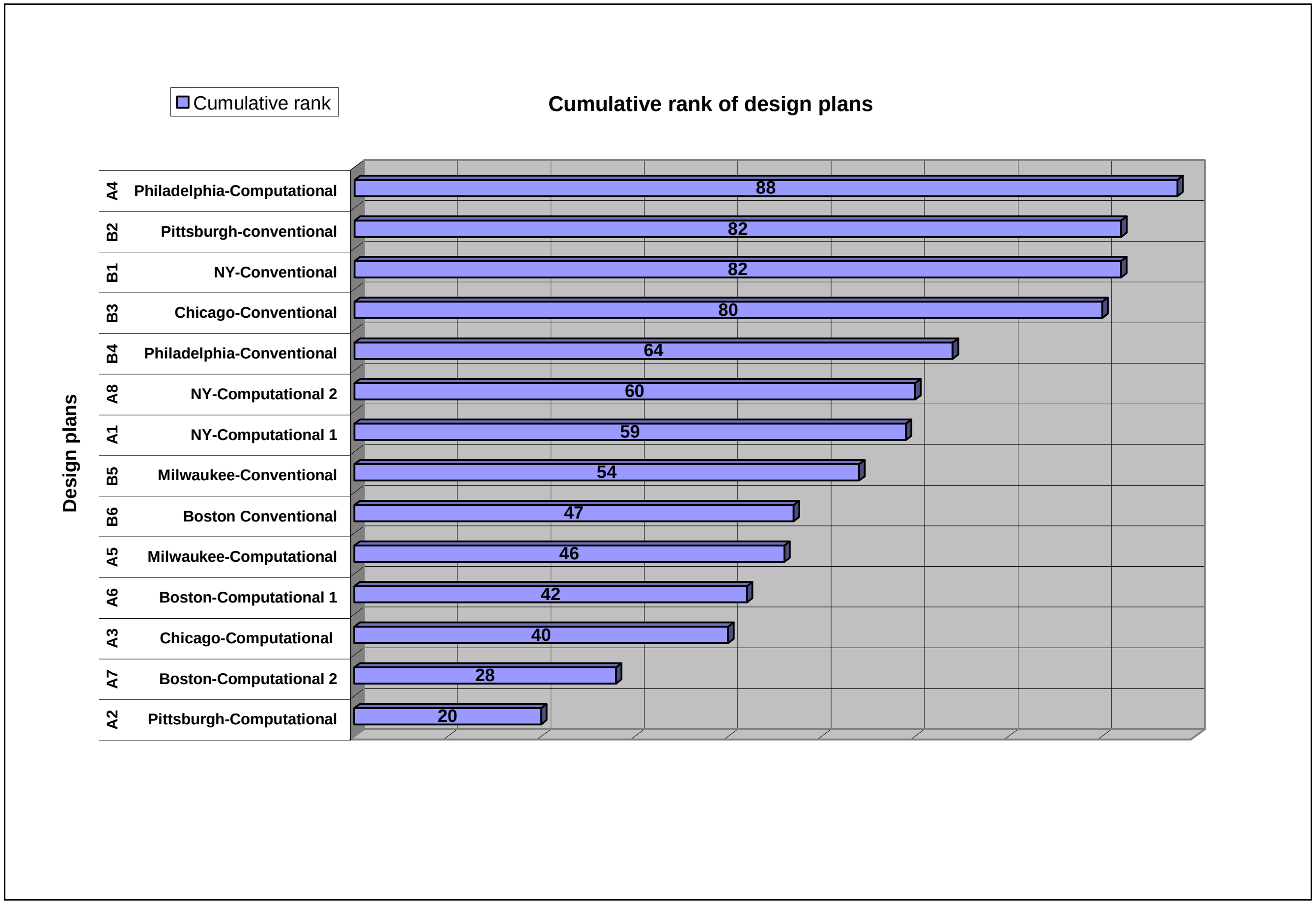
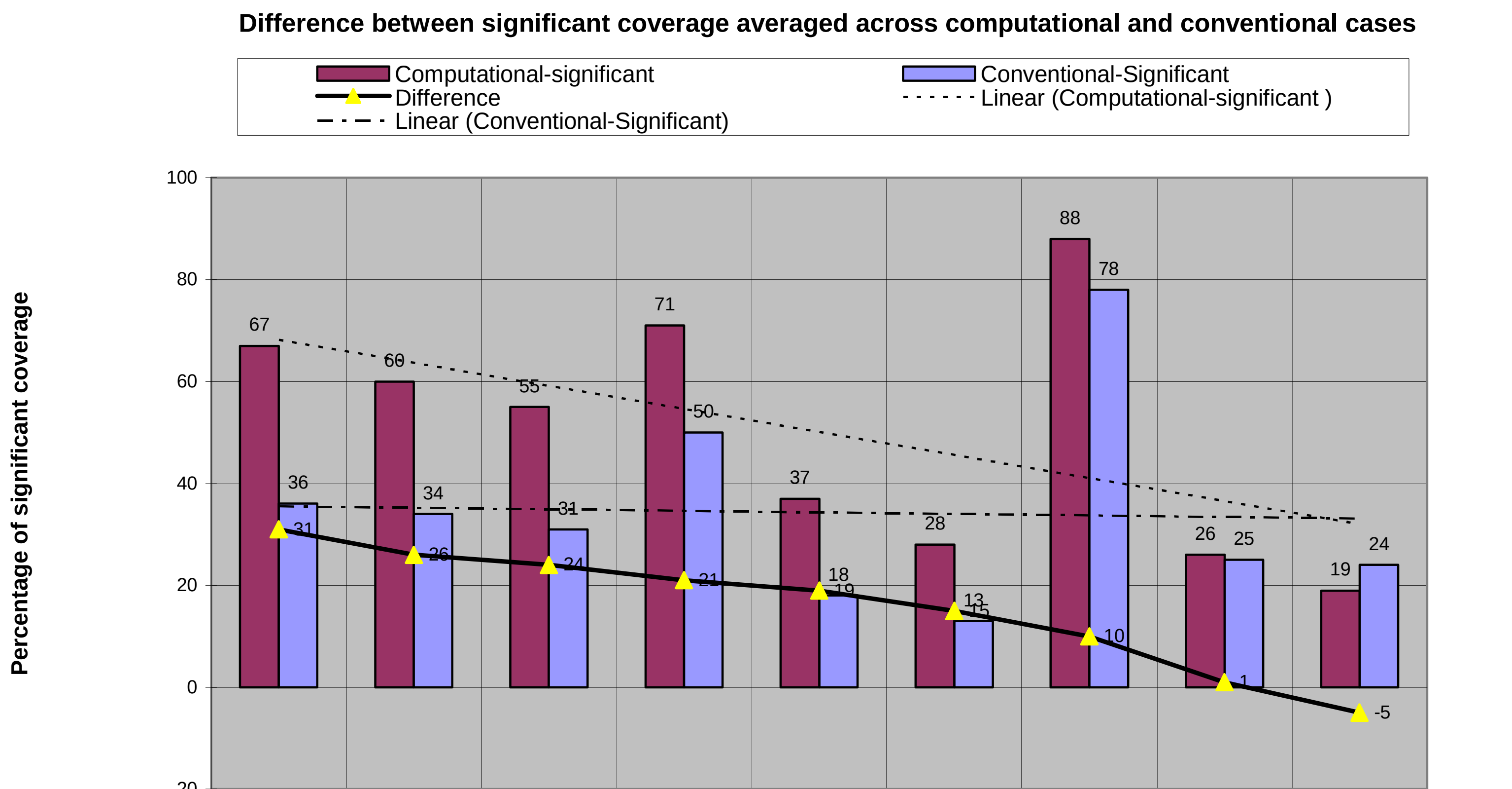


Figure 6.4.Cumulative rank of the urban design plans.



	Public Realm	Townscape	Urban Form	Connection and Movement Network	Landscape Architecture	Sustainable Urban Design	Land -use (Mixed-use and diversity)	Conservation areas	Architectural Character
Computational-significant	67	60	55	71	37	28	88	26	19
Conventional-Significant	36	34	31	50	18	13	78	25	24
Difference	31	26	24	21	19	15	10	1	-5

Figure 6.5. Comparison between the average of significant coverage of the entire set of design aspects in computational and conventional plans

6.3 Summary and Discussion of Findings

This section summarizes and interprets the findings of the first and second analytical tasks. In each task, it combines the assessments of urban design plans and urban design aspects coverage attained with the usage of various criteria to highlight the extent to which findings overlap across analytical tasks.

6.3.1 Summary and discussion of the findings of the first analytical task

The first analytical task involved nominal, ordinal, and interval metrics to examine the extent with which each urban design plan covered the elements and issues that constitute the entire array of urban design aspects. Accordingly, **each plan** was assigned the following:

1. Level of overall coverage using a three-level scale, high, medium, or low depending on the level with which it covered the entire array of design aspects.
2. Rank in covering each design aspect according to the percentage of its significant coverage.
3. Cumulative rank that represents the sum of its ranks attained in covering the entire set of design aspects.

The findings of the first task allowed me to assess the level of overall coverage of urban design plans (see Table 6.7) and to measure their cumulative rank (see Table 6.8). Accordingly, all plans were arranged in two lists. In the first list, the plans were ranked in descending order according to their cumulative rank. In the second list, the plans were ranked in descending order according to their overall design coverage across design aspects. This allowed the assessment of the coverage of each plan individually and to highlight the extent to which both lists overlap.

The comparison between both lists reveals two distinct patterns of similarities and overlaps. The first pattern is the overlap between the levels of overall coverage and of cumulative ranks. With one exception in row 5 that resulted from a marginal difference, the plans with high, medium, and low overall coverage levels, represented in groups 1, 2, and 3 respectively in Table 6.8, overlap with the plans in low, medium, and high cumulative ranks respectively. This pattern of overlap between the lists that were created using two different criteria provides evidence of the reliability with which data was collected and analyzed.

The second pattern is the overlap between the ranks of computational and conventional plans. The first four plans in order of cumulative rank and overall coverage are computational plans (rows 1-4, Table 6.8). Conversely, among the last five plans in order of cumulative rank and overall coverage were four conventional plans (rows 10-13, Table 6.8). Furthermore, six plans had similar ranks across both lists such as the plans in rows 1-3, and 7-9. Other plans in groups 1 and 3 did not involve any overlap across lists. This may be due, in part, to the marginal differences between their cumulative ranks (42, 46, 47; and 80, 82) and between the numbers of design aspects at each of the high, medium, and low coverage levels (see Figure 6.6). However, both lists exhibited the same trend of sorting the plans in order. In both lists, the order of plans at rows 4 and 5 and also at rows 11, 12, and 14 is almost identical with a very marginal difference. This pattern of overlap between the order of computational and conventional plans provides an evidence of the validity of the process of coding and content analysis and of the accuracy of examining the relation between the design aspects coverage and the usage of 3D modeling in the design and development process.

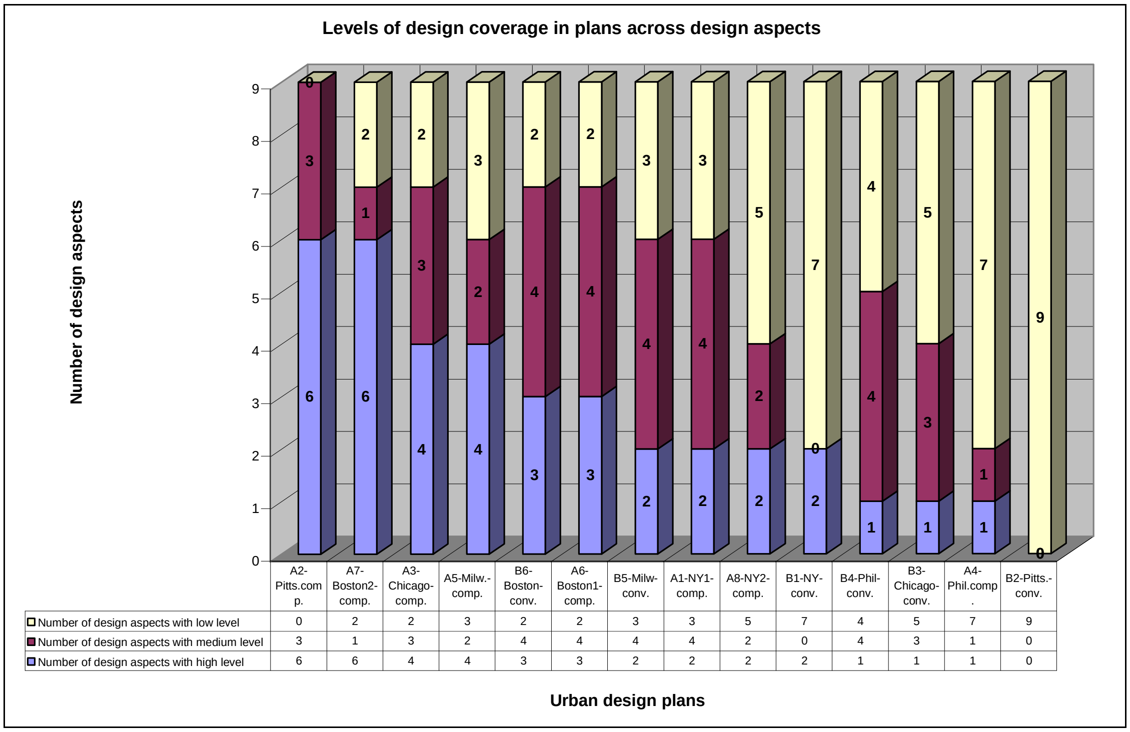
However, a few conventional plans, such as Boston and Milwaukee conventional plans ranked higher than NY computational plans 1 and 2 in both lists. This indicates that, although computational plans are almost always associated with high coverage levels, they are sometimes inferior to conventional plans in design aspects coverage. This may be due to several reasons related to 3D modeling such as the lack of consistent usage, inappropriate methods and ineffective usage across design phases, and technical limitations of the 3D model, such as lack of interactivity, lack of expertise in its usage, and lack of integration with other tools.

Hence, it may be inferred that the analytical techniques and criteria used in this analytical task yielded reliable and consistent findings. The study verified that computational plans can achieve high coverage levels but they do not always ensure the highest coverage level and cumulative ranks without the aforementioned essential procedural and substantive factors. Computational methods and techniques may lead to better and more comprehensive plans than conventional plans. Conventional plans, in contrast, can sometimes cover the design aspects with the same efficiency and effectiveness of computational plans.

These findings may lead to two conclusions. First, the usage of digital tools and methods to analyze and represent urban design elements and issues may not significantly affect the design content of urban design plans without considering other critical factors. These factors include the range of modeling methods, techniques, and functionalities, and the purpose, effectiveness, and consistency with which they were used in the design process. Second, the usage of computational tools and techniques with their conventional counterparts in urban design practice may further enhance the quality of the urban design product in general, and the design content specifically. This conclusion is in light of the finding that some conventional plans have achieved medium coverage levels without using 3D modeling tools and techniques. This recommends integrating both conventional and digital tools and techniques throughout the process of design development to support designers and enhance their capabilities in performing core design tasks.

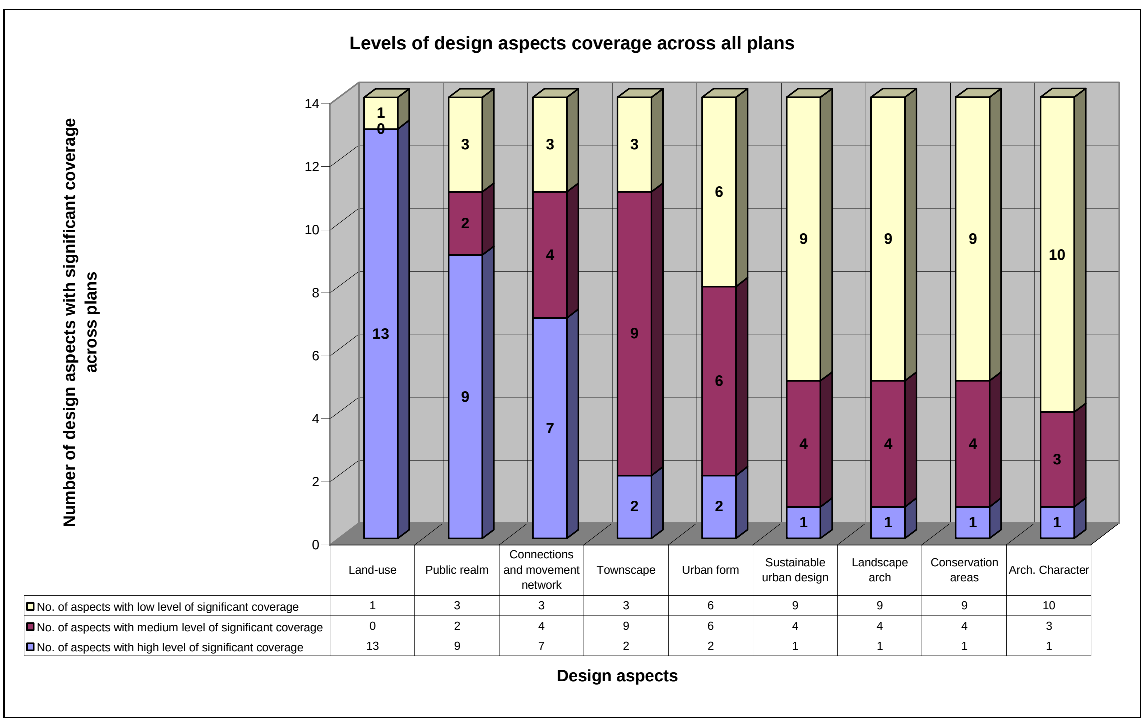
Table 6.7. Distribution of the percentages and levels of coverage in the entire set of design aspects

		Design Aspects																										
		Townscape			Urban form			Arch. Character			Conservation areas			Sustainable urban design			Connections and movement network			Land-use			Public realm			Landscape arch		
No.	Urban design plans	Significant	Minor	No Coverage	Significant	Minor	No Coverage	Significant	Minor	No Coverage	Significant	Minor	No Coverage	Significant	Minor	No Coverage	Significant	Minor	No Coverage	Significant	Minor	No Coverage	Significant	Minor	No Coverage	Significant	Minor	No Coverage
1	**NY-Computational-1**	53	29	18	43	36	21	4	32	64	34	18	48	8	34	58	50	50	0	100	0	0	100	0	0	13	13	74
2	**Pittsburgh-Computational**	94	6	0	79	21	0	41	45	14	66	26	8	34	33	33	87	13	0	100	0	0	88	6	6	63	31	6
3	**NY-Conventional**	13	29	58	29	42	29	0	23	77	0	29	71	17	0	83	87	0	13	100	0	0	17	50	33	0	31	69
4	**Pittsburgh-conventional**	18	53	29	28	36	36	18	5	77	18	16	66	17	17	66	13	37	50	0	100	0	0	67	33	13	31	56
5	**Chicago-Computational**	66	17	17	64	36	0	0	0	100	34	29	37	33	34	33	100	0	0	100	0	0	66	17	17	43	19	38
6	**Chicago-Conventional**	46	36	18	22	64	14	0	50	50	19	39	42	0	0	100	37	37	26	100	0	0	34	16	50	6	44	50
7	**Philadelphia-Computational**	47	47	6	14	29	57	0	0	100	0	16	84	17	33	50	0	37	63	67	33	0	17	50	33	13	13	74
8	**Philadelphia-Conventional**	47	47	6	22	43	35	23	9	68	37	16	47	0	8	92	37	38	25	67	33	0	33	17	50	25	19	56
9	**Boston-Computational-1**	65	12	24	43	43	14	5	27	68	24	21	55	33	42	25	88	0	12	100	0	0	66	17	17	50	31	19
10	**Boston-Computational-2**	65	6	29	86	7	7	68	9	23	18	26	55	66	17	17	100	0	0	100	0	0	67	0	33	25	44	31
11	**Milwaukee-Computational**	59	29	12	57	29	14	9	18	73	5	24	71	25	42	33	88	12	0	67	33	0	66	17	17	69	25	6
12	**Milwaukee-Conventional**	47	35	18	57	29	14	55	23	23	45	16	39	0	8	92	25	25	50	100	0	0	67	0	33	19	50	31
13	**NY-Computational-2**	29	53	18	64	21	15	23	4	73	24	21	55	8	42	50	51	12	37	67	33	0	67	0	33	19	31	50
14	**Boston-Conventional**	35	6	59	29	29	43	45	32	23	32	26	42	42	0	58	100	0	0	100	0	0	67	33	0	44	13	44
	Distribution of extent of coverage																											
1	**Number of aspects with high level of significant coverage**	2			2			1			1			1			7			13			9			1		
2	**Number of aspects with medium level of significant coverage**	9			6			3			4			4			4			0			2			4		
3	**Number of aspects with low level of significant coverage**	3			6			10			9			9			3			1			3			9		



	A2-Pitts.comp.	A7-Boston2-comp.	A3-Chicago-comp.	A5-Milw.-comp.	B6-Boston-conv.	A6-Boston1-comp.	B5-Milw-conv.	A1-NY1-comp.	A8-NY2-comp.	B1-NY-conv.	B4-Phil-conv.	B3-Chicago-conv.	A4-Phil.comp.	B2-Pitts.-conv.
Number of design aspects with low level	0	2	2	3	2	2	3	3	5	7	4	5	7	9
Number of design aspects with medium level	3	1	3	2	4	4	4	4	2	0	4	3	1	0
Number of design aspects with high level	6	6	4	4	3	3	2	2	2	2	1	1	1	0

Figure 6.6. Levels of design coverage in plans across the entire set of design aspects



	Land-use	Public realm	Connections and movement network	Townscape	Urban form	Sustainable urban design	Landscape arch	Conservation areas	Arch. Character
No. of aspects with low level of significant coverage	1	3	3	3	6	9	9	9	10
No. of aspects with medium level of significant coverage	0	2	4	9	6	4	4	4	3
No. of aspects with high level of significant coverage	13	9	7	2	2	1	1	1	1

Figure 6.7. Levels of design coverage in plans across computational and conventional plans

Table 6.8. Lists of urban design plans ranked according to their cumulative ranks and their coverage levels

Order of urban design plans according to various criteria						
	According to their cumulative rank			Groups of common orders across lists	According to their coverage levels	
No.	Level of cumulative rank	Cumulative rank	Urban design plans		Urban design plans	Level of coverage
1	Low	20	Pittsburgh-Computational	Group 1	Pittsburgh-Computational	High
2	Low	28	Boston 2-Computational		Boston 2-Computational	High
3	Low	40	Chicago-Computational		Chicago-computational	High
4	Low	42	Boston 1-Computational		Milwaukee-computational	High
5	Low	46	Milwaukee-Computational		Boston-conventional	Medium
6	Medium	47	Boston Conventional	Group 2	Boston1-computational	Medium
7	Medium	54	Milwaukee-Conventional		Milwaukee-conventional	Medium
8	Medium	59	New York 1-Computational		New York 1-computational	Medium
9	Medium	60	New York 2-Computational		New York 2-computational	Medium
10	High	64	Philadelphia-Conventional	Group 3	New York-conventional	Low
11	High	80	Chicago-Conventional		Philadelphia-conventional	Low
12	High	82	New York-Conventional		Chicago-conventional	Low
13	High	82	Pittsburgh-conventional		Philadelphia-computational	Low
14	High	88	Philadelphia-Computational		Pittsburgh-conventional	Low

6.3.2 Summary and discussion of the findings of the second analytical task

The second analytical task involved nominal, ordinal, and interval metrics to examine the extent with which each design aspect was covered across all plans. It involved the assessment of the level of coverage of each design aspect in each plan and across all plans by using the percentage of its constituent elements and issues that have been addressed with significant coverage. By using this criterion, **each design aspect** was assigned the following:

1. A coverage level which was assessed using a three-level scale, high, medium, and low coverage level depending on certain limits of significant coverage defined in Tables 6.5 and 6.6.
2. Rank according to the average percentage of covering its constituent elements across computational and conventional cases.
3. Rank according to the average percentage of covering its constituent elements across all plans (see Figure 6.7).

The findings of the second task identified the patterns and assessed the extent of coverage of each design aspect with respect to whether a plan was developed with computational plans methods or conventional methods. It classified design aspects according to their levels of coverage across plans into three levels: high, medium, and low level coverage aspects.

The findings helped to arrange the design aspects in three lists, each of which includes the entire list of design aspects listed in descending order using various criteria (see Table 6.9). These criteria are: the percentage of design aspects coverage averaged among computational plans, the percentage of design aspects coverage averaged among conventional plans, the percentage of design aspects coverage averaged across all plans (see Figure 6.7, and Figure 6.8).

Table 6.9. Lists of the design aspects ranked according to their coverage levels across plans and according to their ranks in both computational and conventional plans.

Order of design aspects according to various criteria				
	According to the levels of coverage across plans		According to average of percentage coverage in computational plans	According to average of percentage coverage in conventional plans
No.	Level of coverage	Urban design aspects	Urban design aspects	Urban design aspects
1	High	Land-use (mixed land-use)	Land -use (Mixed-use and diversity)	Land -use (Mixed-use and diversity)
2	High	Public realm	Connection and Movement Network	Connection and Movement Network
3	High	Connections and movement networks	Public Realm	Public Realm
4	Medium	Townscape	Townscape	Townscape
5	Medium	Urban form	Urban Form	Urban Form
6	Low	Sustainable urban design	Landscape Architecture	Conservation areas
7	Low	Landscape architecture	Sustainable Urban Design	Architectural Character
8	Low	Architectural charachter	Conservation areas	Landscape Architecture
9	Low	Conservation areas and areas of visual interest	Architectural Character	Sustainable Urban Design

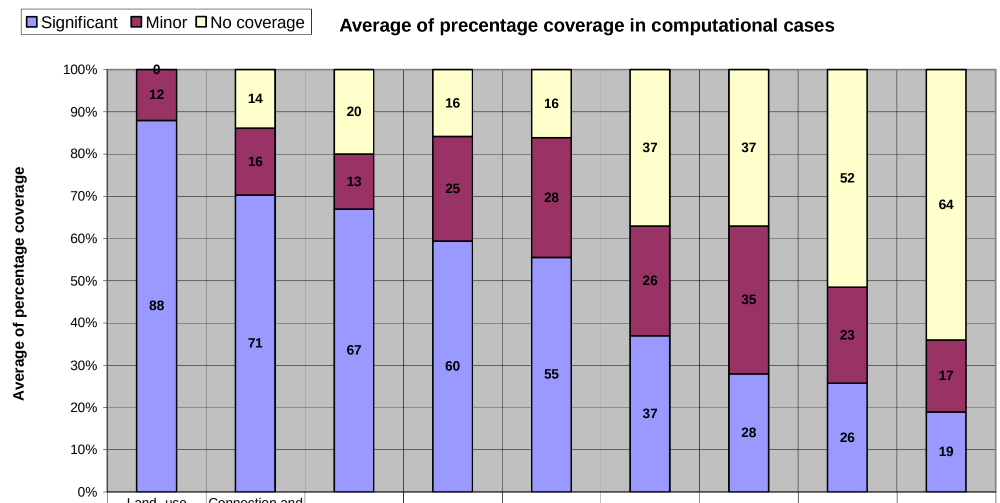
The comparison between the ranks of design aspects provides further evidence of the aspects that both plan types emphasize, and also reveals patterns of similarities in ranks across lists. Both plan types exhibited low coverage levels of three design aspects: architectural character, landscape architecture, and sustainable urban design. Architectural character was the lowest in coverage perhaps due to two main reasons. The first reason is the high degree of abstraction of most urban design plans in US cities, and the second is the design methodology that emphasizes urban design as a process to establish the professional environment for subsequent architectural decisions. However, maintaining the unity of the townscape and urban form of the study areas requires addressing the architectural character, at least, with minimum coverage. Low coverage of the second aspect, landscape architecture, may be due to the same reasons that caused it in architectural character. It represents a gap in the design framework of open space network which represents a key design element of the urban form. The third, sustainable urban design may have been considered implicitly within and /or was the driver of other design policies such as the urban form, land-use, and connections and movement network systems. However, in some plans, sustainable urban design was considered an umbrella that covers the entire design product rather than being explicitly addressed as an independent design aspect.

The findings, as illustrated in Tables 6.8, 6.9 and Figure 6.8, demonstrate that the ranks of design aspects in both plan types are, to a certain extent similar, yet their percentages and thus levels of coverage are significantly different (see also Figure 6.9). This pattern is most clearly obvious in the first five design aspects (rows 1-5 in Table 6.9). The levels of coverage in computational plans far exceed their counterparts in the conventional plans. The three lists include four design aspects: land-use, urban form, and townscape the ranks of which are the same across the three lists (see Table 6.9). Two other design aspects, namely public realm and connections and movement exhibited similar ranks across the three lists.

Consequently, I used both criteria to map each design aspect on two charts each of which is for one type of plan, computational (see Figure 6.10.A) and conventional (see Figure 6.10.B). The first criterion is the percentage of significant coverage averaged across cases. The second criterion is the cumulative rank of each design aspect which represents the sum of its ranks across cases. Each axis was divided into two zones, high and low. The charts, as such, consisted of four quadrants, on which the design aspects were distributed as relevant.

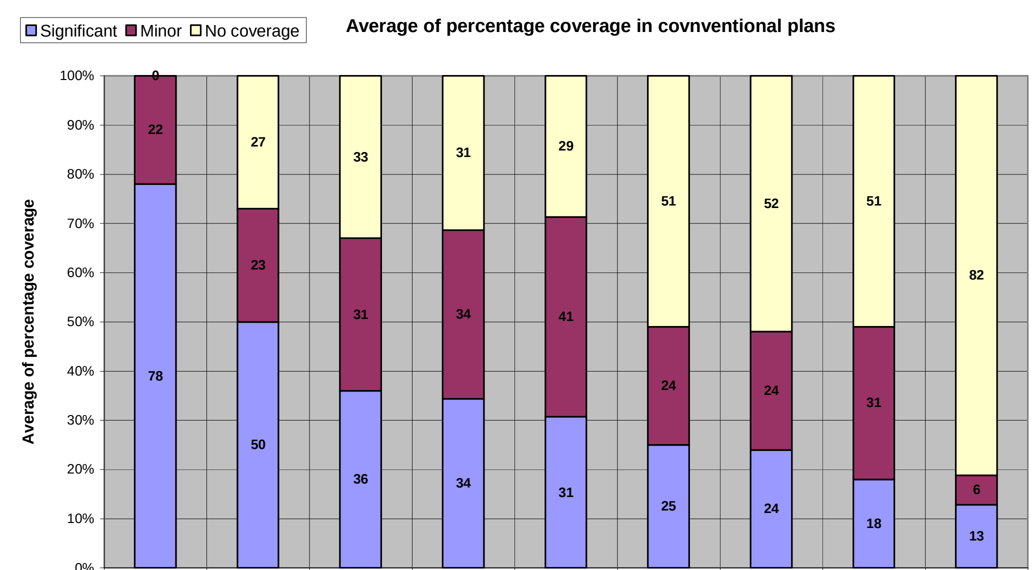
Both charts highlight the difference in quality of the design product of both types of plans (see Figures 6.10.A, and 6.10.B). The comparison between numbers and the modes with which the design aspects were distributed in the four quadrants demonstrates the impact of computational methods and techniques' usage. Their distribution in computational plans indicates a clear diagonal-shape trend of coverage that extends across a wide gap from the low coverage low rank quadrant to the high coverage high rank quadrant. In contrast, their distribution in conventional plans does not indicate a clear trend. They were irregularly scattered on an area smaller than in computational plans. Seven design aspects were in low coverage low rank quadrant while the other two were distributed between low coverage high rank and low coverage low rank quadrants.

The larger number of aspects in the high coverage high rank quadrant of computational plans compared to the fewer number in their conventional counterparts provides another evidence of the impact of using computational methods and techniques on the quality of the design product.



	Land -use (Mixed-use and diversity)	Connection and Movement Network	Public Realm	Townscape	Urban Form	Landscape Architecture	Sustainable Urban Design	Conservation areas	Architectural Character
No coverage	0	14	20	16	16	37	37	52	64
Minor	12	16	13	25	28	26	35	23	17
Significant	88	71	67	60	55	37	28	26	19

Design aspects



	Land -use (Mixed-use and diversity)	Connection and Movement Network	Public Realm	Townscape	Urban Form	Conservation areas	Architectural Character	Landscape Architecture	Sustainable Urban Design
No coverage	0	27	33	31	29	51	52	51	82
Minor	22	23	31	34	41	24	24	31	6
Significant	78	50	36	34	31	25	24	18	13

Design aspects

Figure 6.8. Ranks of design aspects according to the percentage of coverage in computational and conventional plans

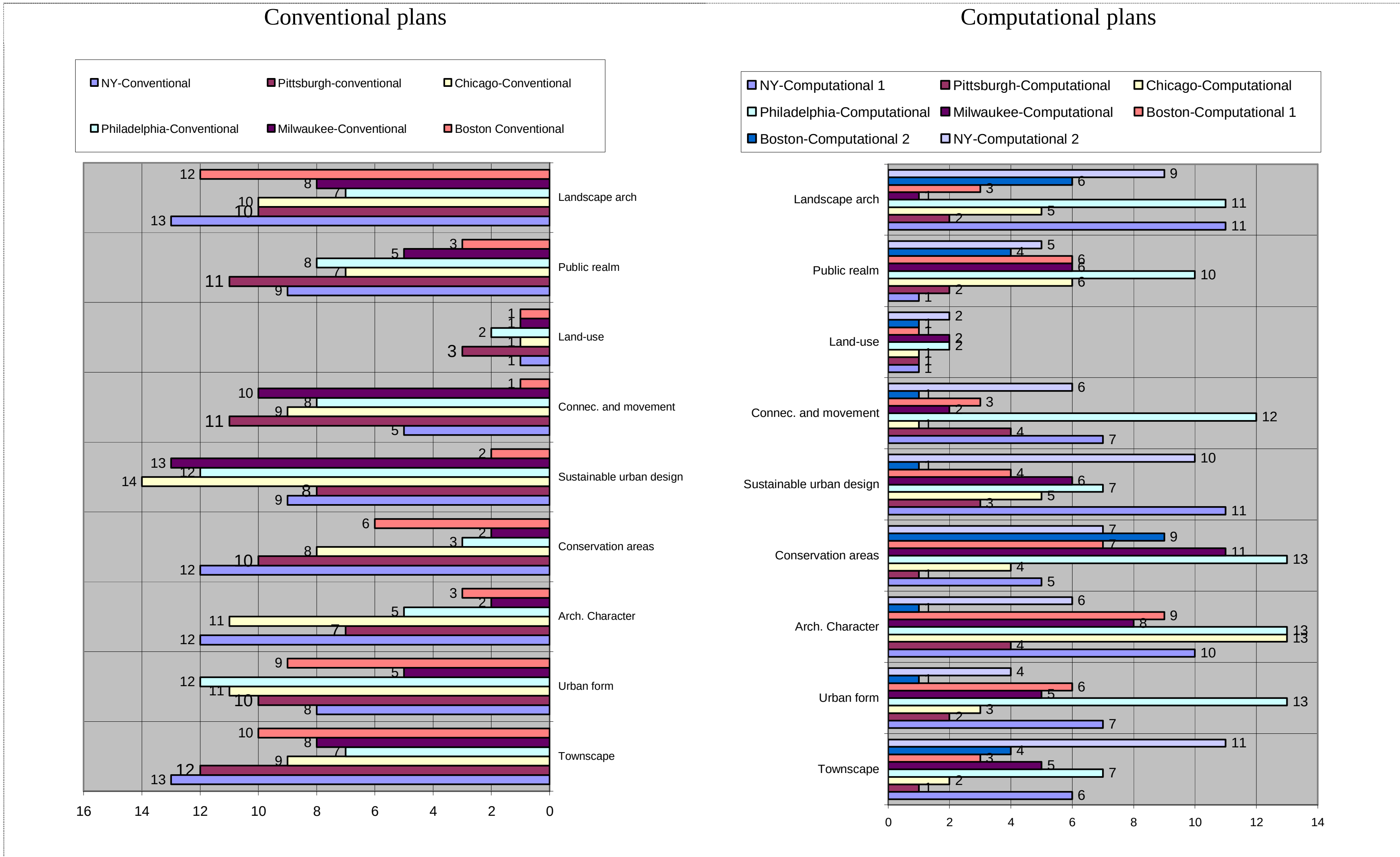


Figure 6.9. Comparison between the ranks of both computational and conventional urban design plans in covering the entire set of design aspects

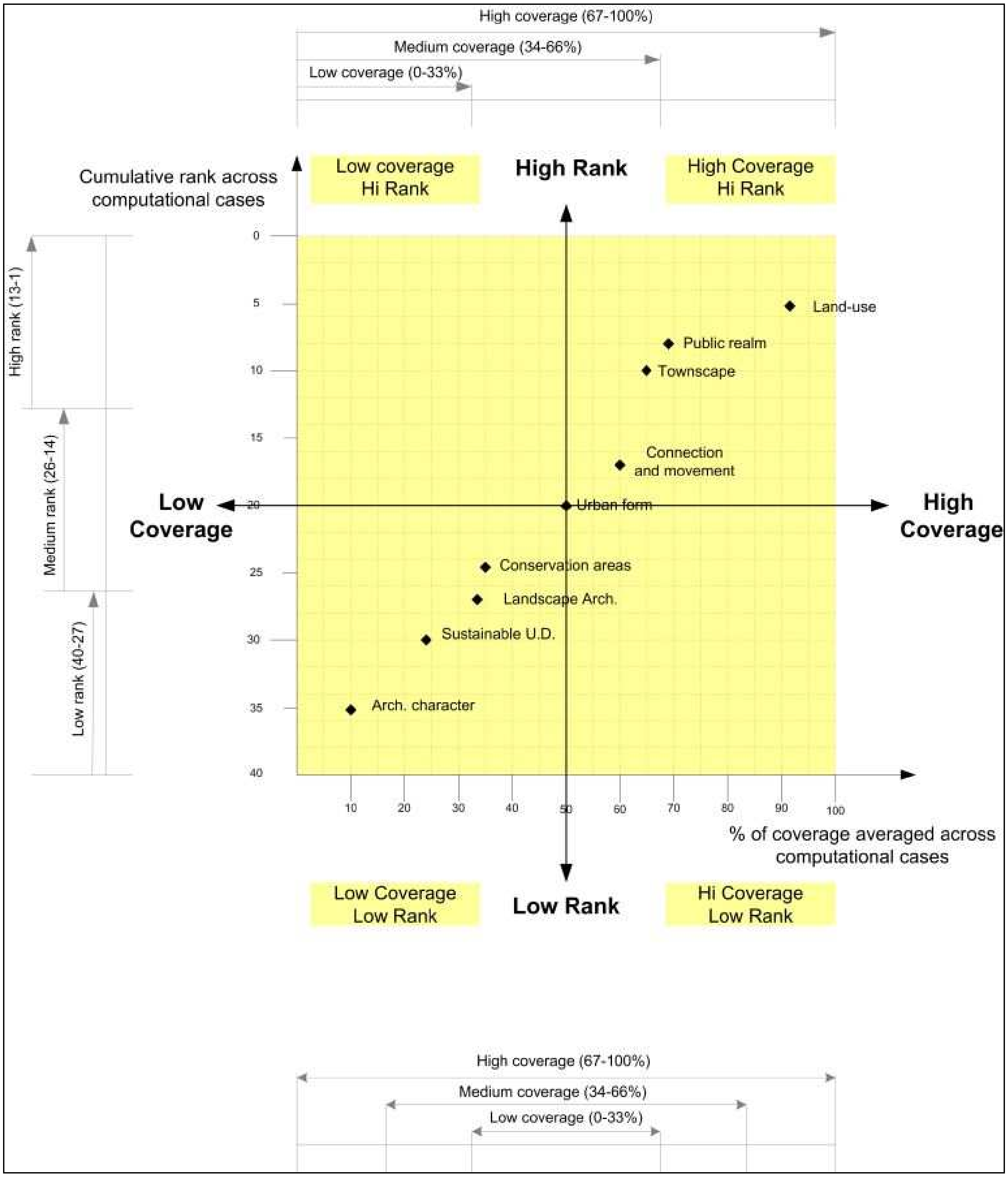


Figure 6.10.A. Distribution of design aspects according to their cumulative ranks and percentage of coverage averaged across computational plans on the four quadrants representing various ranks and coverage levels

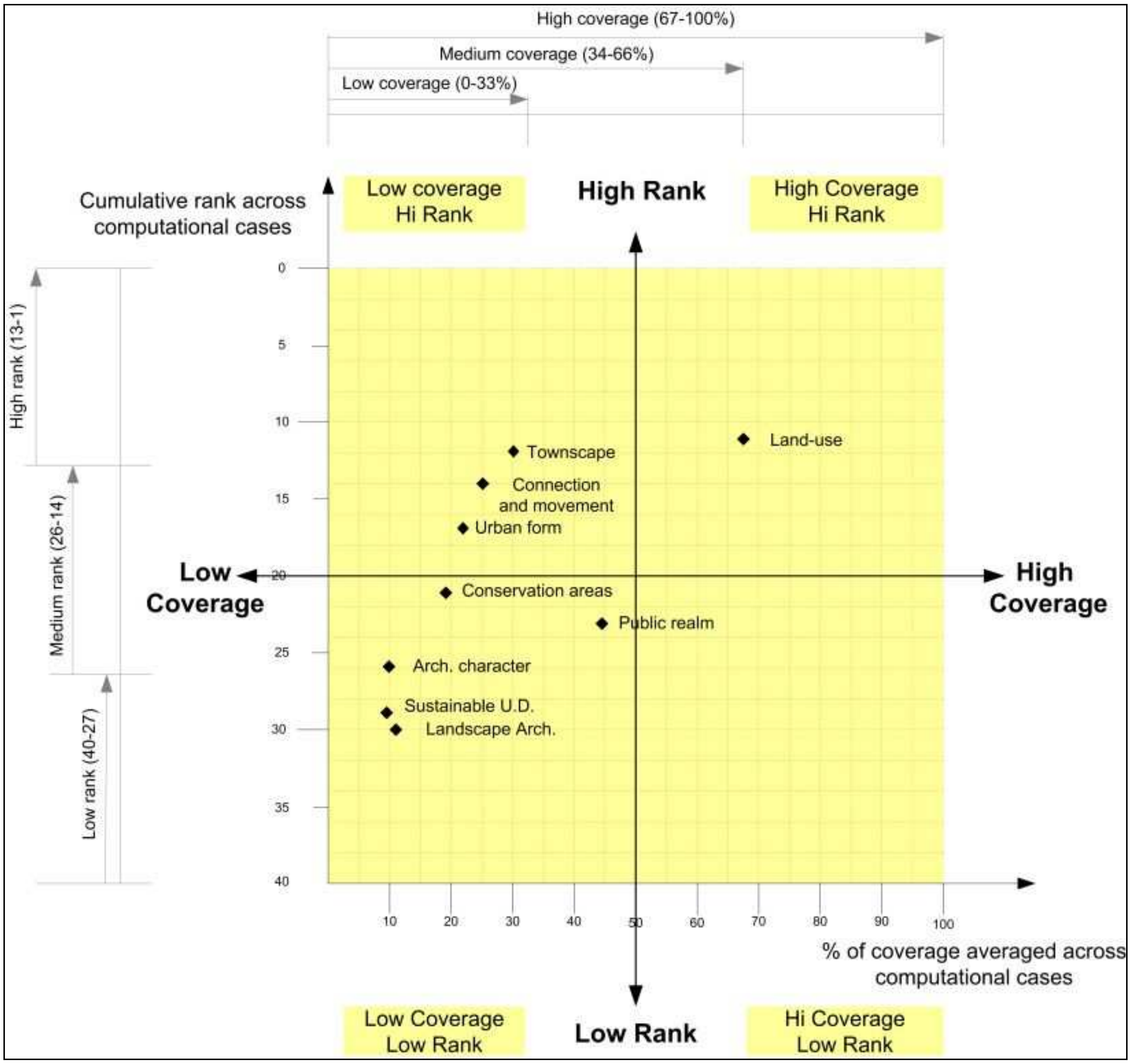


Figure 6.10.B. Distribution of design aspects according to their cumulative ranks and percentage of coverage averaged across conventional plans on the four quadrants representing various ranks and coverage levels

Similarly, I used as a criterion the percentage of design aspects coverage averaged across both computational and conventional plans to distribute the entire set of design aspects among four quadrants. They were illustrated in two charts, each of which is for one type of plan, computational (see Figure 6.11.A) and conventional (see Figure 6.11.B). The charts, as such, were consisted of four quadrants, formed by two axes that extend from urban-wide to local design aspects, and the other extends from 2D to 3D design aspects. Both charts highlight the difference in quality of the design product of both types of plans. The comparison between modes with which the design aspects were distributed in the four quadrants demonstrates the variety of coverage level with which each plan type address the various types of 2D and 3D, urban and local design aspects.

It was found that the design aspects addressed with a high coverage level are those aspects that are concerned with urban-wide 2D urban design elements and issues and/or quantitative controls and design guidelines. Design aspects addressed with medium coverage level are those aspects that are concerned with the urban-wide 3D urban design elements and issues and/or qualitative design guidelines and controls that shape the visual and structural relations between the constituent elements of the spatial structure. Design aspects addressed with the lowest coverage levels were the local 3D design aspects, and to a less extent the local 2D design aspect. A description of these elements, their scope of concern, and scale was given in Table 3.1.

These findings are consistent with the hypothetical statement made by Punter (1999) concerning the dominance and the important role of zoning in controlling the form of development in American cities (Punter 1999, p. 5). Yet, they are slightly inconsistent with his arguments that American planning is dominated by the townscape philosophy, and that plans adopted in the past by all key professionals and governmental participants in the planning and development process failed to positively shape the public realm (Punter 1999, pp. 155-156). Such inconsistency may be due, in part, to certain change of emphasis in urban design and planning practice in US cities that may have occurred since Punter’s study was documented and published.

The difference between the modes with which the design aspects were distributed in the four quadrants of computational plans (see Figure 6.11.A) and conventional plans (see Figure 6.11.B) explains some of the impacts of 3D modeling usage on the design content. The difference was clearly noticed in the urban-wide 2D and 3D quadrant, less clear in the local 2D quadrant, and almost negligible in the local 2D quadrant. These findings support the research hypothesis that 3D modeling usage improves the design aspects coverage.

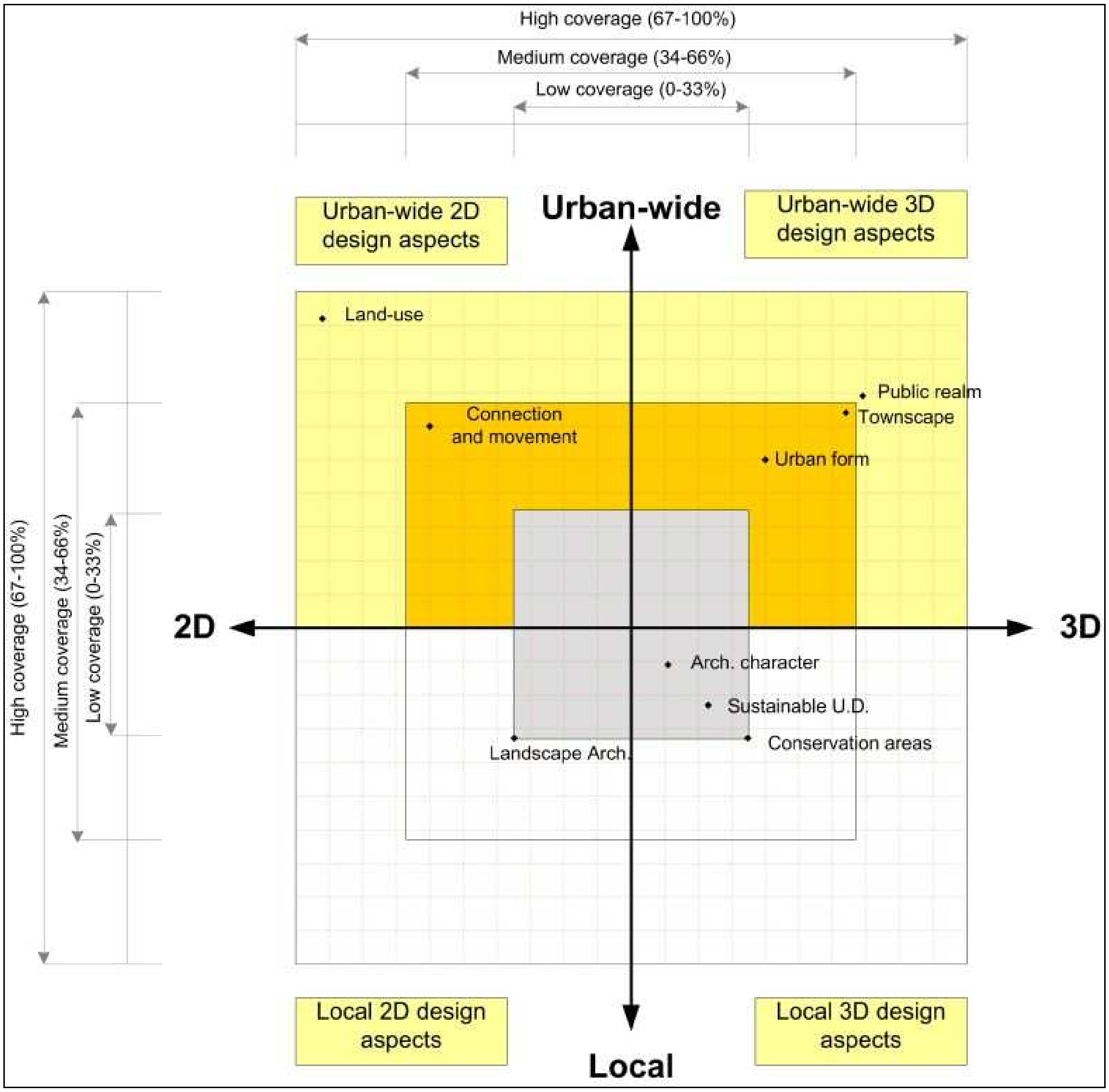


Figure 6.11.A. Distribution of design aspects according to their percentage of significant coverage across computational plans on the four quadrants representing various urban wide and local 2D and 3D types

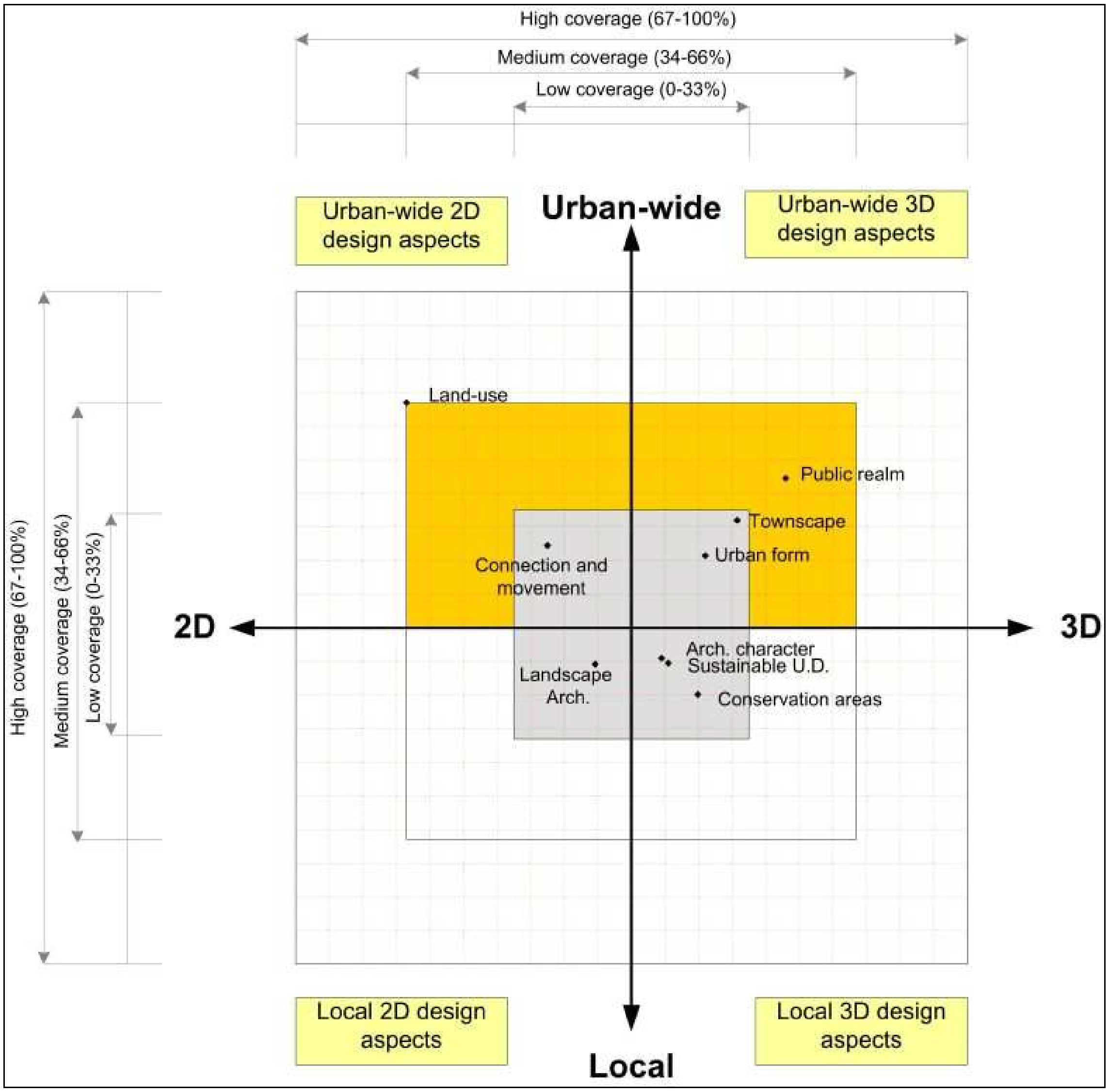


Figure 6.11.B. Distribution of design aspects according to their percentage of significant coverage across conventional plans on the four quadrants representing various urban wide and local 2D and 3D types

These differences may be viewed as a result of 3D modeling that allowed designers to visualize the characteristics and the configuration of the structural and visual relation between 2D and 3D urban elements. The lack of any significant difference in the local 3D quadrant may be due to the technical limitations discussed in section 6.2.2. These findings support the previous conclusions concerning the significance of integrating other IT tools, role of methods of usage, and integrating conventional with computational media for analyzing and representing the urban design aspects.

The variety of levels with which the entire set urban design elements and issues were covered in each plan and across plans may be due to four main reasons. These reasons are: the digital model's purpose, type and functionalities, the plan's scope, goals and objectives, and methodological approach, the extent of model's usage, and the level of designers' expertise and capabilities in appropriate model's usage.

First, the model purposes and thus type may have limited its utility to explanation and education of the public. Other functions were less effectively used. If a model lacks interactive capabilities, then multiple levels of plans representation will not be coupled with representations at multiple levels of details, and as such, will not help designers analyze and represent the attributes of and relationships between urban elements at the local level. It may not effectively help designers to move between and visualize urban elements at various areas of emphasis as they switch between various strategic, urban, and local levels of the physical environment during design development. Models may also lack other essential tools such as GIS analytical tools and databases that could allow designers to use information more effectively and efficiently.

Second, the variety of coverage levels may also be due to the plan's goals and objectives and methodological approach that affect the degree of control, type of design guidance, and the approach of covering the design aspects. Urban design strategies, for example, shape the urban-wide design aspects comprising the spatial structure to provide a sound environment for further detailed design decisions that shape the local design aspects.

Third, the methods and techniques of modeling usage were either inappropriate to the design context, inefficient, were inconsistently used, or they did not support designers at the appropriate design task. Fourth, the variety of levels of designers' skills, professional expertise, and capabilities of model usage may not allow them to configure and control the various design aspects of the urban spatial structure at multiple scales with the same effectiveness.

Therefore, it may be inferred that the modeling usage does not always ensure an overall coverage and design content that is better than what may be attained through usage of conventional methods. Other factors might affect the desired impact and thus the quality of the design product in various modes and extents. These factors include the design methodology, relevance of tools and techniques used, levels of designers' expertise, skills, and capabilities of model usage and the effectiveness, consistency, and methods and techniques of its usage.

6.4 Conclusions

The content analysis of the selected plans demonstrated various degrees of attention to addressing the basic design aspects, and greater than normal attention to spatial and visual qualities in plans that used computational methods. This result refutes the skeptics' criticism of current 3D modeling as applied to urban design. 3D modeling appears to help planners to produce a plan with better design content. Although the small sample cannot support general conclusions, this research also provides a method for conducting additional case studies to increase the confidence in the conclusions. This section outlines the main conclusion of this chapter.

The research used several criteria in the analytical tasks to ensure a high reliability and validity in the measurement of its variables. For example, certain design aspects in a few computational plans were addressed with a coverage level higher than their counterparts in conventional plans, yet that coverage was relatively low. Therefore, the rank and level of coverage were used as criteria to assess the overall coverage level of each plan. The substantial agreement of results and lists of findings among research efforts duplicated under various conditions and using several criteria may indicate, according to Krippendorff (2004), the high reliability of this study (Krippendorff 2004, p.212).

The content analysis of the selected plans assessed their extent of design aspects coverage, and highlighted three main points. First, it compared the extent of coverage in the selected plans with the earlier premise that urban design plans in US cities lack the coverage of basic design aspects in general, and specifically 3D design aspects. Second, it highlighted the different patterns and extents with which computational and conventional plans have addressed the entire set of design aspects. Third, it highlighted the variety of extents with which each design aspect was covered across all plans, and examined any potential relation that may emerge between the extent of coverage and the methods used to develop the plan, i.e. computational vs. conventional. These points are discussed below.

First, the findings demonstrated that the selected plans have exhibited a variety of overall coverage levels which were classified into three levels, high, medium, and low coverage levels. Among the 14 plans, the overall coverage level of four plans (i.e. 28% of the sample) was high, of five plans (36% of the sample) was medium, and the overall coverage level of five plans (36%

of the sample) was low. These levels may translate to rich, average, and poor levels of analytical content respectively. Therefore, the research has refuted to a great extent the premise that most urban design plans in US cities are poor in their design content and that they lack the effective coverage of basic design aspects that would normally be considered to be central to design control in the urban environment. The low-level coverage plans may provide evidence for that premise, yet some of that inadequacy and inefficiency of coverage may be considered in light of the goals and objectives, statement, scope, and the strategic approach of those plans, as well as some measurement errors inherent in the content analysis technique of urban design plans that were mentioned in section two.

Second, the research also compared the pattern and extent of coverage in both computational and conventional plans and found certain similarities and differences. Both plan types cover the entire array of design aspects with a variety of levels that range from high, medium to low levels. The percentage of significant coverage averaged across conventional plans ranged from as low as 13% in sustainable urban design to as high as 78% in land-use. Likewise, this percentage in computational plans ranged from as low as 19% in architectural character to as high as 88% in land-use (see Figure 6.8). Therefore the gaps between the highest and lowest overall coverage levels and cumulative ranks of conventional plans are less than their counterparts in computational plans The ranks and cumulative ranks of design plans and the number of design aspects covered with high, medium, and low coverage levels indicate that computational plans cover the entire set of design aspects more effectively than conventional plans, and as such may produce plans with better design content (see Figures 6.5 and 6.9). These findings are consistent with the hypothesis of this research that the usage of 3D modeling and information systems would result in a more effective coverage of design aspects, and thus richer design content, than in conventional plans.

However, the research provided counter evidence that deviates from this rule in two cases. Although the group of high overall coverage level plans is exclusively computational, the group of low overall coverage level plans is not exclusively conventional. It includes a mix of one computational plan and four conventional plans, and likewise is the group of medium overall coverage plans. In addition, computational plans are not exclusively superior to conventional plans in overall coverage levels and cumulative ranks.

The percentages of coverage of all design aspects, except townscape, demonstrate that some conventional plans rank higher than one or some computational plans. Therefore, the usage of computational tools does not always ensure coverage levels that are higher than that produced with conventional tools. The product quality may be affected by other factors such as the design methodology, relevance of tools and techniques used, levels of designers' expertise, skills, and capabilities of model usage and the effectiveness, consistency, and methods and techniques of its usage. These factors underscore the significant role of appropriate and consistent usage of the methods and functions of digital 3D modeling and information systems in the development process to ensure the desired impact on the quality of the design product.

Third, the findings also revealed the variety of levels with which the design aspects were covered across all plans. These findings also demonstrated the relation between conceptualization, scale and/or scope of concern of the design aspects with their levels of coverage. They revealed a high coverage level of urban-wide 2D design aspects, a medium coverage level of urban-wide 3D design aspects, and a low coverage level of local 2D and 3D design aspects. These findings are inconsistent with the early premise concerning the lack of coverage of 3D design aspects in urban design plans in US cities. Yet, the findings are consistent with another premise that all design and planning applications in urban design plans in US cities are considered within the framework of two-dimensional land-use and rigid zoning codes and regulations. The findings revealed that land-use, townscape, urban form, and public realm are covered far more effectively in computational plans than in conventional plans. These aspects are concerned with the 3D characteristics of and the structural and visual relations between the constituent elements of the spatial structure of the built environment. Their effective and high coverage level in computational plans is due, in part, to 3D modeling tools and information systems capabilities which allowed designers to analyze, design, and represent the 3D design information and issues efficiently and effectively.

The patterns of distribution in the four quadrants of Figures 6.10.A and 6.10.B and Figures 6.11.B and 6.11.B may be considered as models and/or potential assessment tools. They allow one to compare the level of coverage of urban design plans of the same type and across types. The number of patterns with which the entire array of design aspects was distributed on the four quadrants may illustrate the level of overall overage and the type of design aspects it addressed more efficiently than others.

The variety of levels of coverage of design aspects in each plan and across plans may be due to four main substantive and procedural factors. Substantive factors include the digital model's purpose, type and functionalities; the level of designers' expertise and capabilities in appropriate model's usage, and the extent of model's usage. Procedural factors include the plan's scope, goals and objectives, and the methodological approach. Although investigating the effectiveness of 3D modeling and information systems usage is beyond the scope of this study, it may be helpful to investigate the relation between the effectiveness of that usage and the extent of coverage of design aspects in further studies with a larger number of cases.

Accordingly, it may be argued that the effective usage of modeling functionalities may have improved the quality of the decision-making process by providing the following improvements and support to designers' capabilities in performing core design tasks:

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, usage of 3D modeling helped register 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 a hurdle that often hampers the systematic flow of the design process due to the various backgrounds, and hence, perspectives and visions of design team members by improving the ability of all members to visualize the same design concept(s).

To enhance the level of design coverage and in turn the design content of urban design plans in US cities, it is recommended to use a variety of tools that may support designers in core design tasks throughout the design process. The emerging capabilities of digital tools and technologies such as the interactive real-time VR modeling and the Internet GIS are likely to help designers change areas of emphasis of the physical environment and thus cross link between the multiple levels of the urban design and planning process to effectively cover the local 2D and 3D design aspects and other ineffectively covered design aspects.

The dominance of quantitative design guidelines over the qualitative and visual guidelines that are central to design control in urban design suggests that urban design should utilize digital technologies, particularly scientific and dynamic visualizations, to enhance the modes with which urban designers visualize and interact with the visual characteristics of the spatial structure and its constituent elements. The steadily growing utility of scientific and dynamic visualizations in architectural and urban design and planning may help overcome that inadequacy and inefficiency in coverage. Scientific visualization may help designers to effectively use and integrate the multiple and complex spatial and non-spatial datasets. Dynamic visualization may help designers in interactive visual exploration, analysis, and communication of the spatial structure's elements at various scales. These capabilities may allow an efficient cross linkage between the increasingly-adopted strategic urban design approach and other scales of design control.

The causal relation between the usage of 3D modeling and information systems on one hand, and the effective coverage of the entire set of design aspects, and the 3D aspect in particular, on the other hand cannot be proven within the scope of this study. The limited number of examined plans and the impact of confounding variables in various plans did not allow me to verify their causal relation. However, the research highlighted their correlation and provided evidence that may support the causality between both variables. A summary of the mechanism that illustrates that correlation has been demonstrated in Figure 6.12. By using available techniques effectively to deliver 2D and 3D representations, designers appear 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 3D modeling had provided real-time visualization and interactive capabilities. Such tools could allow the planning committees and design teams alike to improve the modes with which they communicate alternative design strategies and scenarios.

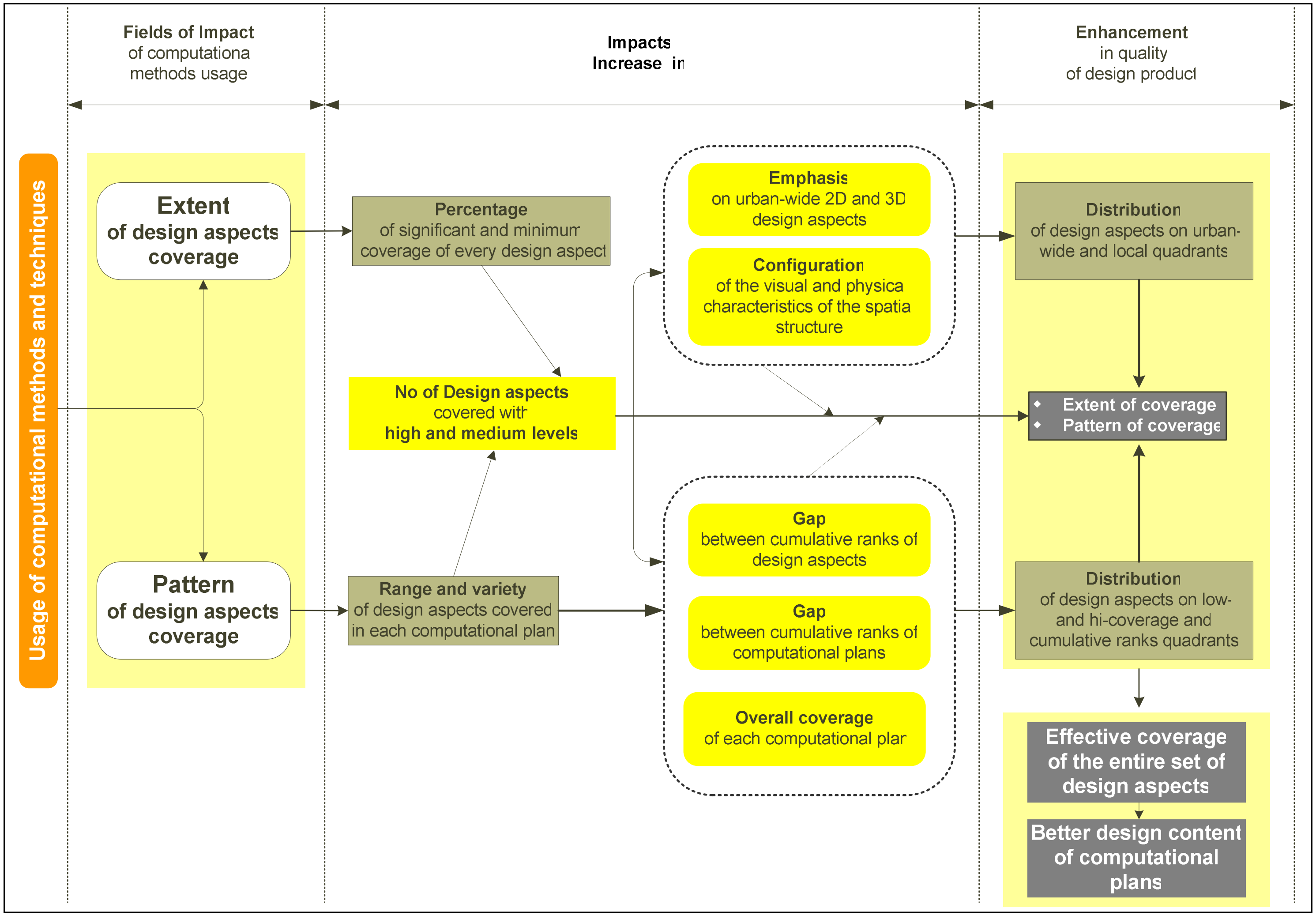


Figure 6.12. Conceptual model summarizing the fields of impact, the increase and enhancement in certain substantive elements underlying the quality of the urban design products as a result of using computational methods and techniques in plan development.

CHAPTER VII

ASSESSMENTS AND DESCRIPTION OF METHODS AND DEGREES OF MODELS USAGE: QUESTIONNAIRES AND INTERVIEWS

In the previous chapter, 14 urban design plans were examined to assess the dependent variable, their design content. To understand how the design content of those plans have been affected by the, independent variable, the usage of 3D digital modeling and IT tools the questionnaire survey method was used. The questionnaire survey instrument was meant to document the methods and assess the extents with which designers and planners used 3D modeling in developing the computational plans that have been examined in chapter VI. In this chapter, the questionnaire survey is explained. This chapter includes four main sections. The first section includes explanations of the instrument, its constituent questions, and process of administration. In the second section, the questionnaire results are analyzed and discussed. In the third section, the results are summarized and conclusions are derived. The fourth section includes description of the interview process and participants viewpoints.

7.1 The Questionnaire Survey Instrument

The questionnaire survey methods was used to document the methods and assess the extents with which designers and planners used 3D modeling and IT tools in developing the eight computational plans (A1 through A8) that have been examined in the previous chapter. A questionnaire survey form, which consisted of two parts and an identifier cover sheet, was six pages in length and is shown in Appendix A.

The cover letter identifier included three main paragraphs. The first paragraph was meant to acknowledge the potential participant in the survey about the nature, goal and scope of the survey. The second paragraph was meant to highlight the significance of the research goal to urban design professional practice, the title of the urban design plan for which information was sought, and the significance of the participant’s potential input in addressing the research questions. The third paragraph stated that there was no intent to draw any comparison between the quality of design plans at different planning departments or firms surveyed in this research.

The first part of questionnaire survey instrument included five closed-ended questions that focused on quantifying and measuring the extent with which designers used various modeling functionalities. Using a scale of 1 to 5, the questions measured the extent with which that usage has supported designers, affected their design outcome and product, and improved the decision-making process (see Appendix A). The second part included five open-ended questions designed to explore methods of 3D model usage in supporting design development tasks as well as the design phases in which they have been used, and for which further assistance is needed. The sources upon which the questions were based were described in section 2.5.1.

To address the research questions and to satisfy the research objectives, the questions concentrated on the following different issues (see Table 2.1):

1. The extent with which designers used the following modeling functionalities in supporting design tasks of developing the urban design plans:
    a. Navigation-Visualization- functionalities;
    b. Decision-support -communication- functionalities;
    c. Analytical functionalities; and
    d. Manipulation functionalities.
2. The extent with which 3D modeling supported designers at each design phase of the process of urban design plans development.
3. The extent with which the modeling usage has affected the quality of the design product of each phase and the design aspects coverage.

For the first issues, question 1 asked the participant to identity the extent with which designers used the entire array of modeling functionalities and techniques during the design development process. The question listed 29 modeling techniques organized into four main categories of modeling functionalities. The assessment scale included five levels, the lowest of which was *not used* followed in ascending order by *very little*, *average*, *very much*, and the highest was *a lot*. The scale included also the *not applicable* option if any functionality was unavailable in the model used in the design process.

For the second issue, questions 2 and 3 focused on the effect of modeling usage and support on the design phases and tasks. Question 2 asked designers to identify the extent to what the modeling usage has effectively supported them at each design phase. The question listed seven design phases that constitute the urban design process as illustrated in Shirvani (1985). The assessment scale included five levels, the lowest of which was *No Impact* followed in ascending order by *Low, Medium,* and the highest, *High Impact*. The scale included also the *not applicable* option if 3D modeling was inapplicable or unused in any design phase. Question 3 was designed in a Likert scale, and asked designers to assess the extent to what they believe that modeling usage has affected the design output of each design phase. The question listed 14 potential impacts that modeling usage may have at each design phase listed in question 2. The impacts were derived from literature review and feedback from designers' interviews. The assessment scale included six levels, the lowest of which was *strongly disagree* followed in ascending order by *disagree, neutral, agree,* and the highest, *strongly Agree* . The scale included also the *not applicable* option if 3D modeling was inapplicable or unused in any design phase.

For the third issue, question 4 focused on the impact of 3D modeling usage on designing each design aspect of the physical environment. Question 4 asked designers to assess the impact of 3D modeling usage on designing each design aspects of the urban design plan. The 9 design aspects listed in this question were similar to those used to assess the design content in urban design plans. However, to keep the instrument short, a fewer number of urban design elements and issues that constitute those design aspects were listed. The assessment scale included five levels, the lowest of which was *No Impact* followed in ascending order by *Low, Medium,* and the highest, *High Impact*. The scale included also the *not applicable* option if 3D modeling was inapplicable or unused in designing any design aspect.

Besides the afore-mentioned issues, further factual information was needed concerning the background of the respondent and attributes of the modeling tool(s) used in the design process. Question 5 included 5 questions that elicit information concerning the attributes of the 3D model such as, extent of modeled area, level of detail, compatibility with other modeling tools, convertibility of its file format to other standard formats, and its accessibility to the public. Question 5 included 2 questions that elicit information about the respondents' background and familiarity with 3D modeling usage such as how long the firm/ department has been using 3D modeling in the design process and who often uses it. Question five included one question that focuses on the potential change in the design process as a result of modeling usage.

The second part of the questionnaire consisted of five open-ended questions. They were meant to elicit designers input as to the methods and efficiency of using 3D modeling during the urban design plans development, and any further assistance needed. The questions were meant to address certain procedural issues related to modeling usage such as, the design functions and applications that modeling was used for, the extent to which it was adequate in supporting designers, what functions they were ineffective in supporting them. One question elicited designers' suggestions for integrating other tools and software to provide effective and efficient support to designers.

7.2 Administrative Procedures and Data Collection

This research used the Internet mail survey to administer the questionnaire survey. In this section, two issues are discussed. In this section, the methods used to distribute the questionnaire forms and to collect and tabulate the data are justified, and the steps of the questionnaire's administrative procedure are explained.

7.2.1 The Internet mail survey method

The questionnaire survey was administered using the Internet mail survey. Such usage was preferred over the conventional methods for several reasons. First, designers who were interviewed were asked about mode of questionnaire administration. All designers expressed their preference to receive the questionnaire form through their e-mail accounts and complete it electronically. Second, it was graphically more appealing and easier to navigate, fill and correct. It was more economic, faster and easier to administer and collect. Some respondents received, completed and submitted the form in one day or in a few days whereas the same process would take longer time in conventional method. Third, it allowed me to customize the cover letter sent to each potential respondent and to address the title of the plan for which s/he was asked to participate in the questionnaire. This helped address specific issues such as reference to previous contacts, telephone conversations and field interviews and thus helped improve the return rate. Fourth, it allowed me to track the status of each questionnaire form sent and to know whether or not and when it has been completed. Subsequently, I was able to send reminder messages only to potential respondents with *not responded* status. Fifth, the Internet mail survey facilitated and ensured the accuracy of the process of tabulating the quantitative results of the closed ended questions. However, a very few inadequacies and thus delays occurred when some potential respondents have had limited access to computers and to their e-mail accounts due to technical reasons.

7.2.2 Administrative procedures

The administrative procedure included five steps that included pre-testing the instrument, sending introduction letters, sending cover letters with a hyperlink to the survey, and sending three reminders.

The first step involved developing and pre-testing the questionnaire instrument. As explained in 2.5.1, two pilot studies were conducted in Houston, one of which was a computational plan. In these studies, observations and interviews with key designers and planners produced data and information that was useful in organizing the questionnaire structure and improve its content and thus responses. Subsequently, 14 conventional questionnaire forms were sent vide a cover letter to designers and planners who participated in developing the plan at the Planning and Development Department at the City of Houston and at the firms that contributed in their development; EE&K Architects, and Environmental Simulation Center (ESC) respectively. There were 10 responses that were reviewed and the questionnaire instrument was revised accordingly. The questionnaire form was developed using the Internet mail survey software tools. The form's layout and color was designed to facilitate the ease and speed of identification by various respondents. Using the Internet mail survey software tools, a mailing list was created for each computational plan. Each mailing list included the names, titles, and e-mail addresses of the designers and planners who participated in designing the plan. These lists allowed to customize each cover letter according to respondent's profile and the title of the urban design plan for which he was asked to provide information.

The second step involved sending e-mails to all potential respondents to inform them that they will be asked to participate in a questionnaire survey for academic research purposes. This step was essential to highlight the type and goal of the questionnaire and to avoid mixing its form with other commercial surveys that are sometimes received through e-mail accounts. The third step included sending cover letters, each of which includes a unique hyperlink that directs the respondent to the survey. Each cover letter was customized with the respondent's name, title, and affiliation and the title of the plan for which s/he was asked to participate in the questionnaire. The fourth step included using the internet mail survey software tool to send three successive reminders each of which one week apart to non respondents. This step involved also several telephone and e-mail contacts with respondents to improve the return rate and to clarify their queries concerning the plans for which they were asked to participate in the questionnaire.

There were a total of 63 questionnaire forms sent to all respondents in the eight mailing lists, among which 23 responded and completed the form and 3 declined to respond. There were also 13 forms returned due to the change in affiliation and thus e-mail addresses of the potential respondents. Therefore, the return rate was 23/63 (36.5%) if the entire sample is considered, and was 23/50 (46%) if the returned forms were excluded.

7.3 Findings and Discussion of Questionnaire Survey Data

In this section, the questionnaire results are analyzed and discussed. In this section, the collected data from each question are tabulated, manipulated, and analyzed to highlight the main findings. In all tables, the highest number in each row is highlighted to show the pattern with which the highest numbers and highest percentages of respondents are distributed. The results are discussed and justified in light of the theoretical premises, research hypotheses, and findings and conclusion derived in the previous chapters. The results of questions 1 through 5 in the questionnaire are discussed in the following sections 2.1 through 2.1 respectively.

7.3.1 The extent of usage of modeling functionalities and techniques during the design development process

In this section, each modeling functionality is discussed to assess the extent of its usage and to identify the most- and least-extensively used modeling technique. Subsequently, modeling functionalities are compared and sorted in order according to their extent of usage. Finally, the overall usage of 3D modeling is assessed and explained. The modeling techniques listed under each category were sorted in descending order according to their extent of usage. In this question, the sum of responses in the *average*, *very much*, and *a lot* extents of usage was used as a criterion to identify the extent of usage of modeling techniques. Likewise, the sum of percentage of responses in the *average*, *very much*, and *a lot* extent of usage was used as a criterion to identify the extent of usage of each modeling functionality.

In the navigation functionality, most functionalities were used with above-average usage. The most extensively-used techniques (1.1 through 1.4 in Table 7.1) were those used to navigate and represent the 3D visual configuration of the study area, and generate 2D and 3D visualizations to view the area with various scales and perspectives. The least extensively-used techniques (1.7-1.9 in Table 7.1) were those used to using advanced or associate tools such as the GIS and VRML. This suggests that visualization functionalities were meant to improve the designers' cognitive capabilities yet less extensively used in core design tasks that involved manipulating and communicating 2D and 3D information. This may be due, in part; to the lack of certain visualization capabilities such as VRML with multiple levels of realism (see 1.8 in Table 7.1). These findings suggest the need to integrate and effectively use visualization in association with other tools, particularly GIS and VR.

The sum of the percentage of responses at the *average* (27.1%), *very much* (28%), and *a lot* (6.3%) extents of usage was 61.4% which indicates that visualization functionalities were used extensively in the design process. The overall extent of using visualization functionalities was within *average* to *very much* extent of usage. The order of percentage of responses from the highest (*very much)* to the lowest (*not used)* also provides another evidence of their extensive usage. These findings are consistent with the qualitative data obtained from designers' and planners' interviews concerning the emphasis on using 3D modeling for visualization and representation purposes.

Table 7.1. Question 1: The extent of usage of modeling functionalities and techniques during the design development process

Modeling Functionalities		Extent of Usage						
No.	**Categories of functionalities**	**Not Applicable**	**Not Used**	**Very little**	**Average**	**Very much**	**A lot**	
1	***Category 1: Navigation-Visualization- functionalities***							
1.1	**Visualizing** the impact of proposed urban design	0	0	2	9	12	0	25
1.2	**Generating** 3D visualizations	0	2	2	7	10	2	19
1.3	**Viewing** the visual configuration of an existing urban pattern	0	0	5	9	9	0	18
1.4	**Generating** 2D Visualizations (e.g. maps & perspectives) at various levels of realism	0	5	3	7	7	1	15
1.5	**Representing** the study area at different geometrical and geographical scales	0	4	4	8	6	1	15
1.6	**Representing** the study area with different types of media.	0	1	9	8	5	0	13
1.7	**Extruding** spatial features in 2D GIS maps to create 3D perspectives	2	5	6	5	3	2	10
1.8	**Generating** 3D VRML models at several levels of realism	7	6	2	2	1	5	8
1.9	**Providing** spatial data through the GIS	2	3	10	1	5	2	8
	Number of responses in each extent of usage	11	26	43	**56**	**58**	**13**	207
	Percentage of responses in each extent of usage to all responses	5.3	12.6	20.8	**27.1**	**28.0**	**6.3**	**61.4**
	Order of each extent of usage in category 1	6	4	3	**2**	**1**	**5**	
	Overall assessment of the extent of usage in category 1							
2	***Category 2: Communication (decision-support) functionalities***							
2.1	**Carrying** out the major reviewing process to city authorities	1	1	3	7	8	3	18
2.2	**Communicating** and assessing the proposed development with city authorities	1	2	2	10	7	1	18
2.3	**Communicating** design concepts-or scenarios- within the design team	1	1	3	8	10	0	18
2.4	**Assessing** the proposed development(s) within the design team	1	0	3	10	9	0	16
2.5	**Selecting** the best design alternative-scenario.	1	3	6	4	9	0	13
2.6	**Communicating** project-specific design data and information within the design team	2	1	7	5	8	0	13
	Number of responses in each extent of usage	7	8	24	**44**	**51**	**4**	138
	Percentage of responses in each extent of usage to all responses	5.1	5.8	17.4	**31.9**	**37.0**	**2.9**	**71.7**
	Order of each extent of usage in category 2	5	4	3	**2**	**1**	**6**	
	Overall assessment of the extent of usage in category 2							
3	***Category 3: Analytical functionalities***							
3.1	**Analyzing the visual/3D characteristics** (townscape, skyline, building views, etc.)	0	1	8	5	9	0	14
3.2	**Analyzing the study area systems** (circulation, Land-use, site analysis, etc.)	0	3	7	9	4	0	13
3.3	**Layering and delayering:** Synthesizing multiple sets of spatial relationships	1	6	4	6	5	1	12
3.4	**Thematic mapping** of various design aspects	3	3	6	6	4	1	11
3.5	**Modeling and testing** spatial/structural relationships between physical components	0	4	9	7	3	0	10
3.6	**Structured query** of data to generate new layers of data and information	2	7	5	3	3	3	9
3.7	**Graphic reduction**: Isolating visual information to reveal spatial relationships.	1	3	10	6	2	1	9
3.8	**Overlay analysis** of different spatial data layers	4	2	10	2	4	1	7
	Number of responses in each extent of usage	11	29	59	**44**	**34**	**7**	184
	Percentage of responses in each extent of usage to all responses	6.0	15.8	32.1	**23.9**	**18.5**	**3.8**	**46.2**
	Order of each extent of usage in category 3	5	4	1	**2**	**3**	**6**	
	Overall assessment of the extent of usage in category 3							
4	***Category 4: Manipulation functionalities***							
4.1	**Visual impact assessment:** Assessing the impact of design alternatives or scenarios	1	1	5	5	11	0	16
4.2	**Modeling and testing** proposed guidelines for newly developed areas.	0	4	7	6	6	0	12
4.3	**Scenario analysis:** Comprehensive analysis of a planning scenario	3	6	6	4	3	1	8
4.4	**Representing** the proposed design with different levels of details.	0	4	11	6	2	0	8
4.5	**Impact analysis:** Testing economic and physical impacts of a proposed design.	5	6	6	4	2	0	6
4.6	**Simulating** pedestrian movement/vehicular traffic	8	9	2	1	2	1	4
	Number of responses in each extent of usage	17	30	37	**26**	**26**	**2**	138
	Percentage of responses in each extent of usage to all responses	12.3	21.7	26.8	**18.8**	**18.8**	**1.4**	**39.1**
	Order of each extent of usage in category 4	4	2	1	**3**	**3**	**5**	
	Overall assessment of the extent of usage in category 4							
	Total Number of responses at each extent of usage	**113.4**	**206.1**	**360.2**	**372.9**	**368.5**	**68.98**	1490
	Percentage of responses in each extent of usage to all responses	7.6	13.8	**24.2**	**25.0**	**24.7**	4.6	100.0
	Order of each extent of usage in category 4	5	4	3	1	2	6	

In the communication functionality, almost all functionalities were used with above-average usage. The variety between the extents of their usage was marginal. The most extensively-used technique was carrying out major reviewing process and communicating the proposed development with city authorities (see rows 2.1and 2.2 in Table 7.1). The least extensively-used techniques was communicating design data and information within the design team (see 2.6 Table 7.1) This suggests that communication functionalities were meant to emphasize using 3D models as a communication platform and as an illustration tool but less extensively used in core design tasks that involved communicating 2D and 3D information within design team. This may be due, in part, to the lack of efficient networking technologies. These findings are consistent with the premise that 3D models can become the interface between designers and other stakeholders. These findings suggest the need to integrate networking and visualization technologies to allow usage of 3D more effectively.

The sum of the percentage of responses at the *average* (31.9%), *very much* (37%), and *a lot* (2.9%) extents of usage was 71.7% which indicates that communication functionalities were used extensively in the design process. The overall extent of using visualization functionalities was within *average* to *very much* extent of usage. The order of percentage of responses from the highest (very much) to the lowest (not used) mimics that of the visualization functionalities and thus provides another evidence of their extensive usage.

In the analytical functionality, most functionalities were used with average or very little usage. The most extensively-used techniques (see rows 3.1 and 3.2 in Table 7.1) were those used to analyze the visual and 3D characteristics of the study area and analyzing its systems. All other techniques were not effectively used particularly graphic reduction and overlay analysis (see rows 3.7 and 3.7 in Table 7.1). The usage and role of those techniques in the design process was mentioned in section 4.2.2, and was further explained in section 8.3.3.1. This suggests that analytical functionalities were meant to improve the designers' capabilities to visualize and understand the structural and visual relationships between urban elements, yet less extensively used in core design tasks that involved manipulating and communicating spatial layers and information. This may be due, in part, to the lack of integration with analytical tools, namely GIS and real-estate databases (see rows 3.4, 3.6 and 3.8 in Table 7.1). These findings suggest the need to integrate and effectively use 3D models with other analytical tools, particularly GIS and databases.

The sum of the percentage of responses at the *average* (23.9%), *very much* (18.5%), and *a lot* (3.8%) extents of usage was 46.2% which indicates that the analytical functionalities were used less extensively in the design process. The overall extent of using the analytical functionalities was within *average* to *very little* extent of usage. The order of percentage of responses from the highest (*very little*) to the lowest (*a lot*) takes the opposite direction shown in visualization and communication functionalities, and thus provides evidence of their less extensive usage. These findings are consistent with the qualitative data obtained from interviews concerning the minimal usage of 3D modeling for analytical applications.

Most manipulation functionalities were either not used or used with very little usage. The most extensively-used technique (see row 4.1 in Table 7.1) was visual impact assessment of design alternatives while other techniques were either not used or not effectively used. Many techniques were reported as not applicable such as impact analysis and simulating pedestrian and vehicular movement (see rows 4.5 and 4.6 in Table 7.1). The usage and role of those techniques in the design process was mentioned in section 4.4. This suggests that manipulation functionalities were used as a visualization tool to assess the impact of designers' decisions on the urban environment. These functionalities were less extensively used in manipulating and simulating the impacts of design decisions. This may be due, in part, to the lack of dynamic and interactive capabilities that can allow simulating changes such as zoning, densities and building heights changes in real-time mode. These findings suggest the need to integrate and use advanced visualization technologies, such as VR with databases to allow for dynamic visualization of the proposed changes in the urban elements.

The sum of the percentage of responses at the *average* (18.8%), *very much* (18.8%), and *a lot* (1.4%) extents of usage was 39.1% which indicates that manipulation functionalities were less extensively used than the analytical functionalities in the design process. The overall extent of using manipulation functionalities was within *very little* to *not used* extent of usage. The order of percentage of responses from the highest (*very little*) to the lowest (*a lot*) does not show any defined pattern as shown in other functionalities, and thus provides evidence of their ineffective usage. These findings are consistent with the qualitative data obtained from interviews concerning the minimal usage of 3D modeling for manipulation applications. These findings highlighted that essential functionalities are missing in current 3D modeling tools and underscore the significance of incorporating it in design practice.

The following step involved comparing the extent of usage of the four modeling functionalities. They were sorted in descending order according to the sum of the percentage of responses at the *average*, *very much*, and *a lot* extent of usage. The communication functionalities were used with the highest extent of usage (71.7%) followed by the visualization (61.4%), analytical (46.2%) and manipulation functionalities (39.1%). This supports the research hypothesis that 3D modeling usage would support designers in core design activities. Ineffective usage of analytical capabilities is inconsistent with the theoretical model developed in chapter V which suggests that using 3D modeling for visualization may support designers in various analytical and communication tasks.

The highest percentage of *Not Applicable* techniques appears in manipulation functionalities (12.3%), then in analytical (6%), and then in visualization and analytical functionalities (5.3% and 5.1%). These figures indicate the need to integrate 3D models with other tools to provide a wider range of modeling techniques that may effectively support designers during the entire design process.

The various extents of usage of modeling functionalities were illustrated in Figure 7.1. The resulting pyramid shape reflects the overall extent of modeling usage. At the pyramid's apex, most communication, visualization, and to a less extent analytical functionalities were used with either very much or average extent of usage. However, the pyramid's sides show two inadequacies. The first is the relatively high percentage of not-used and not-applicable functionalities and the second is the minimal number of functionalities used with *a lot* extent of usage (see Figure 7.1).

Thus, several 3D modeling capabilities were underutilized either in the variety or in the extent of their usage. This was due to either technical factors such as lack of essential tools and capabilities, or human factors such as lack of essential skills needed to use them effectively.

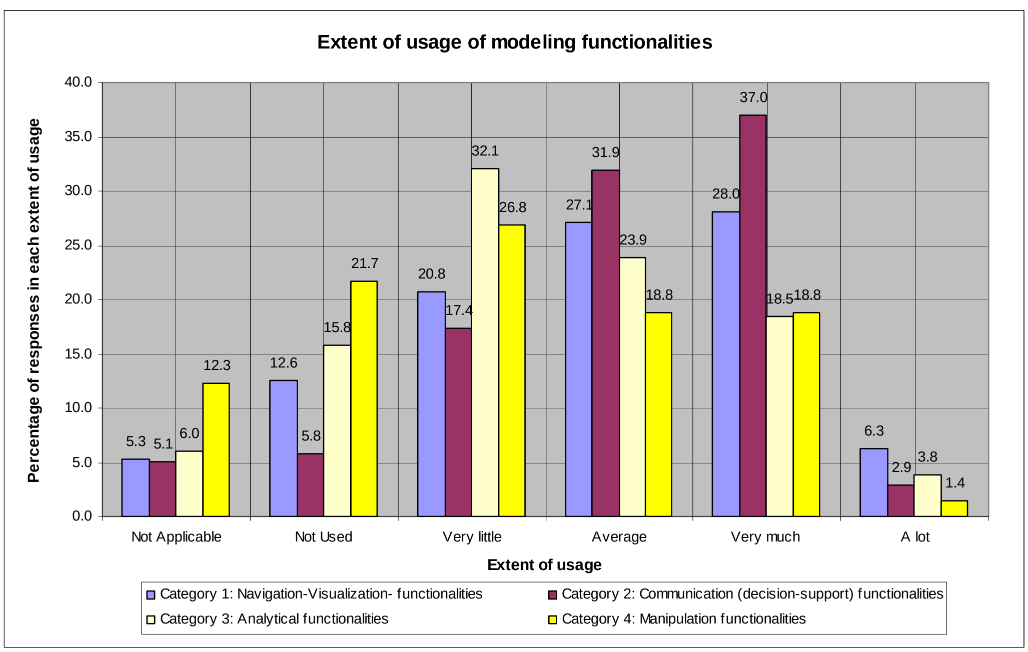


Figure 7.1. Extent of usage of modeling functionalities

7.3.2 The extent of modeling support and impact at each design phase

In this section, data was manipulated to emphasize the design phases for which 3D modeling support was most effective and has the highest impact on designers. Thus, in this section, the design phases that appeared to have been most significantly affected by 3D modeling are reported and justified.

The design phases were sorted in descending order according to the percentage of respondents at the high impact, medium impact, and low impact. The figures indicate that almost all respondents believe that 3D modeling support has provided them with extensive support that had a high impact on various design phases. The most extensive support was found during the generation and evaluation of design alternatives which occur at the advanced phases of the design process (see rows 1 and 2 in table 7.2). Designers at these phases often use visualization and communication functionalities which were effectively used. The least extensive support was found at data analysis and formulation of design goals and objectives that occur at the initial phases of the design process (see phases 6 and 7 in Table 7.2). Designers at these phases often use analytical and manipulation functionalities that were less effectively used.

Table 7.2. The extent of modeling support and impact at each design phase

No.	Design Phases	Extent of Model Support				
		No Impact	**Low Impact**	**Medium Impact**	**High Impact**	**Not Applicable**
1	Generation of alternative concepts	0	1	8	14	0
2	Evaluation of alternative solutions	0	2	6	14	1
3	Translation of solutions into policies, plans, guidelines, and programs	0	4	7	12	0
4	Elaboration of each concepts into workable solutions	0	3	9	10	1
5	Data collection, survey of existing conditions-natural, built, and socio-economic conditions	2	6	5	10	0
6	Data analysis, identification of all opportunities and limits	0	7	8	8	0
7	Formulation of goals and objectives	0	11	6	5	1
	Number of responses in each extent of support	2	34	49	73	3
	Percentage of responses in each extent of support to all responses	1.2	21.1	30.4	45.3	1.9
	Order of each extent of support	5	3	2	1	4

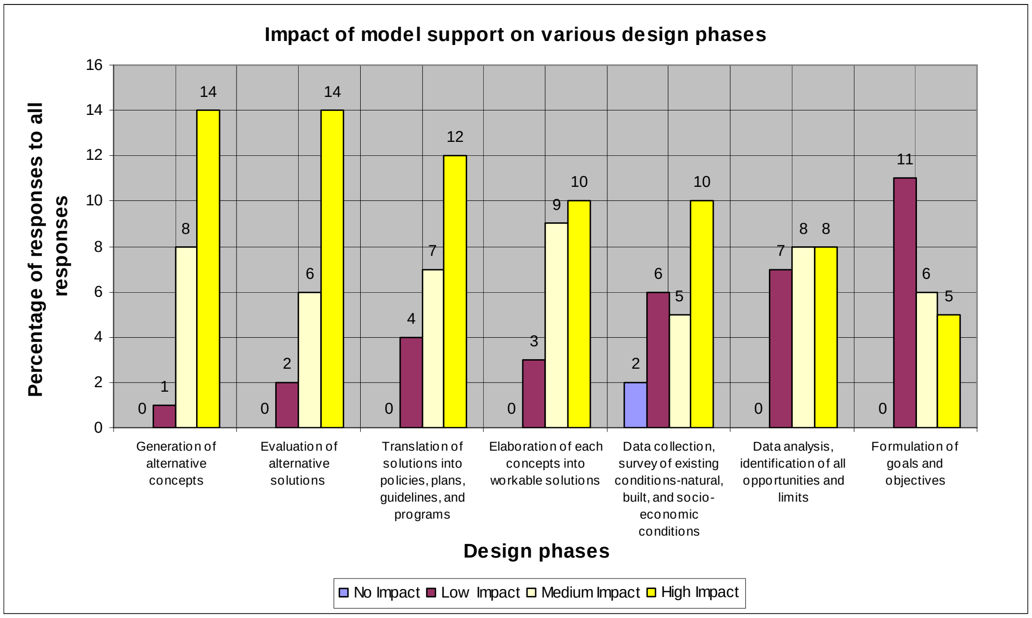


Figure 7.2. Impact of model support in various design phases

These findings suggest that the level of effectiveness and impact with which 3D modeling supports designers at the initial design phases is less than that at advanced phases (see Figure 7.2). Such inconsistency in the extent of modeling usage across design phases may be due, in part to technical and human factors mentioned in the previous section 2.1. The percentage of respondents who reported that modeling usage has no impact is almost negligible, and the sum of those who reported a medium and high impact is 75.7%. This supports the research hypothesis that if the design process employs 3D modeling, then it will support designers at various design tasks and will have an impact on the design process. These findings provides further evidence to the findings of chapter VI that some inadequacies in design aspects coverage in computational plans may be due, in part to inconsistent usage of 3D modeling in the entire design process.

7.3.3 The impact of modeling usage on the output of each design phase

In this section, data was manipulated to emphasize the most significant impacts that most designers agree upon as resulting from 3D modeling support. Thus, in this section, the design impact that appeared to have resulted from 3D modeling are reported and justified.

The impacts were sorted in descending order according to the percentage of respondents at the *strongly agree*, *agree*, and *neutral* assessment levels (see Table 7.3). The majority of respondents either strongly agrees (25.2%) or agrees (42.9%) that 3D modeling support has had an impact on the output of the design process. No respondent strongly disagreed, and the percentage of those who disagree is marginal (11.8%) (see Figure 7.3). These findings are consistent with those of the previous sections 2.1 and 2.2. These findings may justify the superiority of the computational plans and support the conclusions derived in chapter VI concerning the improvements in designers' capabilities that appeared to have improved the quality of the design outcome. These findings also support the research hypotheses that 3D modeling usage support designer and can improve the quality of the design outcome.

The most significant impacts appeared to be the improvement in communication of design concepts to a wider group of professionals (see rows 1 and 2 in Table 7.3). This provides further evidence of the importance of 3D models as platforms of communication among and across design teams. The least impact was reported to be increased the time allocated for analysis and alternatives generation (see rows 13 and 14 in Table 7.3). This may be due in part to technical factors such as lack of dynamic visualization tools or human factors such as ineffective usage of analytical and manipulation functionalities as reported in section 2.1. These findings are inconsistent with the theoretical model which suggests that 3D modeling may allow designers to allocate more time for analysis and generating and testing design alternatives that may ultimately improve the quality of the design output.

7.3.4 The impact of modeling usage on designing each design aspect

In this section, data was manipulated to highlight how modeling usage affected addressing the design aspects. The percentage of respondents who reported a high impact of modeling usage was used as a criterion to sort data in descending order. It was used to sort the design elements that constitute each design aspect and then to sort all design aspects to compare the extent to what design elements and aspects were affected by 3D modeling usage. Thus, in this section, the design aspects that appeared to have been significantly affected by 3D modeling usage are reported and justified.

The findings showed that 3D modeling has various extents of impact on designing the design elements and design aspects (see Table 7.4). In each design aspect, there was some evidence that modeling usage has the highest impact on elements that address overall rather than detailed design issues. For example, the order of design elements of the architectural character (rows 7.1 through 7.3 in Table 7.4) and of the conservation area (rows 9.1 through 9.4 in Table 7.4) shows their order of emphasis from the wider to the detailed issues.

Table 7.3. The impact of modeling usage on the output of each design phase

No.	Impacts of model usage	Assessment: Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
1	Improved the communication of design concepts and alternatives	14	6	2	0	0	1
2	Communicating design concepts to a wider group of professionals	11	10	1	1	0	0
3	Provided a better access to data and information	9	10	3	1	0	0
4	Helped underpin design alternatives with analytical content	7	11	2	2	0	1
5	Considering a greater number of alternative scenarios	7	8	4	3	0	1
6	Analyzing the study area at multiple levels	6	16	1	0	0	0
7	Addressing a greater number of design aspects in the urban design plan	5	13	2	2	0	1
8	Organizing the quantitative base of the urban design process	5	11	6	1	0	0
9	Improved the designers' confidence in the decisions made	4	12	5	2	0	0
10	Helped organize multiple scales of design control (Metropolitan, city-wide, District)	4	10	6	3	0	0
11	Helped generate a larger number of design alternatives	4	9	6	3	0	1
12	Avoiding communication deficiencies among designers	3	8	6	5	0	1
13	Increased the time allocated for generating design alternatives	1	8	4	9	0	1
14	Increased the time allocated for analytical tasks	1	6	9	6	0	1
	Number of responses in each assessment level	81	138	57	38	0	8
	Percentage of responses in each assessment level to all responses	25.2	42.9	17.7	11.8	0.0	2.5
	Order of each assessment level	2	1	3	4	6	5

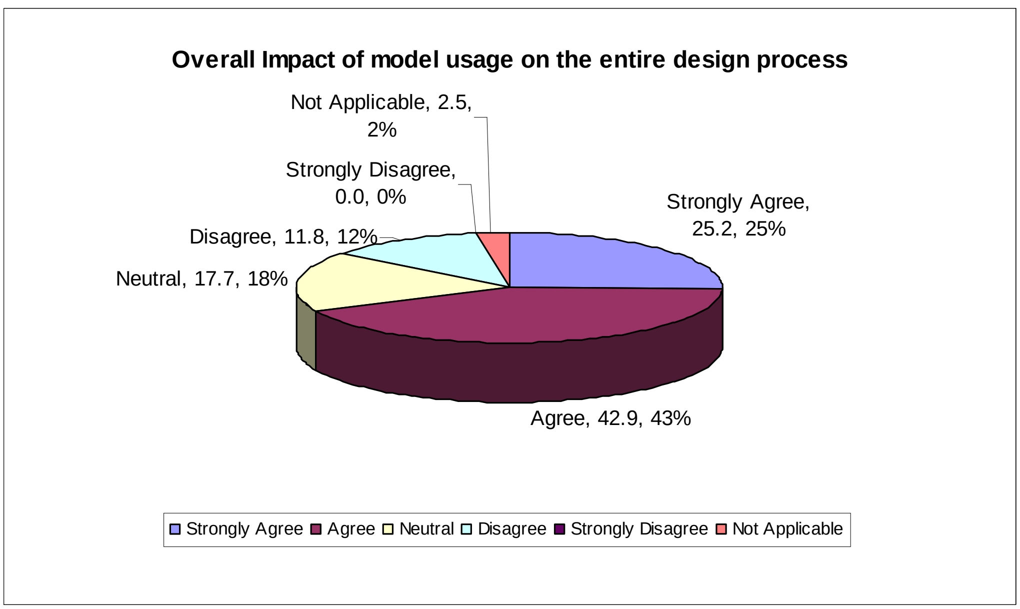


Figure 7.3. Overall impact of model usage on the entire design process

Table 7.4. The impact of modeling usage on designing each design aspect

No.	Design Aspects	No impact	Low Impact	Medium Impact	High Impact	Not Applicable
		Assessment				
1	**Sustainability-Energy and resource management**					
1.1	Ecology and nature conservation	3	6	5	3	5
1.2	Traffic management and alternative transportation	3	8	4	3	4
1.3	Energy conservation	3	8	6	0	5
	Number of responses in assessment level	9	22	15	6	14
	Percentage of responses in each assessment level to all responses	13.6	33.3	22.7	9.1	21.2
2	**Townscape (Visual composition of space)**					
2.1	Skyline	0	2	7	13	0
2.2	Views, vistas, and overlooks	0	2	6	13	1
2.3	District character and identity	0	1	10	11	0
2.4	Continuity of spaces, streetscape, and streetscene	0	3	10	9	0
	Number of responses in assessment level	0	8	33	46	1
	Percentage of responses in each assessment level to all responses	0.0	9.1	37.5	52.3	1.1
3	**Urban Form (Three-dimensional built volume)**					
3.1	Scale (height and massing)	0	1	4	17	0
3.2	Density	2	2	3	15	0
3.3	Visual qualities of open spaces and streets	2	1	7	12	0
3.4	Space system: urban and open space structure	2	0	9	11	0
3.5	Urban pattern and layout	2	1	8	11	0
	Number of responses in assessment level	8	5	31	66	0
	Percentage of responses in each assessment level to all responses	7.3	4.5	28.2	60.0	0.0
4	**Public Realm (The social experience)**					
4.1	Vitality: Economic vitality and maintenance of downtown vitality	5	7	4	4	2
4.2	Security, public perceptions, and sense of community	5	6	6	3	2
4.3	Social interaction	6	8	3	3	2
	Number of responses in assessment level	16	21	13	10	6
	Percentage of responses in each assessment level to all responses	24.2	31.8	19.7	15.2	9.1
5	**Land -use (Mixed-use and diversity)**					
5.1	Diversity and mixed land-use	3	6	7	5	1
	Number of responses in assessment level	3	6	7	5	1
	Percentage of responses in each assessment level to all responses	13.6	27.3	31.8	22.7	4.5
6	**Connection and Movement Network**					
6.1	Street network: accommodation of traffic	1	5	9	5	2
6.2	Pedestrian network: pedestrian routes, links to parking	2	7	7	5	1
6.3	Parking: accommodation of parking, access to parking	2	6	7	5	2
6.4	Accessibility to open spaces (for pedestrians and motorists).	1	9	7	4	1
	Number of responses in assessment level	6	27	30	19	6
	Percentage of responses in each assessment level to all responses	6.8	30.7	34.1	21.6	6.8
7	**Architectural Character**					
7.1	Architectural form: bulk, character, height, massing, scale	0	2	4	16	0
7.2	Elevations: Design vocabulary and design style	1	5	8	8	0
7.3	Elevations' details: detailing, fenestrations, color, texture, and materials.	2	6	8	6	0
	Number of responses in assessment level	3	13	20	30	0
	Percentage of responses in each assessment level to all responses	4.5	19.7	30.3	45.5	0.0
8	**Landscape Architecture**					
8.1	Overall landscape design: open space network and topography.	1	5	7	7	2
8.2	Soft landscape design: Water, landscape layout and improvements	1	6	8	5	2
8.3	Hard landscape design: Street furniture and lighting	2	5	8	5	2
	Number of responses in assessment level	4	16	23	17	6
	Percentage of responses in each assessment level to all responses	6.1	24.2	34.8	25.8	9.1
9	**Conservation areas and/or areas of special character**					
9.1	Architectural form: bulk, character, height, massing, and scale	0	2	8	12	0
9.2	Urban form and townscape	1	3	9	9	0
9.3	Elevations: Design vocabulary, design style.	2	4	7	9	0
9.4	Elevations details: detailing, fenestrations, color, texture, materials	3	7	6	6	0
	Number of responses in assessment level	6	16	30	36	0
	Percentage of responses in each assessment level to all responses	6.8	18.2	34.1	40.9	0.0

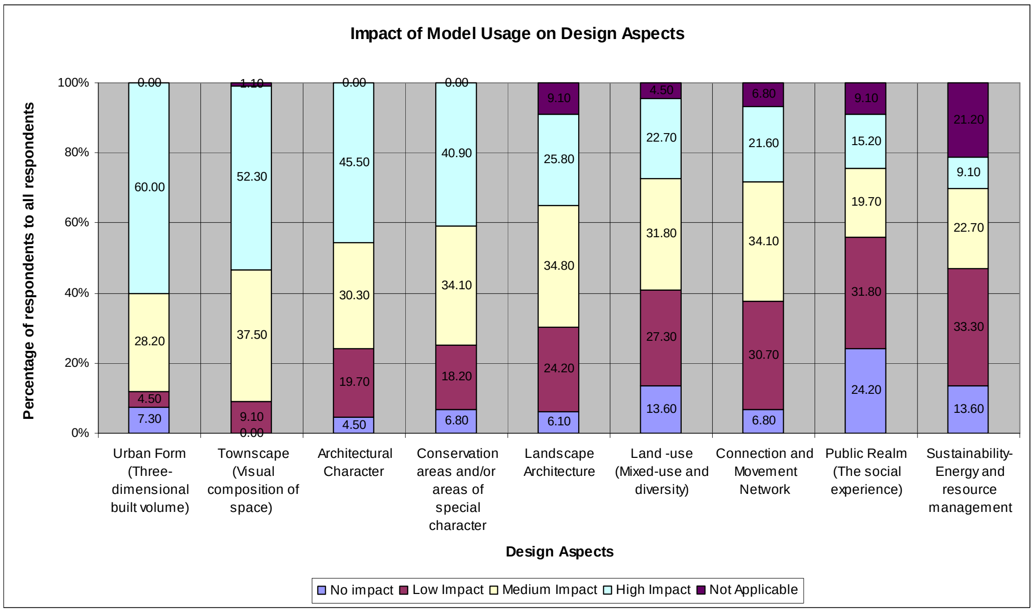


Figure 7.4. Impact of model usage on design aspects

The findings also showed that the order of design aspects from the most to the least affected by modeling follows a certain pattern (see Table 7.4 and Figure 7.4). The modeling usage has the highest impact on urban form (60% of respondents) and townscape (52.3% of respondents), both of which were considered as urban-wide 3D design aspects (Table 3.1).

These findings are consistent with the findings of chapter VI which suggest that the most significant difference between computational and conventional plans appears in urban-wide 3D design aspects, particularly urban form and townscape. These findings support the research hypothesis that the usage of 3D modeling can improve the coverage of 3D design aspects. Similarly, modeling usage has high impact, yet to slightly less extent, on architectural character (45.5% of respondents) and conservation areas (40.9% of respondents) both of which were considered as 3D local design aspects. These findings are inconsistent with the findings of chapter VI which recognizes a minimal difference between computational and conventional plans in local 3D design aspects. This inconsistency may be due, in part, to the overlapping terms used by professionals to define and distinguish between architectural and urban scales and realms. However, these findings provide further evidence to support the research hypothesis that 3D modeling usage can improve the coverage of 3D design aspects.

The findings showed that modeling usage has medium impact on landscape architecture (25.8% of respondents), a local 2D design aspect. It has a medium impact also on land-use (22.7% of respondents) and connection and movement network (21.6% of respondents) both of which were considered urban-wide 2D design aspects (see Table 3.1). These findings are consistent with the findings of chapter VI which suggest that the medium impact of modeling usage on urban-wide 2D design aspects is due to the fact that they are often addressed with high coverage in conventional plans.

The findings showed that modeling usage has low impact on public realm (15.2% of respondents) which is an urban-wide design aspect, and on sustainability (9.1% of respondents) which is a local 3D design aspect. Such low impact on public realm is inconsistent with the findings of chapter VI concerning the high impact of modeling usage on public realm. This may be due, in part, to the fact that public realm, in some references, is considered an urban-wide 2D design aspect that addresses the social experience of the urban spatial network (Carmon, Punter and Chapman 2002, pp.60-61).

7.3.5 Attributes of the 3D models used

In this section, the models' attributes, usage, compatibility, accessibility, and degree of detail are briefly highlighted. The results may help explain some inadequacies in impacts of modeling usage and justify, in part, some inconsistencies that appeared between the questionnaire survey results and the findings of chapter VI.

The findings of topics 1 through 4 showed that current modeling tools, usage, compatibility and degree of detail may allow designers to employ 3D models in design practice (see Table 7.5). The majorities of respondents reported that the extent of the modeled area was at the downtown-city center scale (43.5% of respondents) or city-wide scale (21.7% of respondents). The majority used models with a medium degree of reality and accurate building volumes (52.2% of respondents), that are convertible to other file formats (82.6% of respondents), and that are compatible to some other current tools and technologies (60.9% of respondents). However, further increase in the extent of the modeled area and the model's degree of detail would provide designers with a wider range of modeling techniques that may affect the quality of the design product.

Table 7.5. The attributes of the 3D models used

No.	Questions and Topics	Response Total	Response percentage
1	The extent of the study area modeled by the 3D digital urban model		
1.1	One district/Study area only	2	8.7
1.2	More than one district	2	8.7
1.3	Downtown-city center	10	43.5
1.4	City wide	5	21.7
1.5	City region	1	4.3
1.6	Other (please specify)	3	13
2	The level of details of the area modeled by the 3D digital urban model		
2.1	Detailed architectural model including fenestration	1	4.3
2.2	Detailed elevation	2	8.7
2.3	Major details of building elevations	2	8.7
2.4	Accurate building volumes	12	52.2
2.5	Roofscapes	2	8.7
2.6	Prismatic block models –coarse massing	2	8.7
2.7	Other (please specify)	2	8.7
3	Identify the ability to convert file format to other standard formats		
3.1	Convertible	19	82.6
3.2	Non Convertible	0	0
3.3	Other (please specify)	4	17.4
4	Identify the model's compatibility with other tools		
4.1	Compatible to all other current tools and agencies	6	26.1
4.2	Compatible to some other current tools and agencies	14	60.9
4.3	Non-compatible to any other current tool and agencies	0	0
4.4	Other (please specify)	3	13
5	What is the extent of model's accessibility to the public (check all that apply)		
5.1	Public	9	39.1
5.2	Design team	14	60.9
5.3	City authorities	12	52.2
5.4	Urban planning and design consultancies	14	60.9
5.5	All other engineering and infrastructure consultancies	5	21.7
5.6	Other (please specify)	4	17.4
6	For how long the firm has been using the model in the design and decision-making process?		
6.1	Less than 2 years	0	0
6.2	2+-3 years	3	13
6.3	3+-5 years	5	21.7
6.4	5+-8 years	5	21.7
6.5	More than eight years	10	43.5
7	Who frequently uses the model during the design process?		
7.1	Urban planning/ design team	21	91.3
7.2	Architects	15	65.2
7.3	Engineers	4	17.4
7.4	Surveyors	0	0
7.5	Landscape planners and designers	8	34.8
7.6	Planning department head	11	47.8
7.7	Other (please specify)	2	8.7
8	Which of the following best describes the change in design methodology due to 3D models usage?		
8.1	Conventional methodology without any change	0	0
8.2	Conventional methodology but supported with digital technology	12	52.2
8.3	New methodology designed to fit the models' usage	9	39.1
8.4	Other (please specify)	2	8.7

The findings of topic 5 suggest the need to increase the accessibility of modeling tools to public (39.1% of respondents) and to other engineering and infrastructure consultancies (21.7% of respondents) to higher extents. Such improved accessibility is essential in a multi-disciplinary, collaborative and distributed environment of urban design professional practice. It requires the employment of advanced networking technologies and adopting a participatory approach to foster a wider involvement of public in professional design practice (see rows 5.1 and 5.5 in Table 7.5).

The findings of topic 6 and 7 suggest that modeling tools has not been used for a long time and by all design participants equally. The extent of their usage by architects (65.2% of respondents) and the landscape planners and designers (34.8% of respondents) may explain the medium and low impact of modeling on architectural character and landscape design respectively (see rows 7.2 and 7.6 in Table 7.5).

The findings of topic 8 suggest that modeling usage has not significantly affected the design methodology. The majority (52.2% of respondents) reported that they used conventional design methodology supported with digital technology whereas only 39.1% of respondents reported that they adopted a new design methodology tailored to fit the modeling usage. These findings explain the low overall coverage levels in some computational plans that were reported in the findings and conclusions in chapter VI. They provide further evidence that low or no impact of modeling on certain design aspects is due, in part, to lack of essential expertise in using modeling methods appropriately in design practice. These findings are consistent with the premise that current design practice employ digital tools yet adopt conventional design methodologies. These findings suggest that effective usage of 3D modeling requires adopting a design methodology that is structured around the usage of technology rather than following a modified conventional methodology that may not support designers effectively.

7.4 The Interview Process

This section describes the interview process. It explains participants' selection, data collection, and provides an overall assessment of the informants' viewpoints concerning the 3D modeling usage in urban design practice.

7.4.1 Participants' selection

Four computational plans were selected to conduct structured interviews with key designers and planners who participated in the design development of those plans. Those plans, analyzed in chapter VI, were developed for central areas in Chicago, New York, and

Pittsburgh. Their titles can be found in rows 1 through 3 in Appendix B. They were selected because they were examples of urban design plans that have been developed using 3D digital models and they were the subject of several publications. One plan, namely *Chicago Central Area Plan* 2003, was awarded the *2004 American Institute of Architects (AIA) Honor Award for Regional and Urban Design*.

The informants who were selected to participate in the interview process represented the city planning departments and the firms that participated in developing the selected plans. Some interviewed informants were practitioners in visualization firms and others were professors from research centers and/or academic institutions that were involved in digital modeling for community and urban design. Such selections allowed me to interview informants with diverse backgrounds and a variety of levels of expertise and roles in the design process. For a list of the interviewed informants, see Appendix A, section 4.

7.4.2 Data collection

The interviews followed the structured interview protocol approved by the IRB at the office of the VPR at Texas A&M University (TAMU) (see Appendix A-section 3). These interviews were focused on four main themes: methods of usage of 3D digital models in the urban design process, the impact of such a usage on the design methodology and the design team, how such a usage affected the quality of the design outcome, and the effectiveness of 3D modeling support. All interviews were digitally recorded after obtaining the informants' written consent on the consent form approved by the IRB at TAMU. The emphasis on any of these topics was modified according to the informant's profile and role in the design process.

The Interviews did not involve distributing the questionnaire forms to the informants to avoid creating a group of privileged respondents. Having two or more groups of respondents with different treatments and methods of data collection could have biased the responses. However, the questionnaire form was discussed with a few participants who provided some feedback and advice as to the form's format, content, and presentation.

In addition, the interviews helped collect additional useful material from all the informants such as presentations that used 3D modeling to represent design alternatives in public meetings and planning charrettes, images illustrating the usage of a variety of modeling techniques, and reports of the selected plans as well as other plans that employed 3D modeling in the design development.

The collected data helped to unravel certain undocumented issues related to the usage of 3D digital models in the development of the selected plans. The meetings with the director and two designers at one visualization firm involved exploring how they use 3D modeling to prepare studies for other firms to assess the impacts of urban design proposals on their urban context. Another informant provided information about the construction of the model used in Chicago Central Area Plan 2003 such as the software used, usability, methods of usage, and suggested certain avenues through which the model's utility could be improved.

7.4.3-Overall assessment of participants' viewpoints

The various viewpoints concerning the methods, utility, feasibility, and impact of 3D modeling on design quality reflected the diversity of the informants' roles, levels of expertise, and backgrounds. Although they invariably agreed on the importance of digital modeling in urban design practice, they reflected various viewpoints concerning the appropriate methods of usage and the phases or tasks within which modeling may be used. Younger urban designers, for example, suggest using modeling consistently and effectively during the entire design process. Senior designers, in contrast, were reluctant to apply that suggestion because they think that it sometimes hampers the flow and progress of the design process.

Although most informants expressed their faith in the capabilities of 3D digital modeling in urban design practice, they invariably lack the necessary in-depth knowledge of the appropriate methods of usage. There was also a limited understanding of the role of 3D modeling in supporting designers and the impact of its usage on the quality of design outcome. Most informants emphasized the utility of models as an interface to communicate with the public at large, but they undermined other significant analytical and decision-support functionalities that may significantly improve the quality of the design outcome.

Similarly, informants suggested that the range of modeling tools and applicable modeling functionalities supported designers effectively. Yet, they invariably suggested that if digital models are integrated with databases and networking technology, then they may have a significant impact on the design process and outcome. These results are consistent with those of the questionnaire survey and the case studies. Such consistency provides further evidence of the potential of using 3D models usage not only as visualization and communication tools but also as tools that support design analysis and decision making.

7.5 Conclusions

The questionnaire survey findings provided further evidence to support the research hypothesis. They were compared against the theoretical models developed and premises addressed in the previous chapters. These findings helped explain some inadequacies in the coverage levels of computational plans and allowed me to justify some inconsistencies between research findings and the theoretical model.

The findings showed a wide variety of extents of modeling usage. The findings showed that 3D models were used as communication and visualization tools. There was no evidence that they were used as analytical tools or to support design decisions. The most extensively used functionalities were communication and visualization. Analytical and manipulation functionalities were less extensively used due to technical and human factors. The findings also showed that the overall usage of modeling was between average and very much. These findings are inconsistent with the premise concerning the ineffective usage of 3D modeling in current urban design practice. These findings may lead to the conclusion that modeling usage was used extensively yet not always effectively to support core design tasks.

The findings showed various extents of usage during the design phases. It has been extensively used in advanced phases such as generating and testing design alternatives, and less extensively used in early design phases such as developing design goals and objectives and analyzing and communicating 2D and 3D spatial information and data. Such inconsistency in usage may explain some inadequacies in the design content of some computational plans that were reported in chapter VI and are emphasized in chapter VIII. Such inadequacies suggest that consistent usage of modeling tools may significantly improve the design content of urban design plans. However, they also suggest integrating 3D models with analytical and advanced visualization tools such as GIS and VR to improve designers' cognitive and analytical capabilities in a way similar to the mechanism illustrated in the theoretical model developed in chapter V.

The findings showed 3D modeling usage has various extents of impact on designing the entire set of design aspects. The modeling usage has the highest impact on urban-wide 3D design aspects, namely urban form and townscape, and on local 3D design aspects, namely architectural character and conservation areas. These findings are consistent with those reported in chapter VI. They support the research hypotheses that 3D molding usage may improve the design aspects coverage, and in particular 3D design aspects.

The findings showed that current modeling tools, usage, compatibility and degree of detail may allow designers to employ 3D models in design practice. However, they suggest that effective support and thus high impact on the quality of the design product require further improvements in technical, human, and methodological factors. They require modeling larger areas with a degree of reality that fit the project's goals and help in further future projects. They require allowing the public and all design participants more accessibility to modeling tools. This may foster extensive usage of those tools by various designers to support decision-making. Such extensive usage may help address some gaps in the design content that appeared to have resulted, in part, from ineffective modeling usage by designers in certain disciplines. However, such extensive usage may not lead to the anticipated results if conventional design methodologies are used. Usage of 3D modeling and IT tools may lead to the best results when associated with a design methodology that is structured around using those tools consistently during all design phases.

CHAPTER VIII

COMPARATIVE CASE STUDIES: CHICAGO CENTRAL AREA PLAN (CCAP) AND PITTSBURGH DOWNTOWN DEVELOPMENT PLAN (PDDP)

8.1 Introduction

This chapter uses the comparative case study approach to examine the modeling methods used in two cases. The first is *Pittsburgh Downtown Development Plan: a Blueprint for the 21st Century* (PDDP hereafter). The second is *Chicago Central Area Plan 2003: preparing the central city for the 21st century* (CCAP hereafter). Both plans were produced by a process that incorporated 3D modeling. They were selected because their overall coverage levels and cumulative ranks were the highest among the other computational cases. The chapter's objectives are twofold. The first is to assess and compare the extent and pattern of design aspects coverage in each case with the conceptual models derived from the coverage averaged across computational cases. The second goal is to understand how the usage of 3D digital models affected the design aspects coverage.

The chapter contains three main sections. Section one involves investigating each case study along two dimensions: how 3D models were used in the planning and design process, and qualities of the resulting plan that may be consequences of 3D modeling usage. Section two focuses on discussing and comparing the empirical observations with the conceptual models that have been derived from the previous chapters about the design aspects coverage to derive conclusions. Section three involves comparing the extent and pattern of coverage of both cases to assess the extent to which they vary across computational cases.

Data was obtained from three sources. Two primary sources are the plan's documents and interviews with key designers and planners who participated in its development. Secondary sources are published articles that discussed the plan. The qualitative content analysis was used to analyze the plan's documents and interview data. 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 instructions of published content analysis research with similar aims and from available literature and theories of design content and 3D modeling. The collected data have been categorized and analyzed to establish a cohesive framework of model functionalities and their likely impact on the 3D design aspects in each case.

8.2 Pittsburgh Downtown Development Plan

8.2.1 Goals and design approaches

Pittsburgh Downtown Development Plan (PDDP) is an urban design plan that has been developed using digital tools and specifically 3D digital models. A 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 a and b; Schmertz 1997).

8.2.1.1 The plan's goals and objectives

The plan's explicit and foremost goals were transforming Pittsburgh's Downtown into an 18- to 24-hour city and integrating ongoing public and private development and planning proposals into a "comprehensive 10-year vision" that would include transportation and public infrastructure (Stern 1998 a, p.25; PDDP 1998, p.3). It considered downtown development at three concentric levels: the traditional downtown, the plan's study area which includes the traditional downtown with its surrounding areas and shores, and the downtown's regional context.

8.2.1.2 Design and development approaches

One key design and development approach was to distinguish geographic areas and define phases (see Figure 8.1). The plan was broken into a series of coherent interlocking districts according to their characteristics, uses, and locations. The development plan addressed each district with distinct recommendations that could contribute vitality and strength to the whole (see Figure 8.2). The plan was also broken down thematically into six focus areas. For each focus area, an agreement was first reached on broad principles that subsequently laid the foundation for a general development strategy of the plan. In another breakdown, the development objectives and projects were broken into two phases. In phase one (1-4 years), the plan focuses on the development of the Downtown's traditional boundaries. In phase two (5-10 years), the focus shifted into the areas surrounding the traditional downtown (see Figure 8.3). Another key approach was adopting two types of design guidance: prescriptive and performance guidance to facilitate flexible design control and levels of details in the focus areas and districts. Design guidance emphasized design elements at various hierarchical levels ranging from the intermediate scale of landscape and urban design considerations to the detailed issues of architecture and urban management.

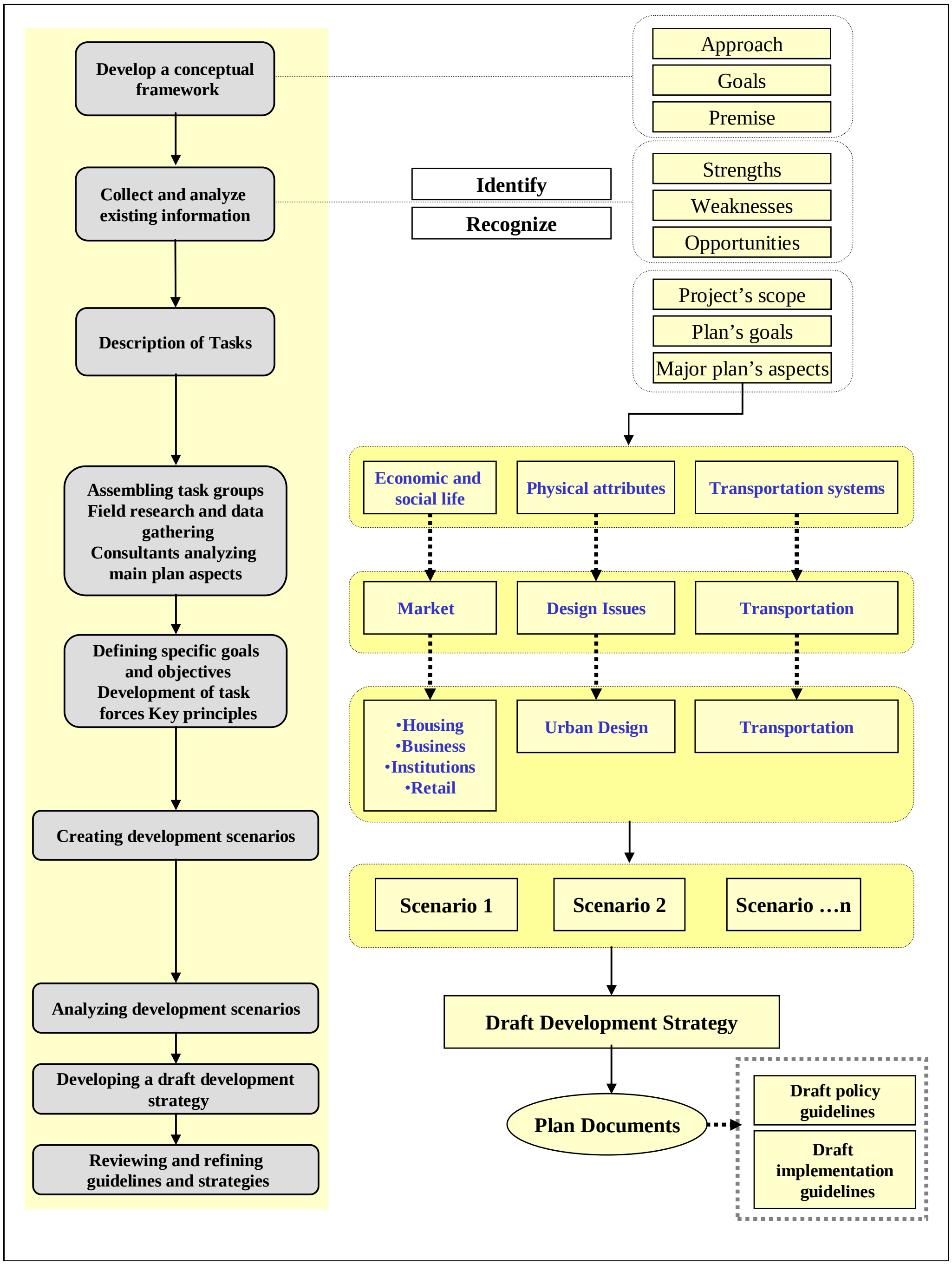


Figure 8.1. Schematic diagram conceptualizing the main design phases and tasks in the development process of PDDP.

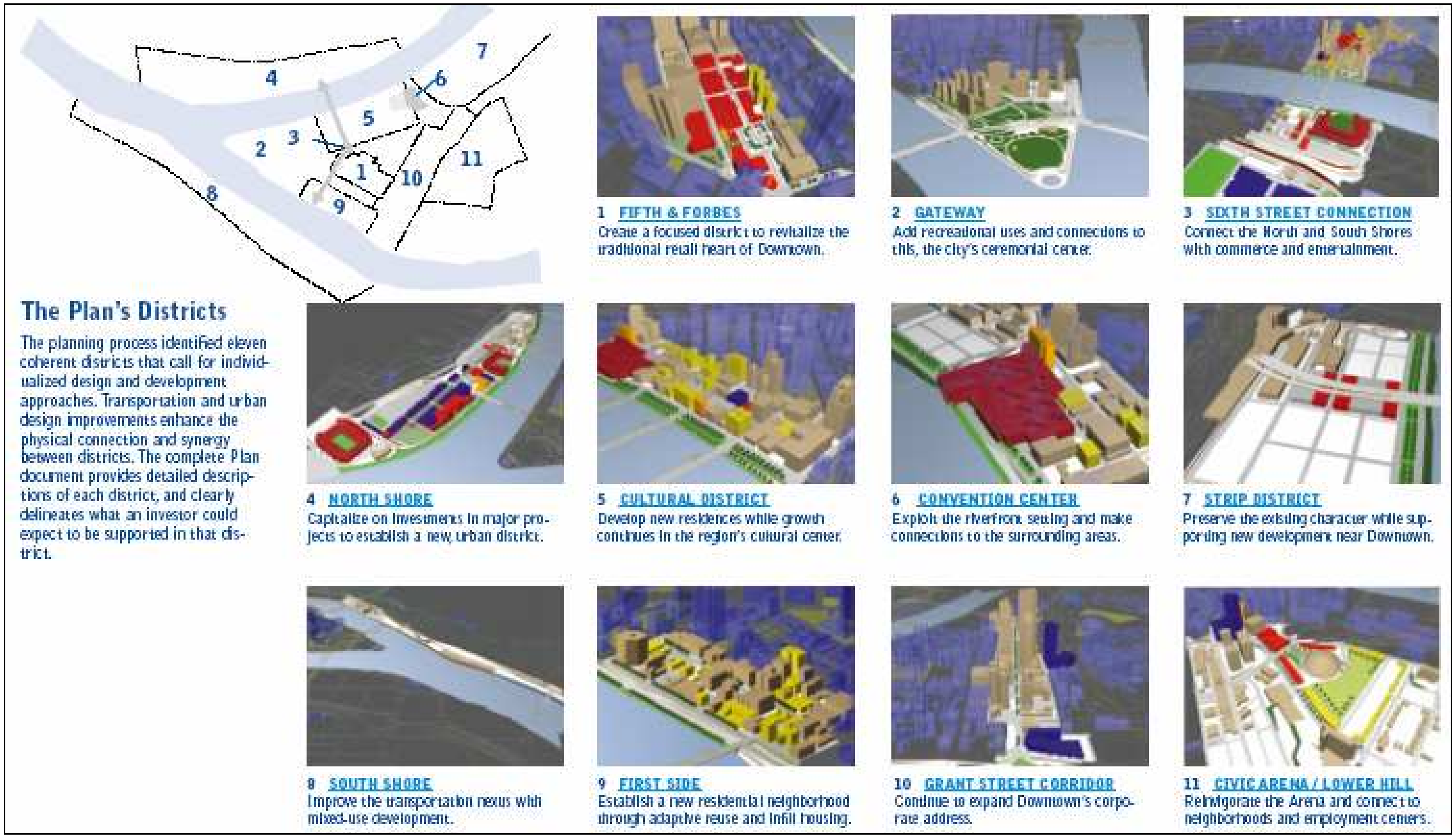


Figure 8.2. One of the development approaches of PDDP was breaking the key design strategy into sub-areas and coherent districts according to their distinctive characteristics, uses, and locations. The 3D model was used to illustrate the districts' location and connections, and synergy with other districts and with the entire downtown area (PDDP 1999, P.11)

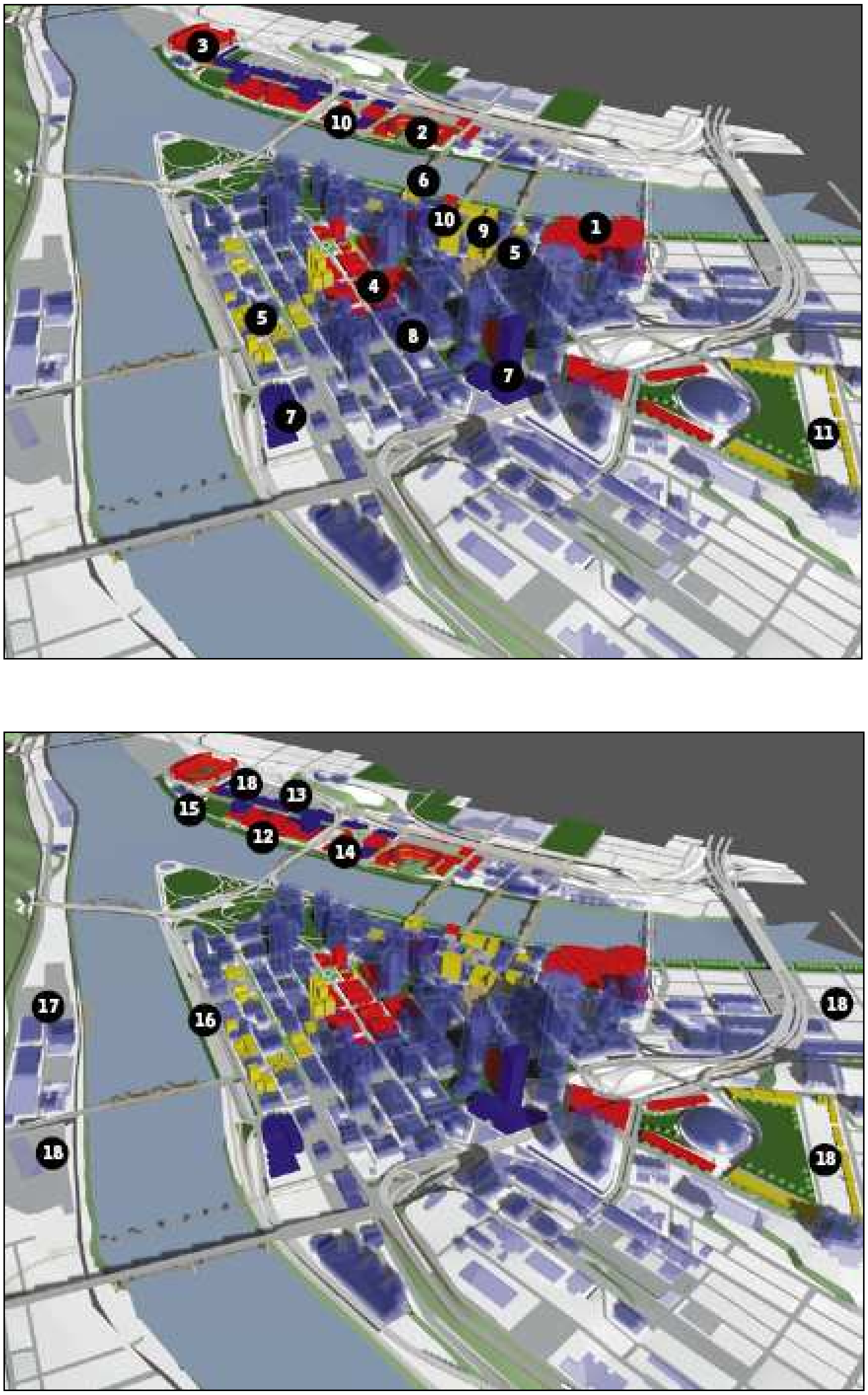


Figure 8.3. Using 3D modeling to represent the development projects proposed in the study area in phases one and two. The upper view represented the projects (1-11) proposed in phase one (1-4 years). The lower view (bottom) represented the projects (12-18) proposed in phase two (5-10 years) (PDDP 1999, p. 5).

8.2.1.3 The collaborative and multidisciplinary approach

The initial step in the plan's development process focused on designing an action plan to guide and advance each stage. It involved defining a team structure that consisted of four key participants: the oversight committees, the community task forces, the planning group, and the core team that would generate and serve as a container of information (PDDP 1998, p.7). Each team was assigned certain tasks and helped create a multi-disciplinary collaborative professional environment. The Oversight Committees formed a partnership to bring the diverse technical, financial, and managerial expertise to the development process. The plan involved six focus areas: retail and attractions, business climate, housing, institutions, transportation, and urban design. Community Task Forces which corresponded to these focus areas convened a diverse group of business leaders, administrators, design professionals, residents, clergy, and other concerned citizens. Each task force included members of the community. There was also participation of stakeholders from the downtown, universities, colleges, technical schools, and representatives from financial institutions, architects, and retail representatives (senior planner-A- interview, 2006).

The planning team invited public participation and conducted detailed research and analysis to inform the development plan and underpin its design policies with analytical content (see Figure 8.1) (PDDP 1998, p.7).

> The planning process was based on an extensive public process and outreach. It adopted a bottom-up approach rather than a top-down approach… This process was very well-planned and thoughtful, yet it took a great deal of time and effort… It considered illustrating the design proposals to the public to gain their support to the plan. (senior planner-A-interview, 2006).

Both approaches underscore the significance of using modeling tools in the development of PDDP from two standpoints. First, design teams need interactive 3D modeling tools to analyze and design the physical environment at multiple levels of details and various degrees of abstraction. Second, design teams need tools to facilitate rapid and effective storage and retrieval of information, various techniques of visualization to inform survey and analysis, and different strategies for communicating information, design concepts, and plans within and across design teams. They also need tools to facilitate rapid exploration of alternative concepts that would help stakeholders to comprehend, accept, and participate in the design process.

> …It was a very collaborative process so that each member of the staff was responsible for an area of focus. All of us worked on the same pace. The computer technology made it easier and provided the platform on which the team collaborated…During the planning process, each of the task forces met monthly to suggest and discuss the ideas, points of recommendations, and the focus areas. (senior planner -A-interview, 2006).

8.2.2 Documenting the modeling methods and techniques and assessing the design aspects coverage in PDDP

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 aspects. These tasks are discussed in the following two sections respectively.

8.2.2.1 3D Modeling methods and techniques: theory versus practice

The content analysis of the 3D modeling focused on two issues:

1. Documenting the extent of usage of 3D modeling functionalities in PDDP.
2. Investigating the extent with which using 3D modeling in PDDP departs from theory.

For the first issue, I 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 (see Table 8.1).

Content analysis of PDDP found that all applicable modeling functionalities were used. The ratio of those used with above average usage to the total applicable modeling functionalities was 14/25 (56%), and the ratio of those used with average and above-average usage to the total applicable functionalities was 24/26 (92%). This ratio indicates an efficient usage of the modeling techniques in the design process but with various extents of effectiveness. Modeling functionalities were sorted according to the number of functions in each extent of usage. The most used functionalities were the communication functionalities followed in descending order by navigation, analytical, and manipulation functionalities (see Table 8.1).

This extent of usage was due, in part, to three main factors. The first factor was the model's type that determined the styles and techniques of analyzing and representing 2D and 3D design elements and issues. The second factor was the multi-disciplinary collaborative approach of the design process that required a platform for coordinating and communicating design ideas and strategies within design teams and across teams as well as an illustrating tool to help educate the public to gain their support to the plan. The third factor is the plan's statement of purpose, goals and objectives which emphasized the issues of transportation and economic revitalization. Such emphasis has lead designers to prioritize the functional considerations and to a slightly less extent the visual considerations in the design content of PDDP (senior planners-A-&-B- and senior designer interviews, 2006).

The most effectively used modeling techniques 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 capabilities (see Figure 8.4). 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 the team to visualize the existing and proposed facilities of each focus area with respect to the downtown's urban pattern (see Figure 8.5). Derivative conceptual models were created to analyze the physical and environmental elements of downtown area. These elements include sun studies, open spaces system, relative density, landmarks and visual aspects to explore the view structure in and around the downtown area (see Figure 8.6). The GIS functionality allowed the team to create multiple linkages between 3D entities to produce a genuine 3D GIS (Gosling and Gosling 2003, p. 251) (see Figure 8.7). The impact of using those techniques on the 3D design aspects coverage is explained in the discussion of findings.

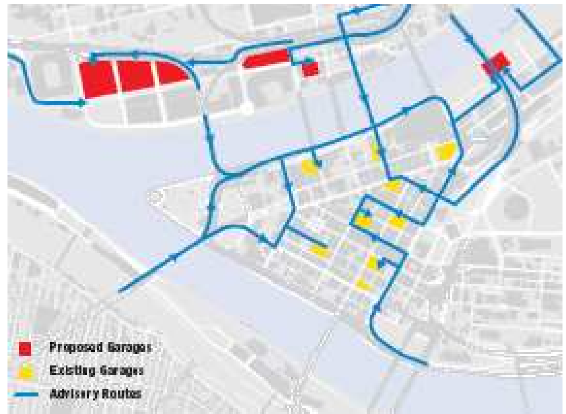
The second issue involved setting the computational analysis techniques of Hong's (1997) conceptual model against their counterparts in PDDP (see Table 8.2). Hong (1997) followed Shirvani's approach (1985) to classify urban design information elements and issues into 2D and 3D categories, and used that classification to develop a conceptual model for the computational analysis and representation of those elements and issues.

Content analysis showed that 3D modeling in PDDP departs significantly from Hong's conceptual model in two main aspects: the extent of usage and modes of representation (see Table 8.2). In contrast to Hong's conceptual model which involved using 3D modeling in 3D design issues only, PDDP involved using it 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 with conventional and digital modes of representation which may improve the capabilities of designers and public to comprehend design concepts. These findings confirm that 3D computer modeling was used extensively and appropriately in the plan development. They suggest that the model's functionalities have effectively supported designers and thus, may have affected the quality of the design product. To verify these assumptions, the second task involved an assessment of design aspects' coverage in PDDP.

Table 8.1. The extent of usage of 3D modeling functionalities in the development process of PDDP.

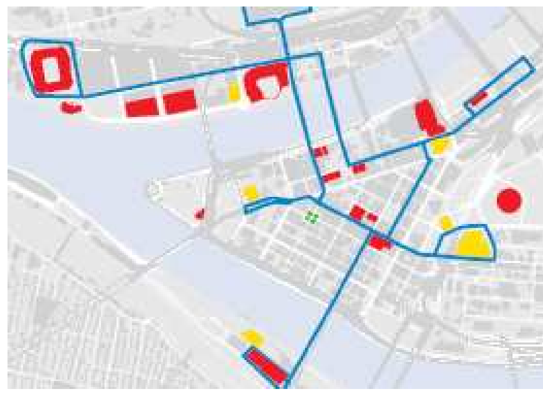
Modeling Functionalities		**Extent of Usage**					
No.	**Categories of functionalities**	**Not Applicable**	**Not Used**	**Very little**	**Average**	**Very much**	**A lot**
1	***Category 1: Navigation-Visualization- functionalities***						
1.1	**Viewing** the visual configuration of an existing urban pattern					■	
1.2	**Visualizing** the impact of proposed urban design						■
1.3	**Providing** spatial data through the GIS					■	
1.4	**Extruding** spatial features in 2D GIS maps to create 3D perspectives						■
1.5	**Generating** 2D Visualizations (e.g. maps & perspectives) at various levels of realism			■			
1.6	**Generating** 3D visualizations				■		
1.7	**Generating** 3D VRML models at several levels of realism	■					
1.8	**Representing** the study area at different geometrical and geographical scales				■		
1.9	**Representing** the study area with different types of media.					■	
	Number of functions in each extent of usage	1	0	1	**2**	**3**	**2**
	Overall assessment of the extent of usage in category 1					■	
2	***Category 2: Communication (decision-support) functionalities***						
2.1	**Communicating** project-specific design data and information within the design team						■
2.2	**Communicating** design concepts-or scenarios- within the design team						■
2.3	**Assessing** the proposed development(s) within the design team						■
2.4	**Communicating** and assessing the proposed development with city authorities					■	
2.5	**Carrying** out the major reviewing process to city authorities					■	
2.6	**Selecting** the best design alternative-scenario.				■		
	Number of functions in each extent of usage	0	0	0	**1**	**2**	**3**
	Overall assessment of the extent of usage in category 2						■
3	***Category 3: Analytical functionalities***						
3.1	**Modeling and testing** spatial/structural relationships between physical components				■		
3.2	**Analyzing the study area systems** (circulation, Land-use, site analysis, etc.)					■	
3.3	**Analyzing the visual/3D characteristics** (townscape, skyline, building views, etc.)				■		
3.4	**Graphic reduction**: Isolating visual information to reveal spatial relationships.						■
3.5	**Layering and delayering:** Synthesizing multiple sets of spatial relationships						■
3.6	**Structured query** of data to generate new layers of data and information				■		
3.7	**Overlay analysis** of different spatial data layers				■		
3.8	**Thematic mapping** of various design aspects				■		
	Number of functions in each extent of usage	0	0	0	**5**	**1**	**2**
	Overall assessment of the extent of usage in category 3				■		
4	***Category 4: Manipulation functionalities***						
4.1	**Representing** the proposed design with different levels of details.	■					
4.2	**Modeling and testing** proposed guidelines for newly developed areas.			■			
4.3	**Visual impact assessment:** Assessing the impact of design alternatives or scenarios						■
4.4	**Simulating** pedestrian movement/vehicular traffic	■					
4.5	**Impact analysis:** Testing economic and physical impacts of a proposed design.				■		
4.6	**Scenario analysis:** Comprehensive analysis of a planning scenario	■					
	Number of functions in each extent of usage	3	0	1	**1**	**0**	**1**
	Overall assessment of the extent of usage in category 4			■			
	Total Number of functions at each extent of usage	**4**	**0**	**2**	**9**	**6**	**8**

Pedestrian Enhancements: Pedestrian enhancements are proposed for most of the traffic-sensitive streets in downtown Pittsburgh.

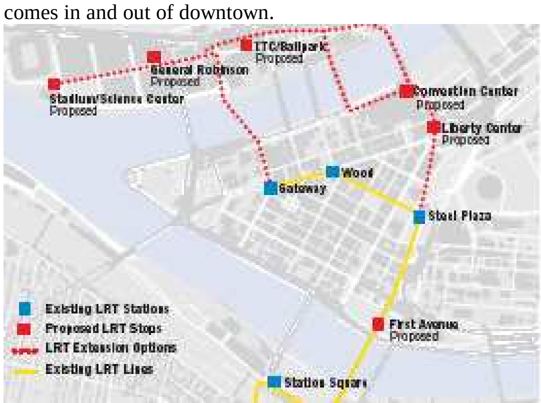


Parking Advisory System: Shown are some of the proposed routes that could be equipped with electronic signs.

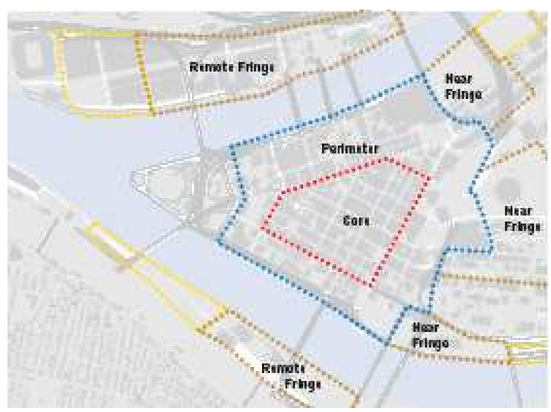
Through Bus Routing Concept: The concept brings buses in one corridor and out another which is shown in the schematic of a through routing system with each corridor color coded as it comes in and out of downtown.



Shuttle Routes: Shuttle routes could provide supplemental transit service for the through routes Red indicated major visitor attractions.

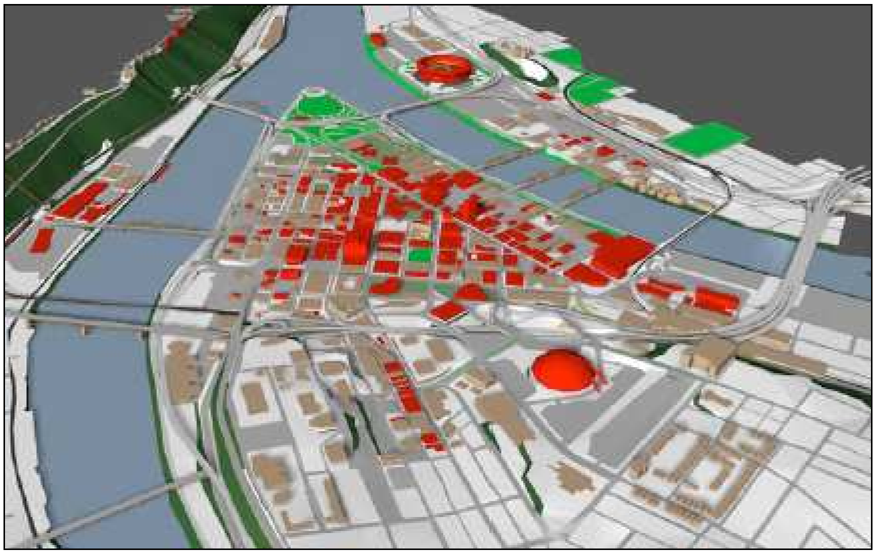


LRT Connection to North Shore: A transit connection between the North Shore and the Golden Triangle was an important factor in making the relationship between fringe parking and proposed development work.



Shared Parking Options: The development strategy involved adding from 3,000 – 5,000 spaces in demand. To address this problem, a five-tiered system has been proposed. The zones, characterized by distinct levels of convenience, rate structures and a distinct market, would include core, perimeter, near fringe, remote fringe and satellite.

Figure 8.4. Using layering and de-layering techniques to analyze and represent the recommended improvements for elements of the transportation focus area in 2D media. The plan has involved using digital 3D modeling to represent these improvements to the public and other design participants in 3D media (PDDP 1999, pp. 50-52).



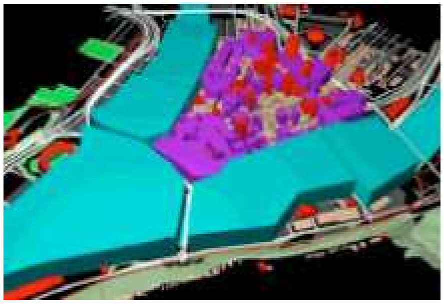
This view represented the existing retail & attractions facilities in the Downtown area, and helped show that they dominate the ground floors of the Downtown area, but are often underutilized or disconnected (PDDP 1999, p.13)

This view represented the proposed revitalized retail core in the Fifth and Forbes district, and a spectrum of family-oriented entertainment attractions on the North Shore, linked by the Sixth Street corridor. It also represented other outlying proposed retail and entertainment centers. Red indicates new and expanded retail and attractions (including hotels); beige buildings are existing facilities (PDDP 1999, P.16).

Figure 8.5. Using graphic reduction technique and color coding to isolate and represent the existing buildings and proposed development and expanded facilities of each of the six focus areas in PDDP.

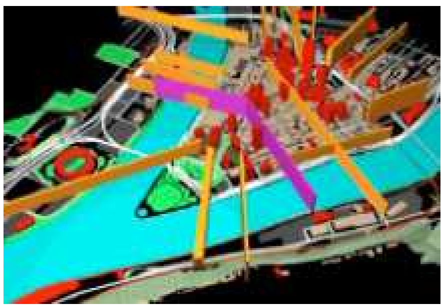
Open Spaces

Sun Studies



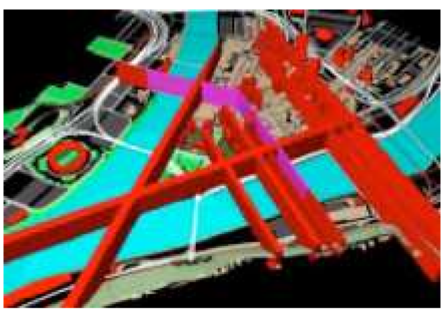
Open spaces as solids

Mid-Morning equinox



Views into the city

Noon equinox

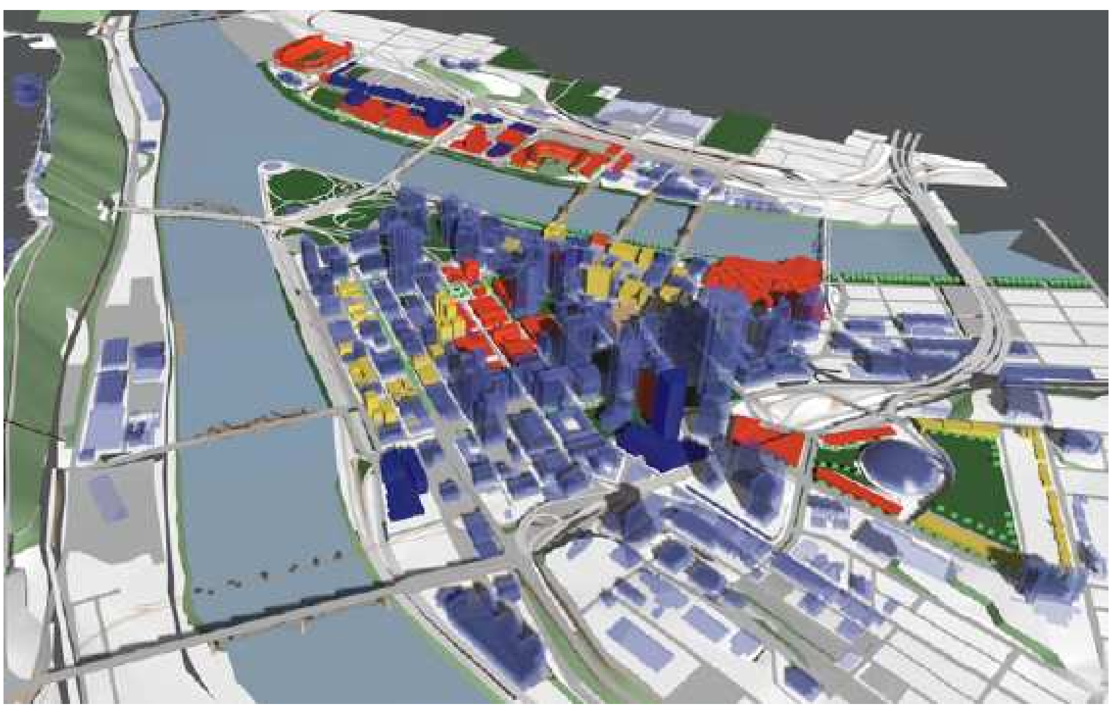


Views out of the city

Mid-Afternoon equinox

Figure 8.6. Computer-assisted analysis of the physical and environmental elements of Pittsburgh's downtown area. The 3D model was used analyze sun studies, open spaces and visual aspects (PDDP 1999, pp.56-57).

The 3D model was used to represent the urban form of the Golden Triangle, the visual focus of the Three Rivers Basin. The 3D model was meant to create views that help visualize and configure the pyramidal shape of the skyline of the Golden Triangle through the use of zoning controls that require lower buildings along the riverfronts and permits taller ones in the core of the Triangle (PDDP 1999, p.55).



The 3D model was used to represent a series of public space improvements, including new open spaces, brighter street and sidewalk treatments, and greater access to the waterfront. These improvements were meant to knit together the various proposed developments and were represented in various colors (red, blue, and yellow) (PDDP 1999, p.60).

Figure 8.7. Using 3D modeling to represent the development strategy, and the key themes that constituted the urban design focus area.

Table 8.2. Comparison between the computational analysis and representation of urban design elements and issues of Hong's conceptual model and their counterparts in PDDP.

Computational analysis and representation according to Hong's model										**Urban Design information and issues**	**Computational Analysis and Representation used in PDDP**								
Charts	Tables	Diagrams	Figure ground	Thematic maps	2Dimensional maps	Photographs	Perspective drawings	Computer 3D models			Computer 3D models	Perspective drawings	Photographs	2Dimensional maps	Thematic maps	Figure ground	Diagrams	Tables	Charts
									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 and age Distribution								■	■
									2D	**Natural Environment**									
■	■									Local climate (temp, sun, wind, etc.)								■	■
									2D	**Building Regulations**									
	■				■					Building height control	■	■		■					
	■			■						Building bulk control (FAR, coverage)	■			■	■				
	■									Building uses	■							■	

8.2.2.2 Assessment of design aspects coverage in PDDP

This section assessed the extent and pattern of design aspects coverage of PDDP using several criteria derived from the analysis results. In the content analysis at this task, I modified and adopted RTPI's list of design aspects (see Table 8.3). I used that agenda also to document the computational and conventional techniques of representing the constituent urban design elements and issues of PDDP (see Table 8.4). These aspects were classified according to their design conceptualization, goals, and scope of concern into 2D and 3D aspects and into local or urban-wide scale (see Table 3.1). This list was compared with its counterpart in PDDP to assess the extent with which PDDP has covered the essential 2D and 3D design issues.

Table 8.3. Assessment of design aspects coverage in PDDP

Urban Design Elements and Issues				Extent of Coverage		
Types	**Scale**	**Number**	**Design Aspects**	**No coverage**	**Minor**	**Significant**
3D	**Urban**	1	**Townscape (Visual composition of space)**			
			Number of design elements and issues in each extent of coverage	0	1	16
			Percentage of design elments and issues in each extent of coverage	0	6	94
		2	**Urban Form (Three-dimensional built volume)**			
			Number of design elements and issues in each extent of coverage	0	3	11
			Percentage of design elments and issues in each extent of coverage	0	21	79
		3	**Public Realm (The social experience)**			
			Number of design elements and issues in each extent of coverage	1	1	4
			Percentage of design elments and issues in each extent of coverage	6	6	88
	Local	4	**Architectural Character**			
			Number of design elements and issues in each extent of coverage	3	10	9
			Percentage of design elments and issues in each extent of coverage	14	45	41
		5	**Conservation areas and/or areas of special character**			
			Number of design elements and issues in each extent of coverage	3	10	25
			Percentage of design elments and issues in each extent of coverage	8	26	66
2D	**Urban**	6	**Connection and Movement Network**			
			Number of design elements and issues in each extent of coverage	0	1	7
			Percentage of design elments and issues in each extent of coverage	0	13	87
		7	**Land -use (Mixed-use and diversity)**			
			Number of design elements and issues in each extent of coverage	0	0	3
			Percentage of design elments and issues in each extent of coverage	0	0	100
		8	**Sustainable urban design**			
			Number of design elements and issues in each extent of coverage	4	4	4
			Percentage of design elments and issues in each extent of coverage	33	33	34
	Local	9	**Landscape Architecture**			
			Number of design elements and issues in each extent of coverage	1	5	10
			Percentage of design elments and issues in each extent of coverage	6	31	63

Table 8.4. Techniques used to analyze and present urban design aspects in PDDP

		Presentation Techniques													
No.	**Basic Urban Design Elements and 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**
1	Townscape	■	■			■	■	■	■			■			
2	Urban form	■	■			■	■	■	■			■			
3	Architectural character	■	■			■	■	■					■		
4	Conservation areas	■	■				■	■	■				■		
5	Connections and movement	■	■			■	■	■	■				■		
6	Land-use (Mixed use and diversity)	■	■				■	■						■	■
7	Public realm	■	■				■	■	■						
8	Landscape Architecture	■	■				■	■							

The extent of coverage was assessed using three criteria. The first criterion is the quantity of design aspects at each coverage level. The plan has addressed 6, 3, and 0 design aspects with high, medium, and low coverage levels respectively. These figures indicate that (2/3) 67% of the design aspects were addressed with high coverage level, and (1/3) 33 % of them were addressed with medium coverage level (see Figures 8.8 and 8.9 and table 8.5). The plan did not include any design aspect with low coverage level. These percentages are higher than their counterparts of the levels of coverage averaged across computational cases (average computational hereafter). Therefore, the overall coverage level of (PDDP) is considered a high level according to the criteria adopted in Table 6.4.

The second criterion is the extent with which PDDP has addressed certain design aspects. Content analysis of PDDP found that the variety of effectiveness and levels of design aspects coverage may be related to their scale and scope of concern. It has found that the plan involved high coverage of land-use and connection and movement issues (100% and 87% respectively), both of which are 2D design elements that are concerned with the city/district level, and a medium coverage of landscape architecture issues that are concerned with the local level. It found also a high (94%, 88%, and 79%) coverage of 3D design issues related to townscape, public realm and urban form respectively, all of which are concerned with the characteristics of and structural and visual relations between urban elements at the city/ district level. Conversely, it indicates a minor coverage of the architectural character and conservation areas that are concerned with 3D design issues of individual elements or groups of elements at the local level (see Table 8.5 and Figure 8.10).

The third criterion is the effectiveness with which PDDP covered the entire list of design aspects. Content analysis found that the difference between the highest and lowest percentage of coverage (100%-34%) is less than its counterpart in the average of computational cases (92%-11%). The difference in PDDP involved a variety of gradual levels which indicates that more design aspects were addressed with high to medium levels of coverage (see Figure 8.8). Therefore, the effectiveness of coverage in PDDP was higher than the average attained across computational cases.

Table 8.5. Percentage of design aspects coverage in PDDP, CCAP, and average computational plans sorted according to their ranks

No.	Average of computational cases		Pittsb-Comput.		Chicago-Comput.	
	Design aspects	**Average percentage of significant coverage**	**Design aspects**	**Percentage of significant coverage**	**Design aspects**	**Percentage of significant coverage**
1	Land -use (Mixed-use and diversity)	**92**	Land -use (Mixed-use and diversity)	**100**	Connection and Movement Network	**100**
2	Public Realm	**68**	Townscape	**94**	Land -use (Mixed-use and diversity)	**100**
3	Townscape	**65**	Public Realm	**88**	Townscape	**66**
4	Connection and Movement Network	**59**	Connection and Movement Network	**87**	Public Realm	**66**
5	Urban Form	**50**	Urban Form	**79**	Urban Form	**64**
6	Conservation areas	**34**	Conservation areas	**66**	Landscape Architecture	**43**
7	Landscape Architecture	**33**	Landscape Architecture	**63**	Conservation areas	**34**
8	Sustainable Urban Design	**23**	Architectural Character	**41**	Sustainable Urban Design	**33**
9	Architectural Character	**11**	Sustainable Urban Design	**34**	Architectural Character	**0**
10	Number of design aspects addressed with high coverage level	**2**		**6**		**4**
11	Number of design aspects addressed with medium coverage level	**5**		**3**		**4**
12	Number of design aspects addressed with low coverage level	**2**		**0**		**1**

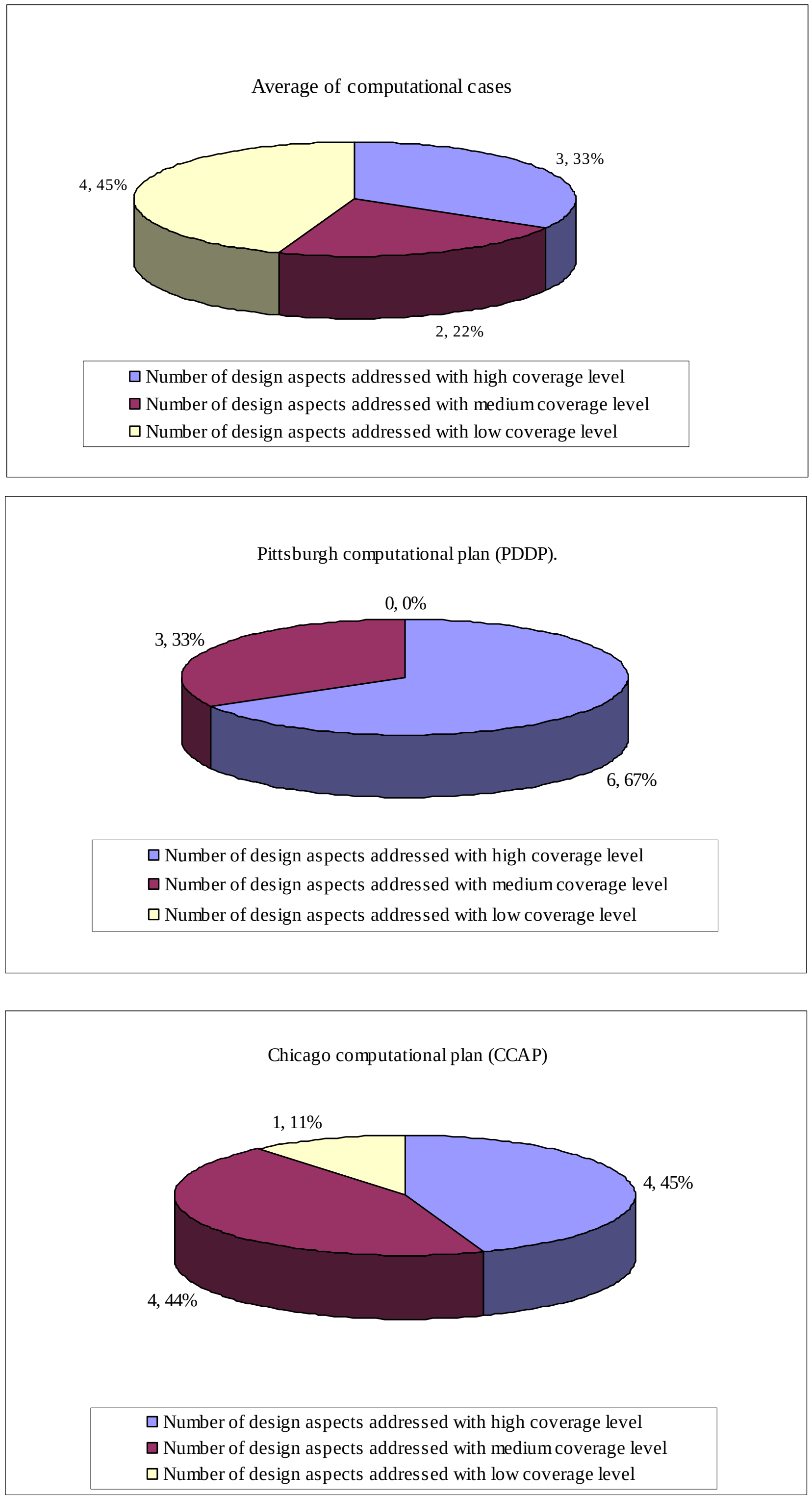
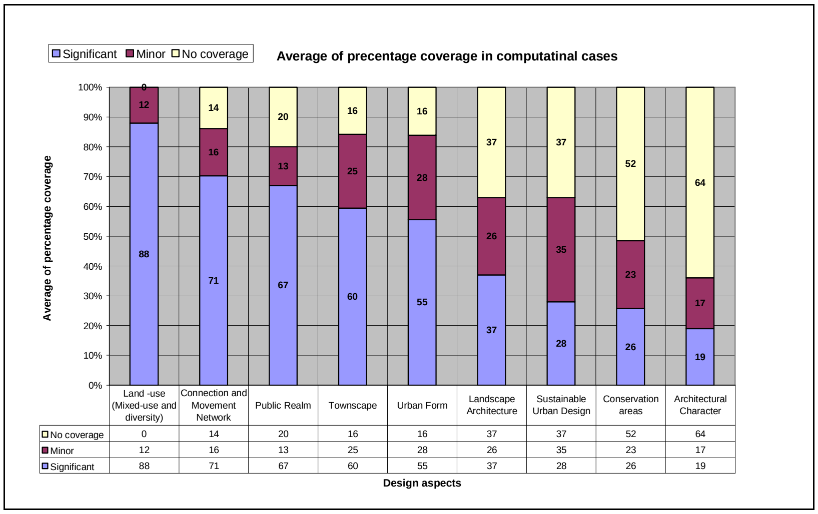
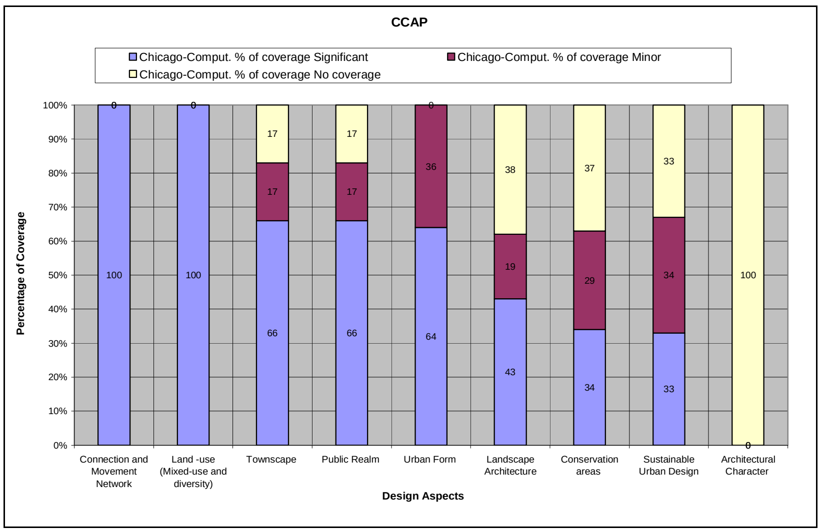


Figure 8.8. Comparison between the percentages of design aspects coverage of PDDP and CCAP with percentage of coverage averaged across all computational plans.





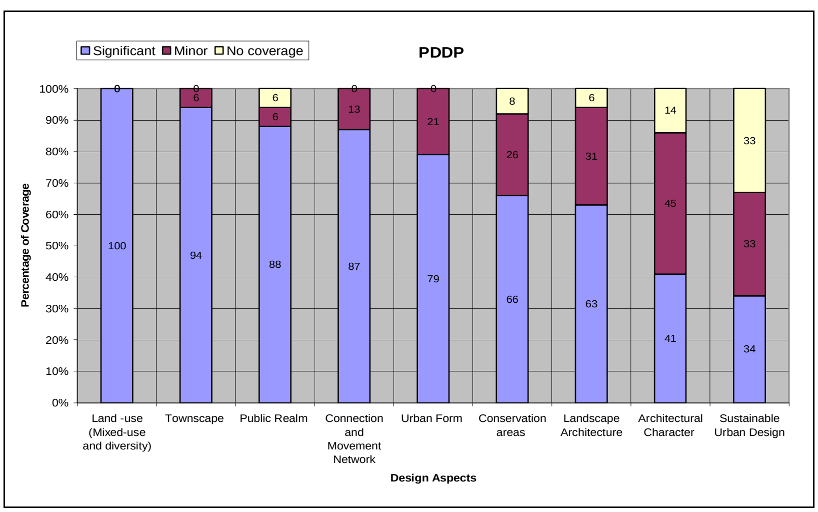


Figure 8.9. Comparison between the percentage of design aspects coverage of PDDP and CCAP with the average of computational plans

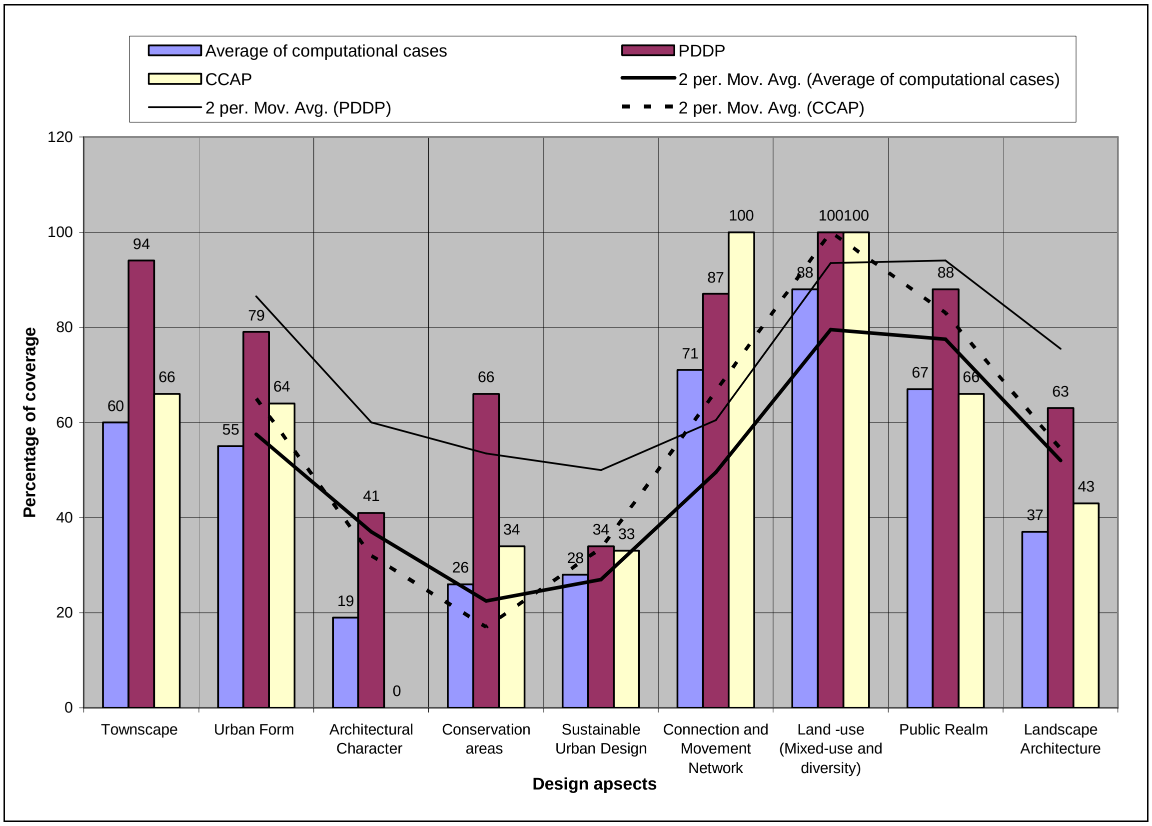


Figure 8.10. The trend lines of design aspects coverage in PDDP and CCAP compared with the trend line of design aspects coverage averaged across all computational plans.

The pattern of coverage was assessed using two criteria. The first criterion was the trend with which PDDP covered the entire list of design aspects. The content analysis found that 6/9 (67%) design aspects were addressed with high coverage level, 3/9 (33%) of the design aspects were addressed with medium coverage level, and there was no low coverage design aspects (see Figure 8.8 and see also Table 6.3 for the limits of each level). The trend line of PDDP, illustrated in Figure 8.10, mimics that of the average computational cases. They change their directions at the same points and design aspects. The gap separating their paths slightly varies along their paths, yet it diminishes at two design aspects, the land-use and connection and movement network. Therefore, the plan's trend of coverage may be considered static (constant) coverage. This is consistent with the premise derived from chapter VI concerning the trend of coverage of average computational plans which was related to the plan's overall coverage level. It suggested that high or low overall coverage plans address most design aspects with high or low coverage levels respectively.

The second criterion was the pattern of design aspects distribution in two models derived from the coverage of average computational cases. Their quantity and location in the four quadrants of both models indicate their coverage levels in PDDP, and how these levels differ from those in the average computational cases.

The first model illustrates their distribution in the four quadrants of low and high coverage and rank (Figure 8.11.A). In PDDP, most design aspects (6/9 or 67%) are located in high coverage level quadrants whereas in the average computational cases, 5/9 (56%) are located in high coverage level quadrants (Figure 8.11.C). Their uniform distribution in three quadrants and the regular shape of the line linking them indicates the PDDP plan's tendency to address them with a variety of levels according to the plan's statement of purpose. The line linking them is similar in shape and slope to its counterpart of the average computational plans, yet it predominantly falls within the high coverage and low cumulative rank quadrants. These findings provide further evidence of the high overall coverage of PDDP and of the effective coverage of a broader array of design elements and issues with an above-average extent of coverage.

The second model illustrates their distribution in the four quadrants of urban wide and local 2D and 3D design aspects (Figure 8.12.A). The location and extent of design aspects coverage with respect to the model's center, the point of axes intersection, illustrates the pattern of emphasis on design aspects with certain scale and scope of concern. Their locations in the high coverage zones of the urban-wide 2D and 3D quadrants are closer to the borders and thus more extensively covered compared to their location in the computational plans model. Similarly, their locations in the medium coverage zone of local 2D and 3D quadrants of PDDP differs markedly from their locations in the medium coverage zone of the average computational cases model.

Larger shaded areas in PDDP's model indicate how the extent of coverage of local 2D/3D aspects is higher than that of the average computational cases (see Figures 8.12.A and 8.12.C). The difference in the extent of shaded areas highlights that PDDP covers local 2D and 3D design aspects more effectively than the average computational cases and supports the finding that computational plans address urban-wide 2D and 3D design aspects effectively and efficiently.

The distribution of design aspects in the four quadrants indicates that the design content of CCAP has emphasized the urban-wide 2D and urban-wide 3D design aspects almost equally, followed in descending order by local 2D and local 3D design aspects. This order of emphasis in the design content is consistent with the emphasis of the plan's goals and objectives on functional considerations such as, transportation and economical improvements and on visual considerations such as, townscape improvements and integrating the development proposals physically and visually with the downtown area. This may provide evidence that the usage of modeling functionalities has helped designers address the problem's area and fulfill the plan's statement of purpose.

The findings refuted to a great 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. These findings support the research hypothesis that the effective usage of 3D modeling functionalities may increase the coverage of design aspects and thus improve the design content.

8.2.3 Empirical justification and conclusions

8.2.3.1 Empirical justification

The variety of levels with which PDDP addressed the design aspects was due, in part, to four factors: the model's type and thus function(s), the plan's statement of purpose, goals and objectives, the plan's methodological approach, and the extent of model's usage.

First, the model's iconic type has confined its role to explanation and education of public. Due to model's lack of interactive capabilities, the plan used multiple scales of representation yet with the same degree of abstraction (see Figure 8.7). 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. This may explain the medium coverage of design aspects at the local scale as opposed to the high coverage of urban-wide 2D and 3D design aspects.

Second, PDDP involved three hierarchical levels of design control: development projects, downtown, and regional context. The statement of purpose, goals and objectives considered integrating development projects with the downtown, extending the traditional downtown's boundaries, and emphasizing downtown's regional role as the main priorities (PDDP, 1998, p.3). PDDP focused on economic development and transportation issues in the Downtown area (senior designer interview 2006). Such focus was due to the sophisticated and extensively-used public transportation system that needed significant improvement, particularly due to its conflict with pedestrian movement (senior planner-A- interview 2006). This may explain the plan's emphasis on functional and visual design considerations which has lead to high coverage of urban-wide 2D design aspects, namely land-use and connection and movement network design aspects (Figure 8.4). The plan's usage of design guidelines to establish a 24-hour city and to complement Pittsburgh's natural features and physical form also explains the high coverage of urban-wide 3D design aspects particularly public realm, townscape and urban form. It also explains the extensive coverage (63%) of landscape architecture compared to percentage averaged across computational cases (33%).

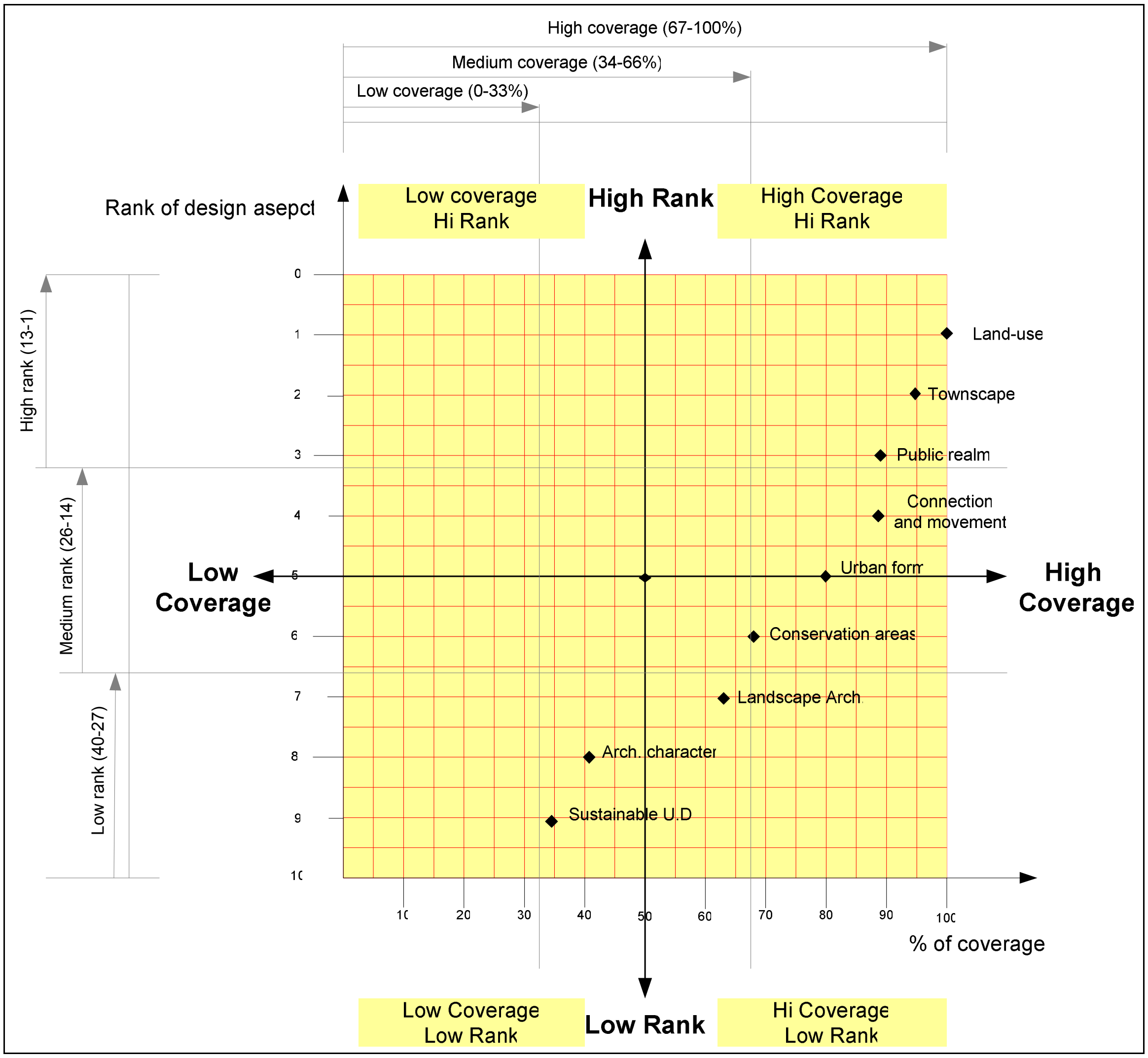


Figure 8.11.A. Distribution of design aspects in PDDP according to their ranks and level of coverage.

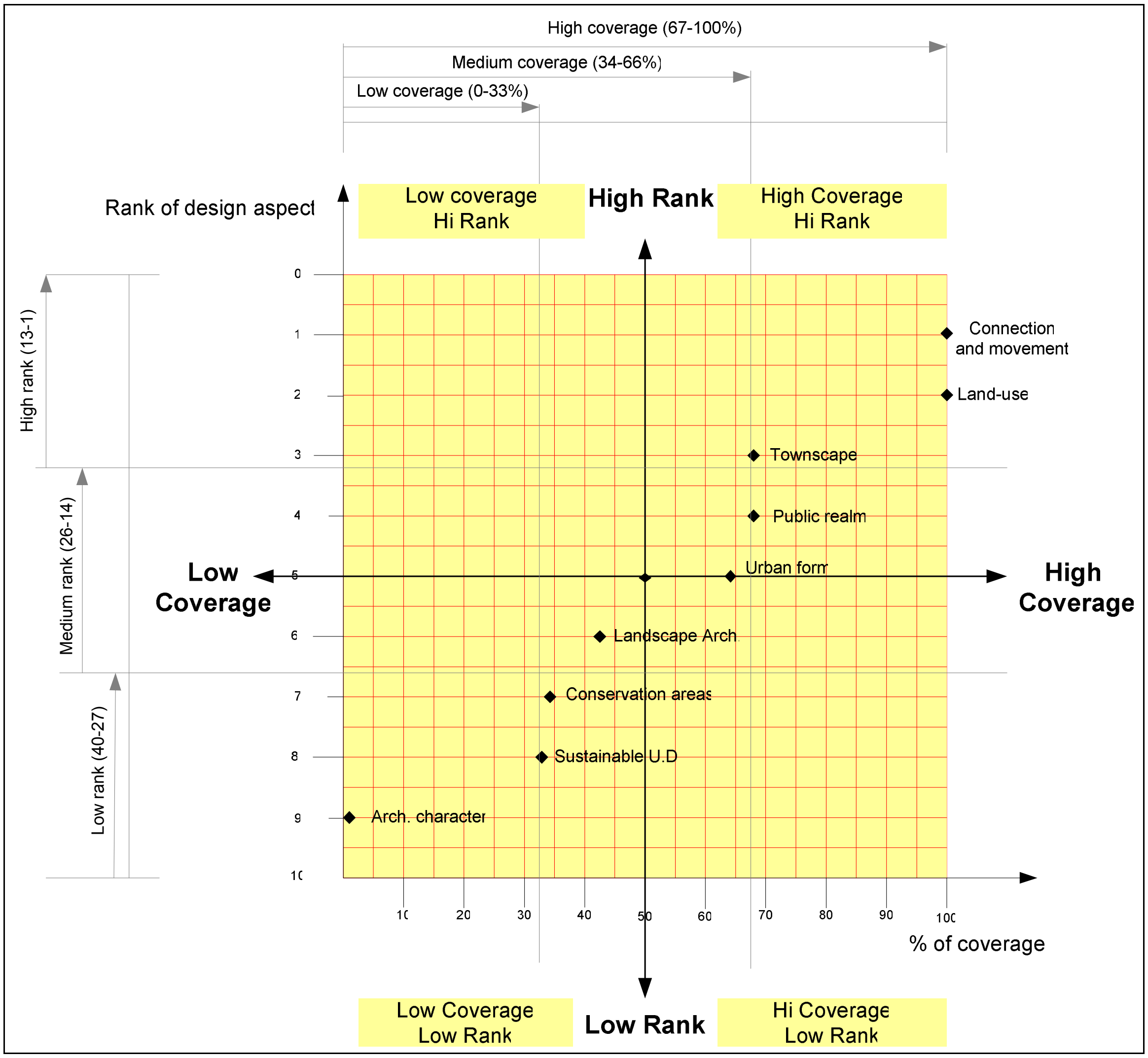


Figure 8.11.B. Distribution of design aspects in CCAP according to their ranks and level of coverage.

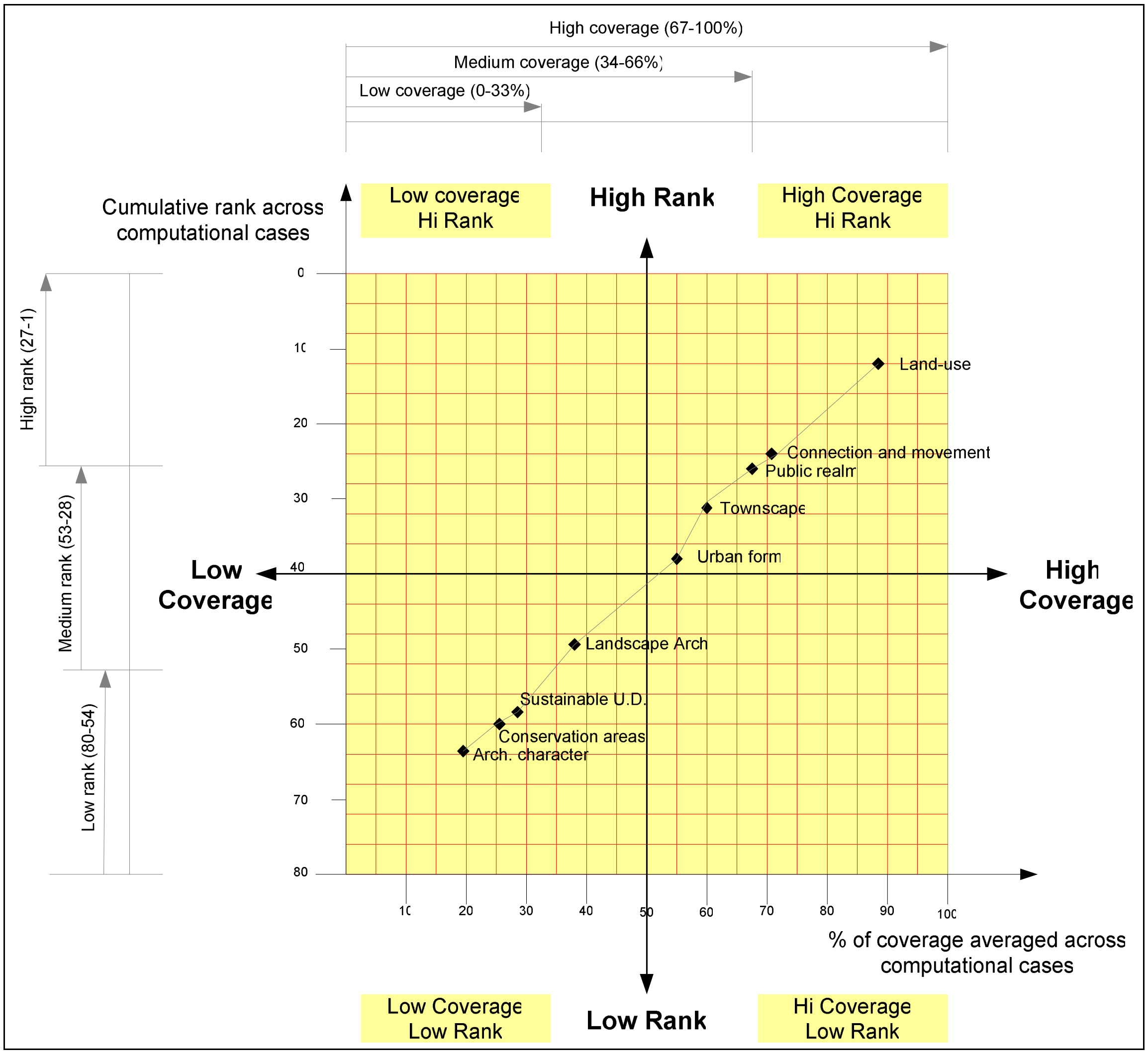


Figure 8.11.C. Distribution of design aspects according to their ranks and level of coverage averaged across computational plans.

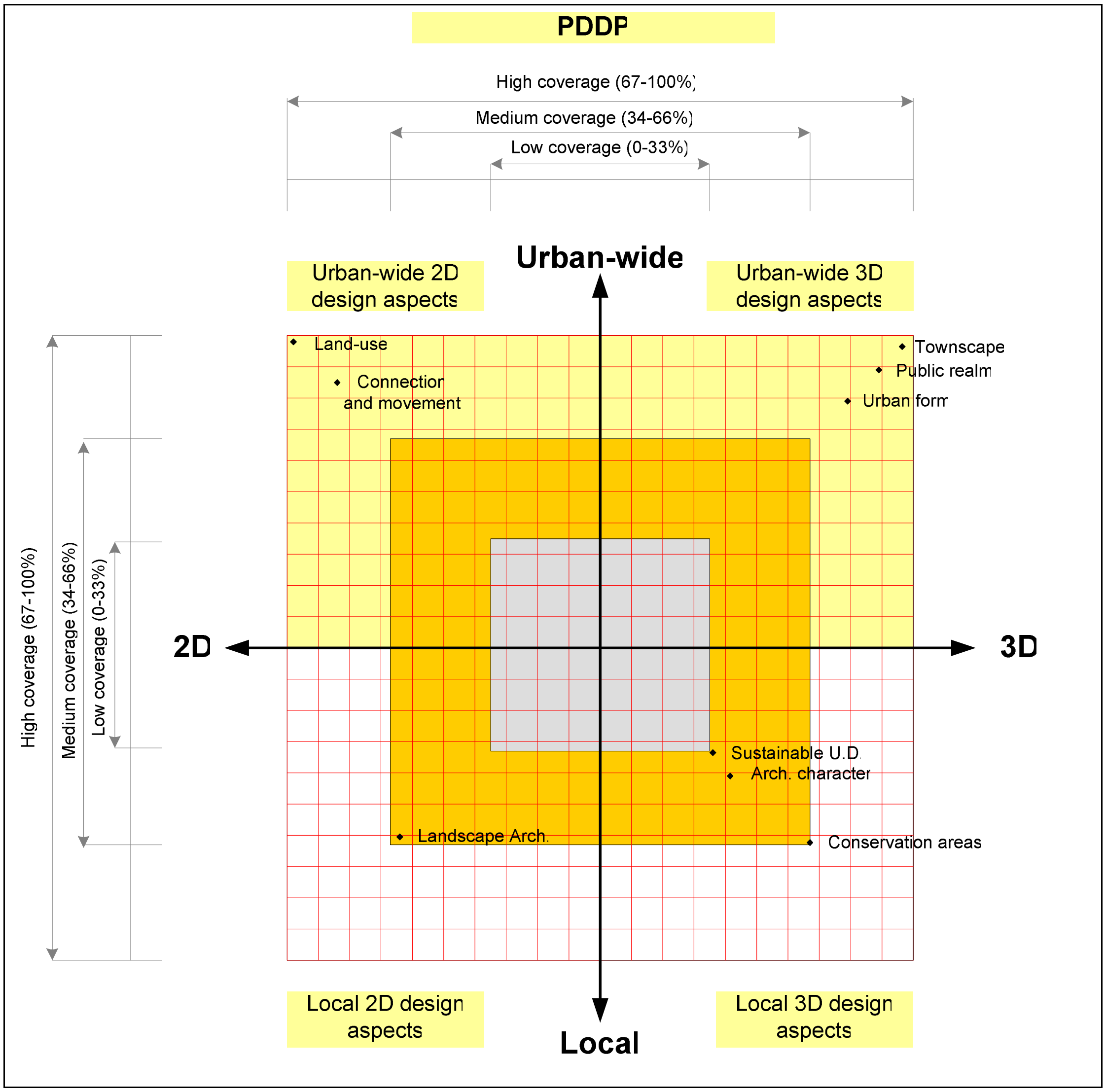


Figure 8.12.A. Levels of design aspects coverage in PDDP according to their scale and scope of concern

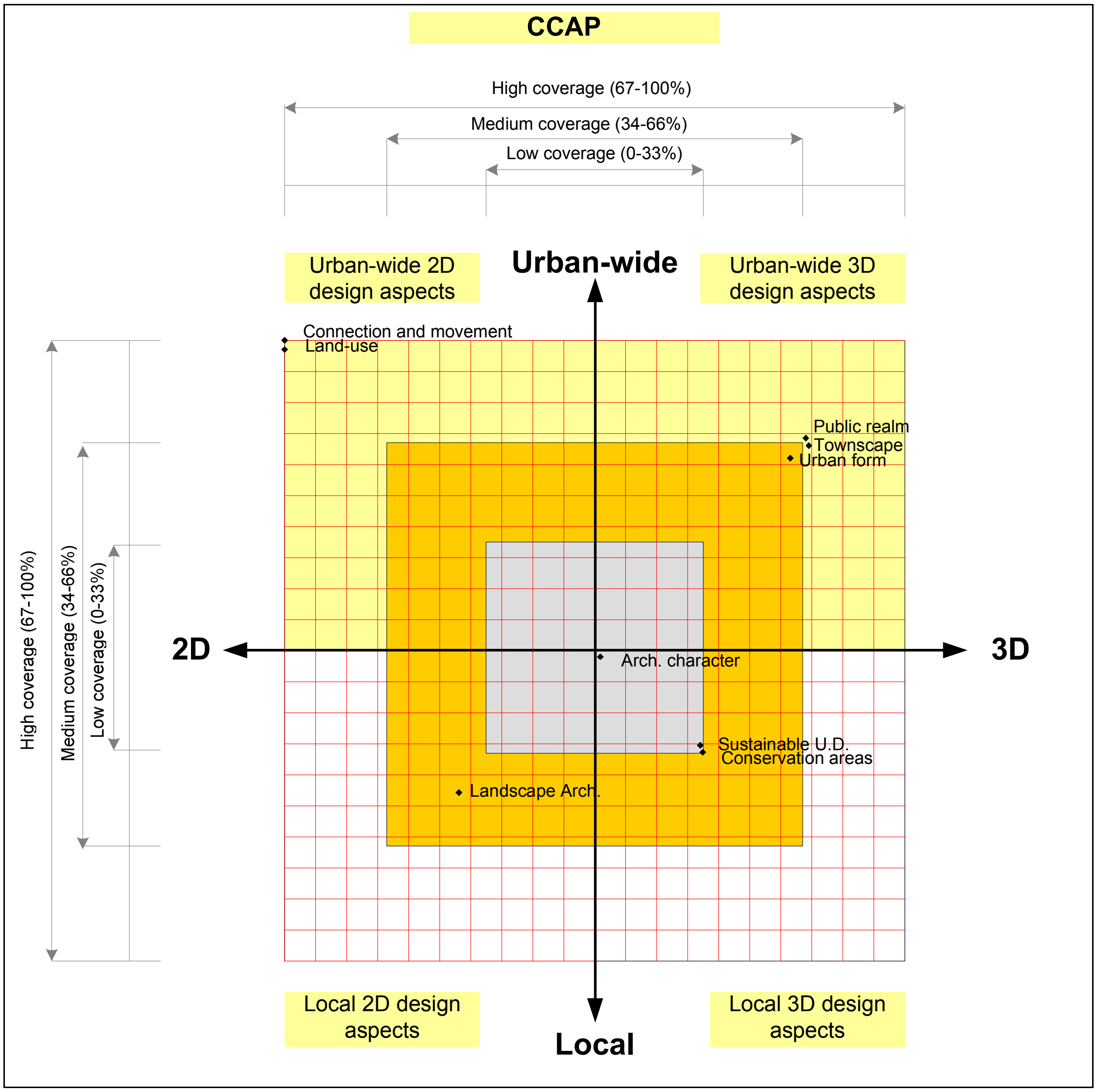


Figure 8.12.B. Levels of design aspects coverage in CCAP according to their scale and scope of concern.

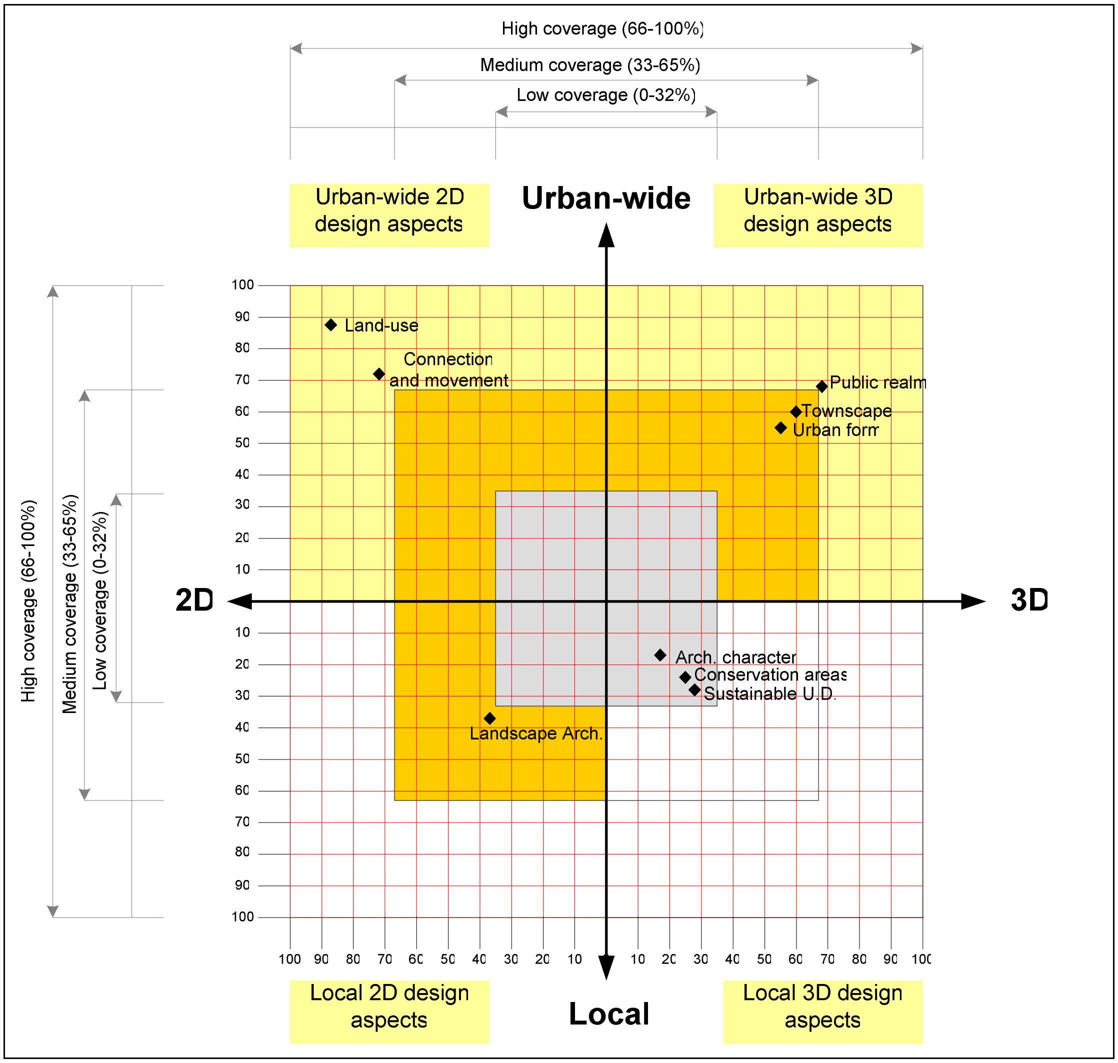
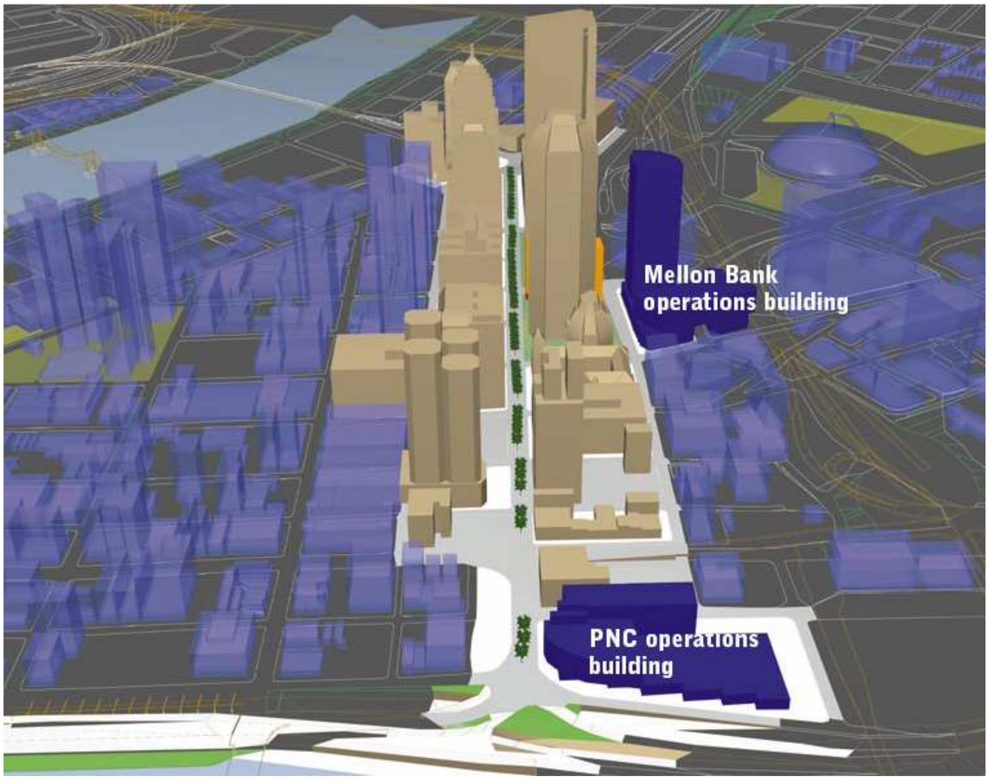


Figure 8.12.C. Levels of design aspects coverage averaged across computational plans according to design aspects scale and scope of concern



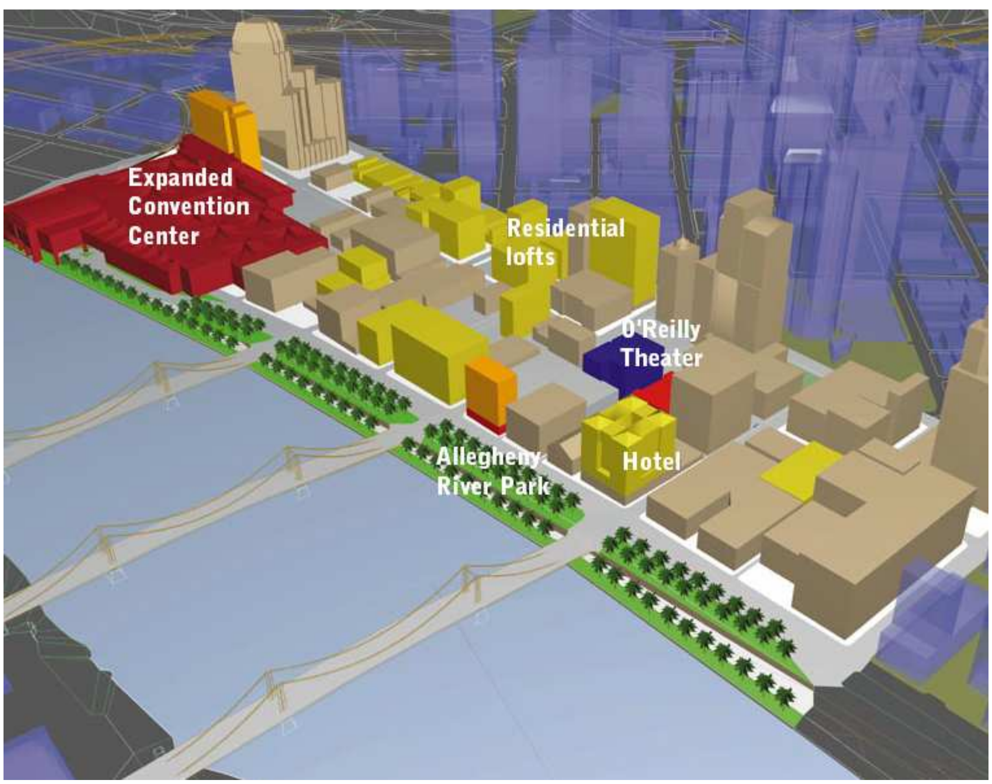


Figure 8.13. Using 3D modeling to represent the visual relationship of the proposed development projects in Grant Street Corridor (top) and Cultural District (bottom) and their urban context.

Third, its methodological approach was underpinned by the awareness of “design as a process” (Stern 1998 a, p.25; PDDP, 1998, p.3). This has lead to analyzing and representing the downtown’s spatial structure and physical form at an abstract wider level rather than local detailed level (see Figure 8.13). The projects’ proposals were illustrated in a diagrammatic and abstract level to create a sound environment for subsequent detailed architectural design decisions. This may explain why the architectural character (41%) was the second lowest design aspect (8/9) in rank of the design aspects and that its minimum coverage was the highest (45%) (see Table 8.5).

Fourth, compared to theory, the higher than average usage of 3D modeling to address 2D and 3D design issues alike was due, in part, to three main factors. The first was the designers’ tendency to use the modeling functionalities, particularly the visualization and analytical functionalities to address and consider the impact of their design decisions on the visual and spatial qualities of the built environment (see Figure 8.7). The 3D model was a GIS model which was compatible with the city’s GIS system (senior planner-A- interview 2006). It was easy to use and navigate both on-line and on compact media (CD’s). It was made available to be purchased by architectural firms and consultancies (senior planner-B- interview 2006). Its usage appeared to have enhanced their cognitive capabilities, and thus facilitated considering a wider number of design aspects, design alternatives, and strategies.

The second factor was designers’ communication within and across design and planning teams in various design phases and tasks, as well as with public at large to foster their wider involvement in the decision-making process. The 3D model was the interface between the planning committees on one hand and the tasks forces, consultancies, the public, and stakeholders on the other hand. The usage of the 3D model was part of the education process of the development of PDDP (senior designer interview 2006).

The third factor was the novelty of using a collaborative and participatory planning process that is extensively supported by technology and modeling. Therefore, it has lead to a wider involvement of public at every stage of the design and decision-making process and helped gain the public support (senior planners A and B interview, 2006).

These factors and the improvements that they have lead to are explained in section 8.2.3.2.

8.2.3.2 Conclusions of PDDP case

The content analysis of PDDP demonstrates both an effective and efficient 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 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. The extent of coverage, cumulative ranks, and trend line of coverage of the urban design aspects in PDDP mimic to a large extent their counterparts in the average computational plans. These findings refute to a great 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 also revealed that PDDP involved an effective usage of 3D modeling functionalities to analyze and represent all 3D- and most of 2D-information elements and issues. 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. The causal relationship between the extensive usage of modeling functionalities and the coverage level of urban design aspects is discussed in section 8.5, and compared to the theoretical model developed in chapter V (see Figure 8.14).

The effective usage of most of the model's functionalities appeared to have improved the quality of the decision-making process 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. The 3D model allowed designers to understand and navigate through the urban form easily (senior designer interview 2006). According to a senior planner, the usage of modeling functionalities gave designers an opportunity to see the different perspectives of the area with different dimensions. Its usage helped show the big picture of the study area, improve the plan's presentation, and illustrate it to the public in a way that was easy to understand (senior planner-A- interview, 2006).

   > …It was something that has an identity. It looked great to people which helped to create a public support to the plan particularly those who came to visit it eventually. (Senior planner-B- interview, 2006)

2. Providing a platform for communicating design ideas among and across design teams. This helped 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. The usage of 3D modeling functionalities helped educate people so that they can easily understand and view the design alternatives within their urban context (senior designer interview, 2006). Such usage also made coordination with consultants and task forces easier because it enabled representing and assessing the impact of the design recommendations to them immediately and quickly (senior planner-A- interview 2006).

3. Utilization of available 2D and 3D information in analysis functions which supported designers in analytical applications. This has improved, yet to a certain extent, the analytical content and results and thus facilitated the generation of well-spaced and diverse urban design strategies and growth scenarios.
4. Facilitating the representation and assessment of the impact of strategic design recommendations and detailed design alternatives on their urban context. The 3D model was basically a GIS model which was compatible with the city's GIS system The 3D was available on line and on compact media for architects and was helpful in conducting several analytical and visualization functionalities

By effective use of techniques to deliver 2D and 3D representations, 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.

Therefore, fulfilling designers' needs in the various design stages requires using a range of tools rather than a specific tool. This requires not only integrating existing tools but also developing new tools and techniques that could fulfill designers' needs and support new design conceptions and strategies to improve the design content and coverage of urban design plans.

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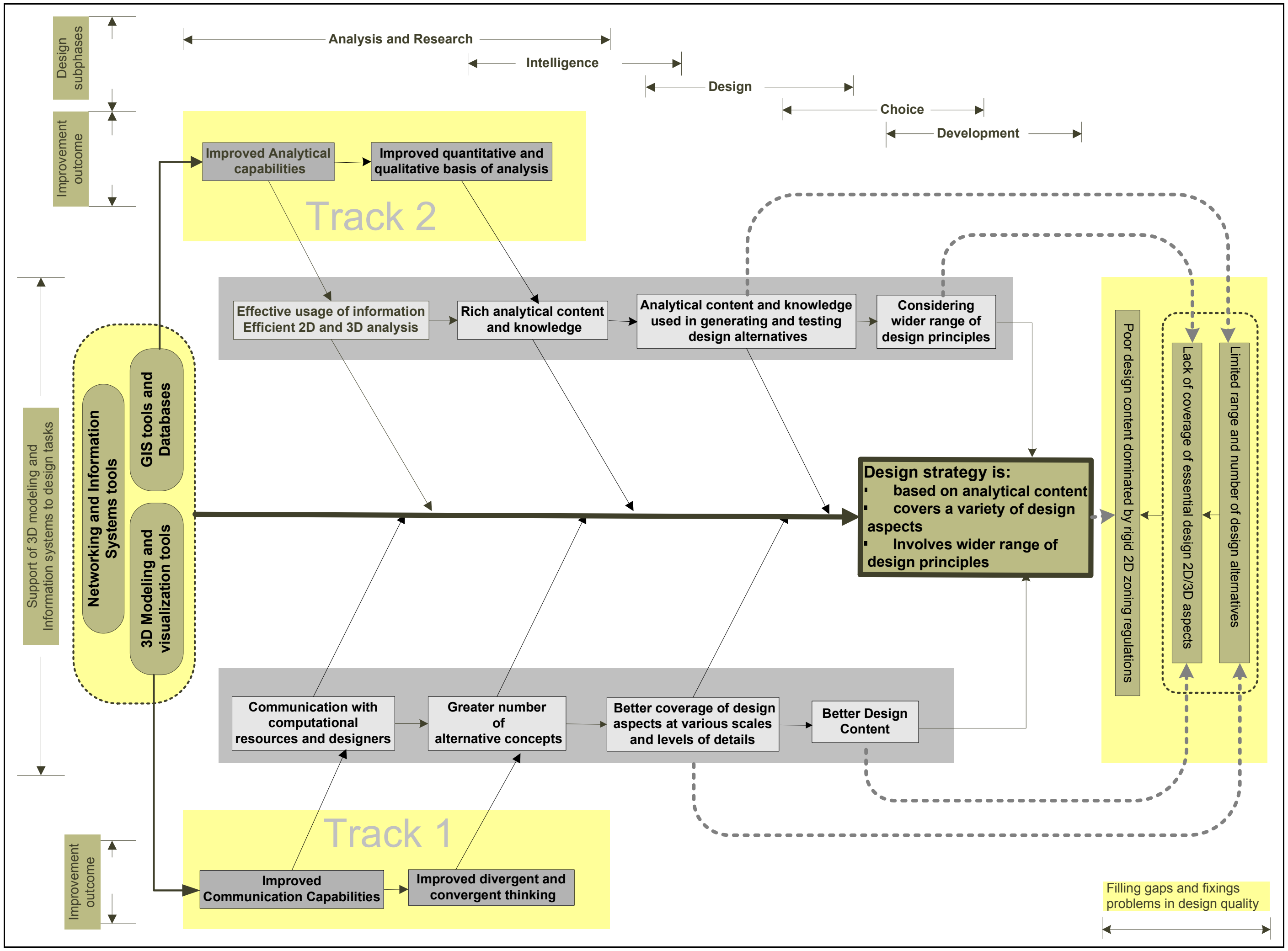

Figure 8.14. Conceptual model outlining the causal relation between the usage of 3D modeling and information systems tools and qualities of the design outcome.

8.3 Chicago Central Area Plan 2003

Chicago Central Area Plan (CCAP) is an example of an urban design plan that has been developed using digital tools and specifically 3D digital models (see Figure 8.15). It has been developed by Skidmore, Owings, & Merrill LLP (SOM) as the lead consultant for the City of Chicago to create a vision and action plan for Chicago's Central Area. The 20-year plan was meant to create a framework for the next generation of economic and residential growth, and establishes an agenda for the development of a transit, open space, infrastructure, and environmental systems (SOM 2005).

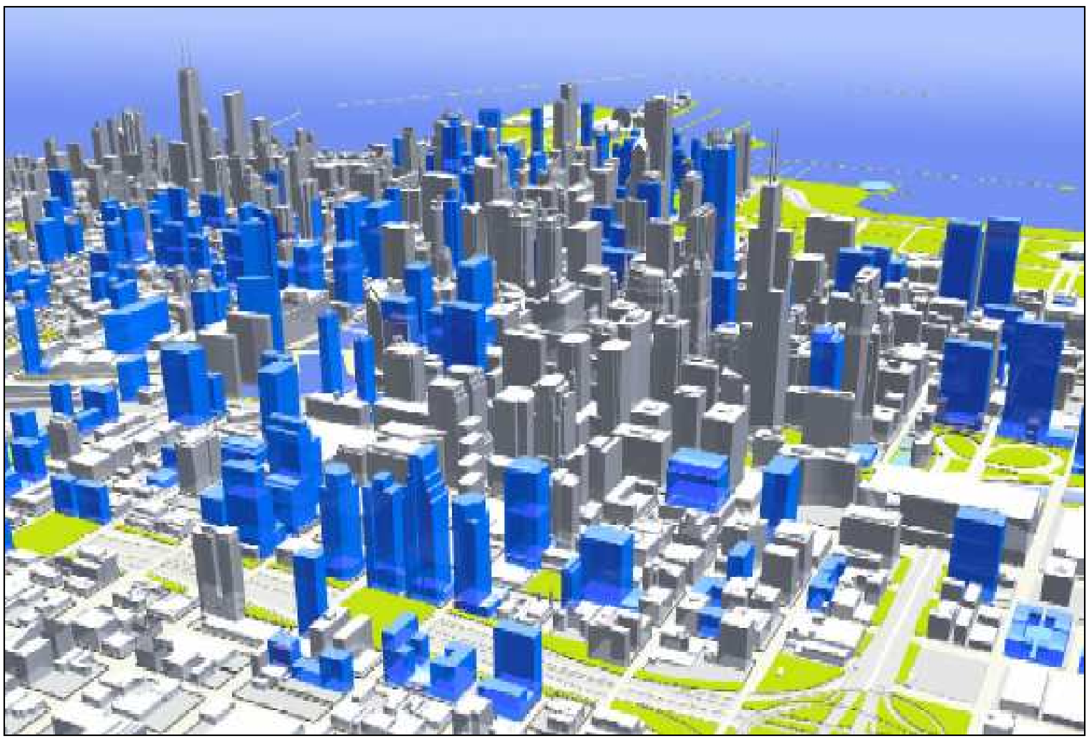

Figure 8.15. A view of the 3D model that simulates the expansion of the central business district west to the Kennedy Expressway and visualizes the expected changes in relation with its urban context (CCAP, 2003, P.5).

8.3.1 Chicago central area plan 2003: the guiding themes

The growth of Chicago's Central Area over the last 15 years brings with it new questions about the location, scale, and design of new buildings; how future land-uses and densities can be organized; balancing growth with quality of place and quality of life; and how to make mass transit the first choice for every one traveling to the Central Area (AIA 2004, p.1). The plan, encompassing almost six square miles with some of the densest urban districts in the nation, is distinguished by its scale. Planning in the U.S rarely is conducted at this scale.

There guiding themes organize this plan:

1. Theme one- **Development Framework**: Direct growth to create a dynamic Central Area made up of vibrant and diverse mixed-use urban districts.
2. Theme two **- Transportation:** Strengthen connections to keep the Central Area easy to reach and get around.
3. Theme three **- Waterfronts and Open Spaces**: Expand and Connect waterfronts and open spaces to create great public spaces (CCAP 2003, p. v).

To build on the qualities of Central Chicago, the plan emphasizes the connections between its three guiding themes. Connections mean that development, transportation, open space, and growth all build upon and support each other. Therefore, the plan emphasized two types of connections: physical connections, and connecting people. Physical connections were meant to allow people to move rapidly between its different districts, and allow workers to live near their jobs or reach them easily by public transit. To connect people, the plan was designed to make the Central Area a meeting place for people from all over the Chicago area and the nation, and maintain its role as center of global economy with an internationally-renowned quality of life (CCAP 2003, p. v).

The CCAP, completed in 2003, is readily available on the Web and has been the subject of several publications (Dulin 2003; Lockwood 2003; Mchugh 2002). In 2004, it was awarded the 2004 *American Institute of Architects (AIA) Honor Award for Regional and Urban Design*. The effectiveness of the plan, according to the AIA jury, can be seen in the transformation of how new development projects are understood in Chicago. The jury stated that:

> …This plan takes a complex problem and explains it with understandable themes and graphics that communicate well. It illustrates an understanding of the city as a growing organism, recognizing the past so it keeps the historic character but adapts and develops in a bigger way (AIA 2003, p.1)

A careful review of the plan as documented in reports and Web sites reveals artifacts of the 3D modeling methods and techniques that can be used to assess the extent of the use of digital technology. Structured in-depth interviews have been conducted with key designers and decision-makers in the firms that participated in the development and modeling of CCAP and in the Department of Planning and Development at the City of Chicago. The qualitative data obtained from those interviews helped unravel certain undocumented modeling methods and techniques which empowered creative design decisions and allowed interpretation of certain design aspects in findings of content analysis.

8.3.2 Documenting the modeling methods and techniques and assessing the design aspects coverage in CCAP

This section explains the methods used for analyzing the selected case study. This section documents how digital modeling and information technology tools have been used to support designers in the selected case. It examines CCAP from the following aspects:

1. Documenting the 3D modeling methods and functions: Applications and mechanism of designers support.
2. Assessment of Chicago City Center Plan's design content: Coverage of 2D and 3D urban design elements and issues.

8.3.2.1 3D modeling methods and functions: Applications and mechanism of designers support

The content analysis of the 3D modeling focused on two issues:

1. Documenting the extent of usage of 3D modeling methods and techniques in CCAP.
2. Assessing the extent of support to designers provided by 3D modeling methods and applications.

For the first issue, I modified and adopted Batty's classification (Batty et al 1998 a) to document the array of modeling methods and techniques under a four main categories: navigation, communication, analytical, and manipulation functionalities (see Table 8.6). These functionalities were discussed in detail in Section 4.22.

The second issue involved investigating how and to what extent computational methods have represented a framework of applications that supports designers and decision-makers. Literature suggests that the urban applications that information systems and digital models should support are: visualization, analysis, simulation, decision-support, and collaboration (Koshak 2002, pp.76-80). These applications were defined in section 4.2.2.

The qualitative data obtained from interviews were coded and tabulated to define the array of applications that information systems and digital models have supported (see Table 8.7). The results were contrasted with applications suggested in the literature review to assess the extent with which they supported designers and, as such, affected the design outcome.

Table 8.6. The extent of usage of modeling functionalities in the development process of CCAP.

Modeling Functionalities and Techniques		**Extent of Usage**					
No.	**Categories of functionalities**	**Not Applicable**	**Not Used**	**Very little**	**Average**	**Very much**	**A lot**
1	***Category 1: Navigation-Visualization- functionalities***						
1.1	**Viewing** the visual configuration of an existing urban pattern				■		
1.2	**Visualizing** the impact of proposed urban design					■	
1.3	**Providing** spatial data through the GIS				■		
1.4	**Extruding** spatial features in 2D GIS maps to create 3D perspectives				■		
1.5	**Generating** 2D Visualizations (e.g. maps & perspectives) at various levels of realism						■
1.6	**Generating** 3D visualizations						■
1.7	**Generating** 3D VRML models at several levels of realism		■				
1.8	**Representing** the study area at different geometrical and geographical scales						■
1.9	**Representing** the study area with different types of media.				■		
	Number of functions in each extent of usage	0	1	0	**4**	**1**	**3**
	Overall assessment of the extent of usage in category 1					■	
2	***Category 2: Communication (decision-support) functionalities***						
2.1	**Communicating** project-specific design data and information within the design team						■
2.2	**Communicating** design concepts-or scenarios- within the design team						■
2.3	**Assessing** the proposed development(s) within the design team					■	
2.4	**Communicating** and assessing the proposed development with city authorities						■
2.5	**Carrying** out the major reviewing process to city authorities						■
2.6	**Selecting** the best design alternative-scenario.					■	
	Number of functions in each extent of usage	0	0	0	**0**	**2**	**4**
	Overall assessment of the extent of usage in category 2						■
3	***Category 3: Analytical functionalities***						
3.1	**Modeling and testing** spatial/structural relationships between physical components				■		
3.2	**Analyzing the study area systems** (circulation, Land-use, site analysis, etc.)					■	
3.3	**Analyzing the visual/3D characteristics** (townscape, skyline, building views, etc.)				■		
3.4	**Graphic reduction**: Isolating visual information to reveal spatial relationships.				■		
3.5	**Layering and delayering:** Synthesizing multiple sets of spatial relationships				■		
3.6	**Structured query** of data to generate new layers of data and information				■		
3.7	**Overlay analysis** of different spatial data layers						■
3.8	**Thematic mapping** of various design aspects					■	
	Number of functions in each extent of usage	0	0	0	**5**	**2**	**1**
	Overall assessment of the extent of usage in category 3				■		
4	***Category 4: Manipulation functionalities***						
4.1	**Representing** the proposed design with different levels of details.			■			
4.2	**Modeling and testing** proposed guidelines for newly developed areas.						■
4.3	**Visual impact assessment:** Assessing the impact of design alternatives or scenarios						■
4.4	**Simulating** pedestrian movement/vehicular traffic	■					
4.5	**Impact analysis:** Testing economic and physical impacts of a proposed design.	■					
4.6	**Scenario analysis:** Comprehensive analysis of a planning scenario	■					
	Number of functions in each extent of usage	3	0	1	**0**	**0**	**2**
	Overall assessment of the extent of usage in category 4			■			
	Total number of functions of each extent of usage	**3**	**1**	**1**	**9**	**5**	**10**

Table 8.7. The extent of effectiveness of modeling applications in CCAP.

Applications	Extent of Effectiveness: Not applicable	Not effective	Less effective	Effective	Very effective
Communication (Decision-support)					■
Visualization and representation				■	
Analysis of the area's physical character			■		
Collaboration					■
Simulation of the proposed changes	■				

Table 8.8. Summary of the extent of design aspects coverage in CCAP.

Number	Urban design elements and issues	Percentage of elements and issues in each extent of coverage: No coverage	Minor	Significant	Number of elements and issues in each extent of coverage: No coverage	Minor	Significant
1	Townscape (Visual composition of space)	17	17	66	3	3	11
2	Urban Form (Three-dimensional built volume)	0	36	64	0	5	9
3	Architectural Character	100	0	0	12	10	0
4	Conservation areas and/or areas of special character	37	29	34	14	11	13
5	Connection and Movement Network	0	0	100	0	0	8
6	Land -use (Mixed-use and diversity)	0	0	100	0	0	3
7	Sustainable urban design	33	34	33	4	4	4
8	Public Realm (The social experience)	17	17	66	1	1	4
9	Landscape Architecture	38	19	43	6	3	7

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

The content analysis at this task also involved two issues:

1. Assessment of the extent and pattern of design aspects coverage and thus the design content of (CCAP).
2. Documentation of the techniques of analyzing and representing urban design elements and issues.

For the first issue, and as described in chapter VI, I modified and adopted RTPI’s agenda as a framework of the essential 2D and 3D design issues and elements of urban design plans. A summary of the results are listed in Table 8.8. In the second issue, RTPI’s agenda was also used to document the extent with which various computational and conventional techniques were used to analyze and represent the constituent urban design policies of CCAP (see Table 8.9).

Table 8.9. The extent of usage of various presentation techniques in CCAP.

[0: No usage; 1: Average usage; 2: Significant usage]			Usage of Various Presentation Techniques													
Number	**Extent of Coverage**	**Design Aspects**	**3D Computer models-existing**	**3D Computer models-Manipulated**	**3 Dimensional maps**	**Physical Models**	**Perspective drawings**	**Photographs**	**2Dimensional maps**	**Thematic maps**	**Schematic maps**	**Surface maps**	**Figure ground**	**Diagrams**	**Tables**	**Charts**
1	Significant	**Townscape (Visual composition of space)**														
1.1		District character and identity	2	2	0	0	2	2	1	2	2	1	1	0	0	0
1.2		Views, vistas, and overlooks	1	1	0	0	2	2	0	0	0	0	0	0	0	0
1.3		Skyline	1	1	0	0	1	2	0	0	0	0	0	0	0	0
1.4		Continuity of spaces, streetscape, and streetscene	0	0	0	0	2	2	2	1	1	0	0	0	0	0
2	Significant	**Urban Form (Three-dimensional built volume)**														
2.1		Density	2	2	0	0	2	2	2	1	0	1	1	0	0	0
2.2		Scale (height and massing)	2	2	0	0	2	2	1	0	0	0	0	0	0	0
2.3		Space system: urban and open space structure	2	2	0	0	2	2	2	1	1	0	0	0	0	0
2.4		Shadow patterns	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5		Urban pattern and layout	2	2	0	0	1	1	2	0	0	1	1	0	0	0
3	None	**Architectural Character**														
3.1		Architectural form: bulk, character, height, massing, scale	1	1	0	0	2	2	0	0	0	0	0	0	0	0
3.2		Elevations: Design vocabulary and design style	0	0	0	0	1	1	0	0	0	0	0	0	0	0
3.3		Elevations' details: detailing, fenestrations, texture, and materials	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Minimum.	**Conservation areas and/or areas of special character**														
4.1		Urban form and townscape	2	2	0	0	2	2	2	0	2	1	1	0	0	0
4.2		Architectural form: bulk, character, height, massing, and scale	2	2	0	0	2	2	0	0	0	0	0	0	0	0
4.3		Elevations: Design vocabulary, design style.	0	0	0	0	2	2	0	0	0	0	0	0	0	0
5	Significant	**Connection and Movement Network**														
5.1		Accessibility to open spaces (for pedestrians and motorists).	1	1	0	0	2	2	2	1	2	0	0	0	0	0
5.2		Street network: accommodation of traffic	1	1	0	0	2	2	2	2	2	0	0	0	0	0
5.3		Pedestrian network: pedestrian routes, links to parking	1	1	0	0	2	2	2	2	2	0	0	0	0	0
5.4		Parking: accommodation of parking, access to parking	0	0	0	0	2	2	1	2	2	0	0	0	0	0
6	Significant	**Land -use (Mixed-use and diversity)**														
6.1		Zoning	2	2	0	0	0	0	0	0	0	0	0	0	0	0
6.2		Diversity and mixed land-use	2	2	0	0	1	2	2	1	1	0	0	0	1	1
7	Significant	**Public Realm (The social experience)**														
7.1		Vitality: Economic vitality and maintenance of downtown vitality	1	1	0	0	1	2	2	0	0	0	1	1	2	2
7.2		Social interaction	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7.3		Security, public perceptions, and sense of community	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Minimum	**Landscape Architecture**														
8.1		Overall landscape design: open space network and topography.	1	1	0	0	0	0	0	2	2	2	0	0	0	0
8.2		Soft landscape design: Water, landscape layout and improvements	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.3		Hard landscape design: Street furniture and lighting	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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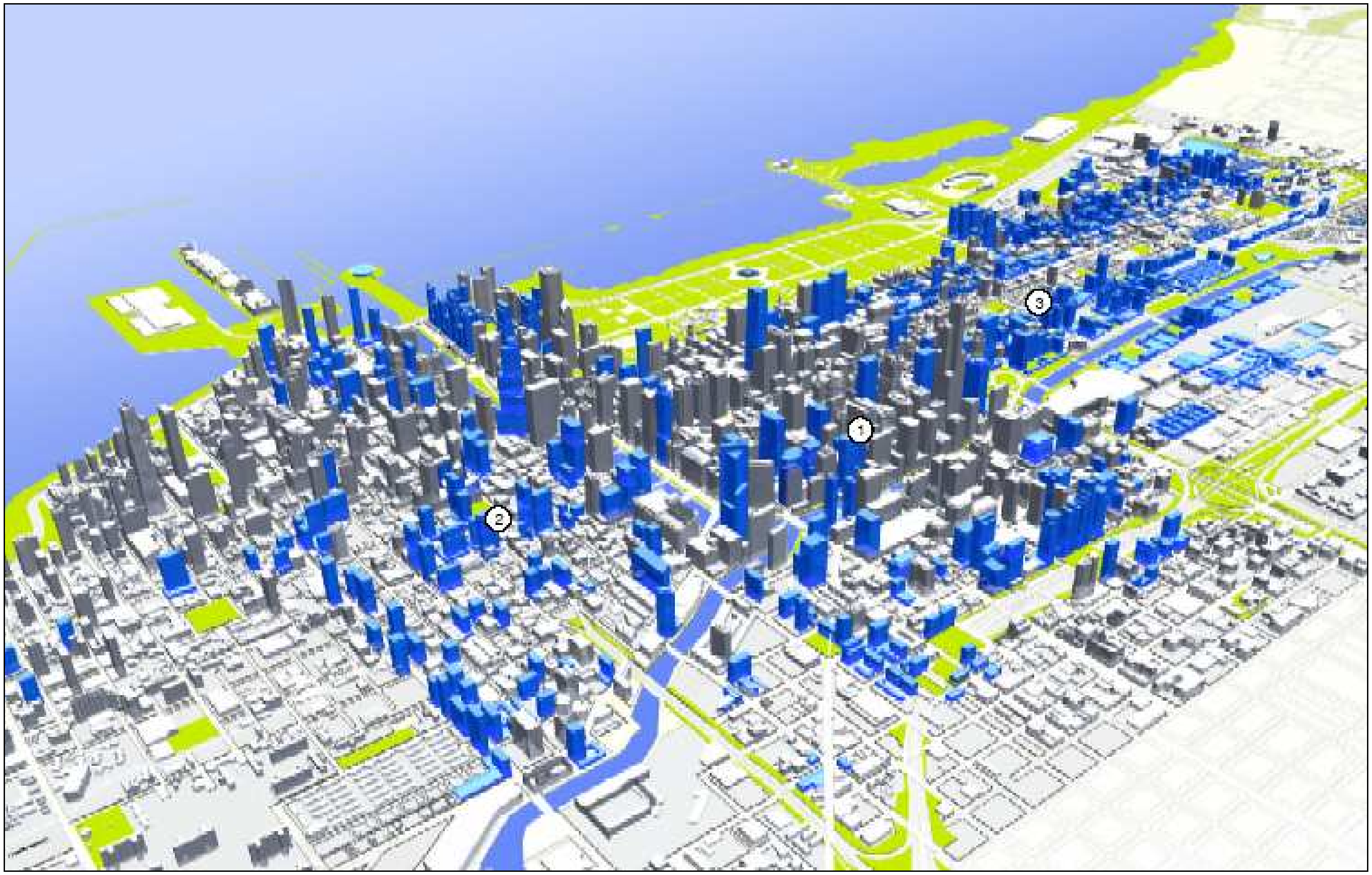

Figure 8.16. Using 3D modeling to create views that help visualize and assess the potential impacts of the guiding themes of the plan. This view represents the new strategy of zoning in the districts (1-3) comprising the entire Central Area. It is meant to help assess the potential shifts in land use and the changes in the overall density of development, character, infrastructure, transit and open spaces (CCAP 2003, p. 110).

Figure 8.17. Using 3D modeling to represent the impact of design recommendations at a district scale. This view represents the design recommendations (1-9) for The Expanded Loop District (District 1) (CCAP 2003, p.1

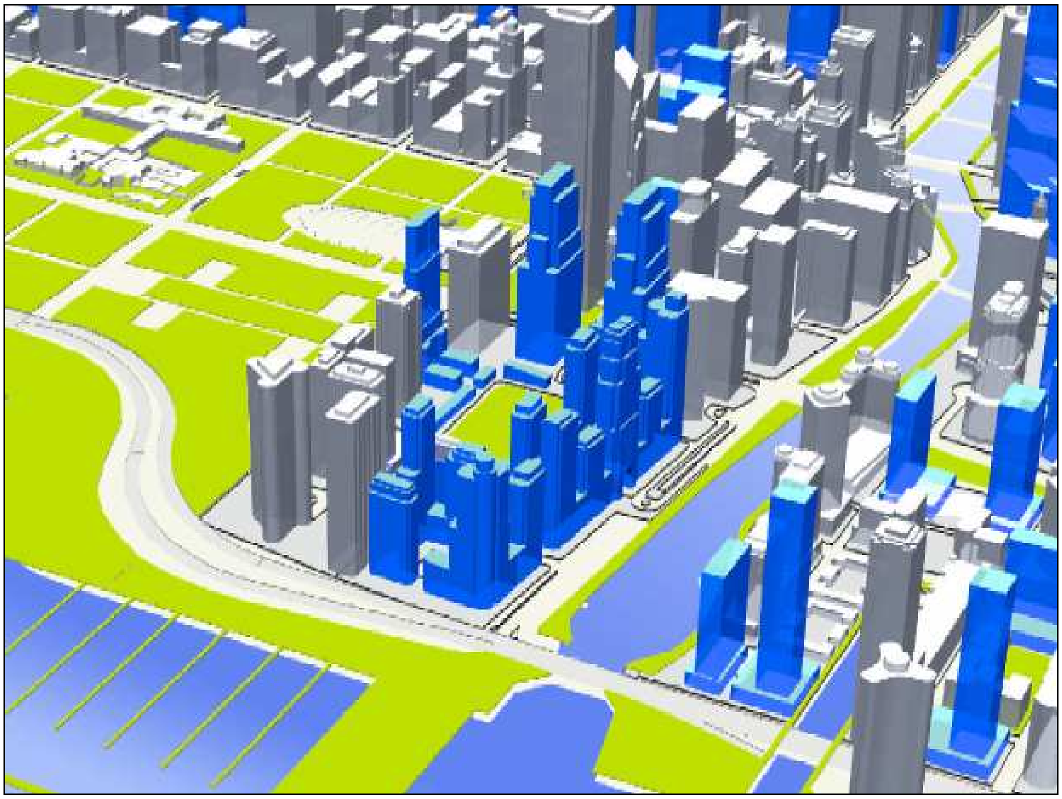

Figure 8.18. Using 3D modeling to help assess the visual impact of design proposals at the neighborhood scale. This view represents the proposed Lakeshore East neighborhood in relation with the existing urban context and other adjacent proposed developments (CCAP 2003, p. 119).

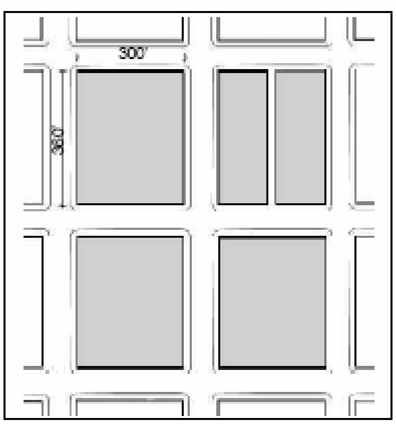	
X2-a: The typical block within the Central Area covers a little less than 3 acres and is bisected by alleys that improve circulation and separate uses.	**X2-b:** Density and diversity within each block contribute to Chicago's street level interest and its economic vitality.

Figure 8.19. Using a combination of 2D and 3D representations to analyze and represent various aspects of the physical environment at the scale of small blocks of buildings and spaces (CCAP, 2003, p.10)

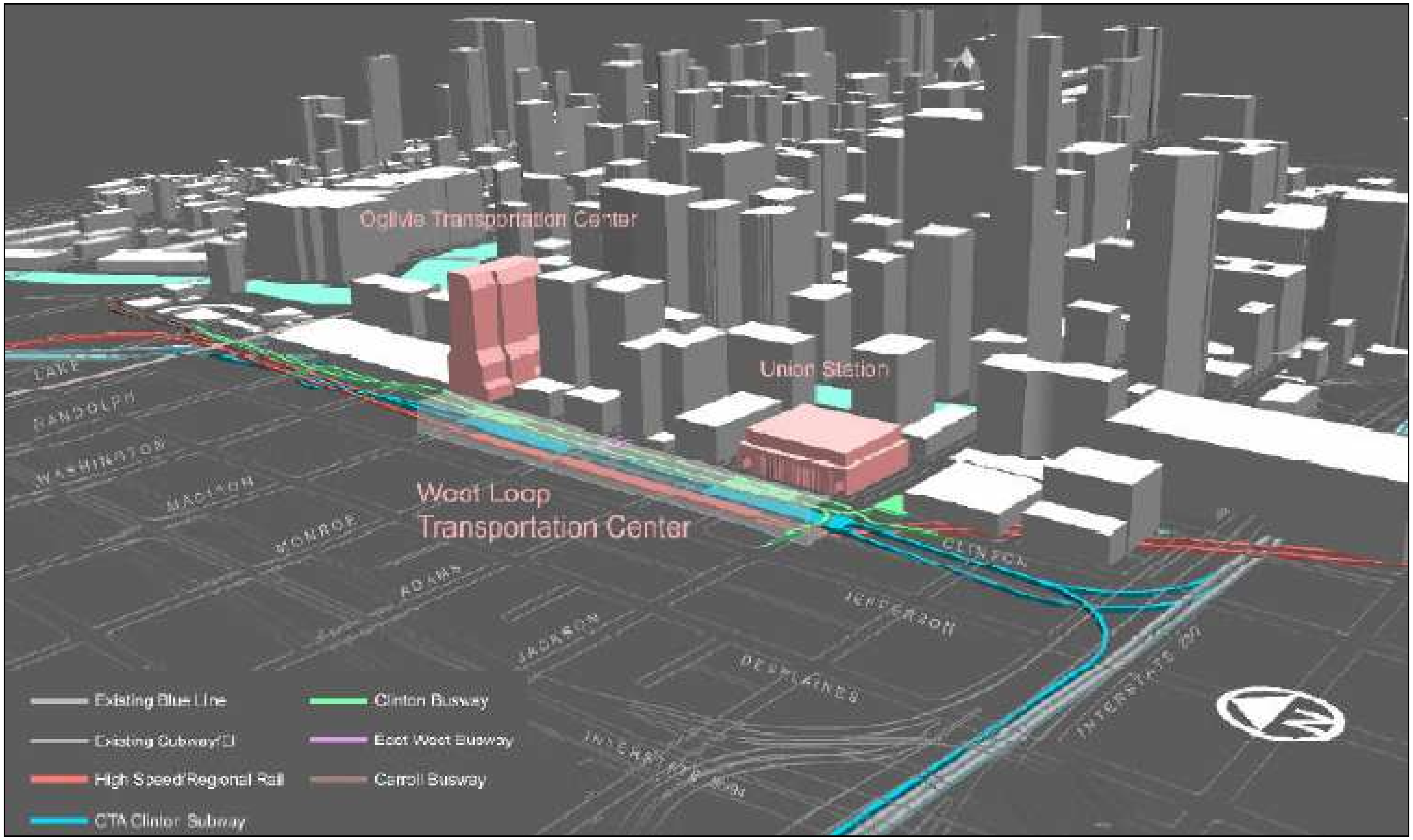

Figure 8.20. The 3D model was used to test the impact of the proposed West Loop Transportation Center along Clinton Street between the Ogilvie Transportation Center and Union Station. The model helped to assess the potential of the proposed Transportation Center to connect all parts of downtown, provide the Expanded Loop with excellent transit access, and provide platforms to serve high speed rail (CCAP 2003, p. 60).

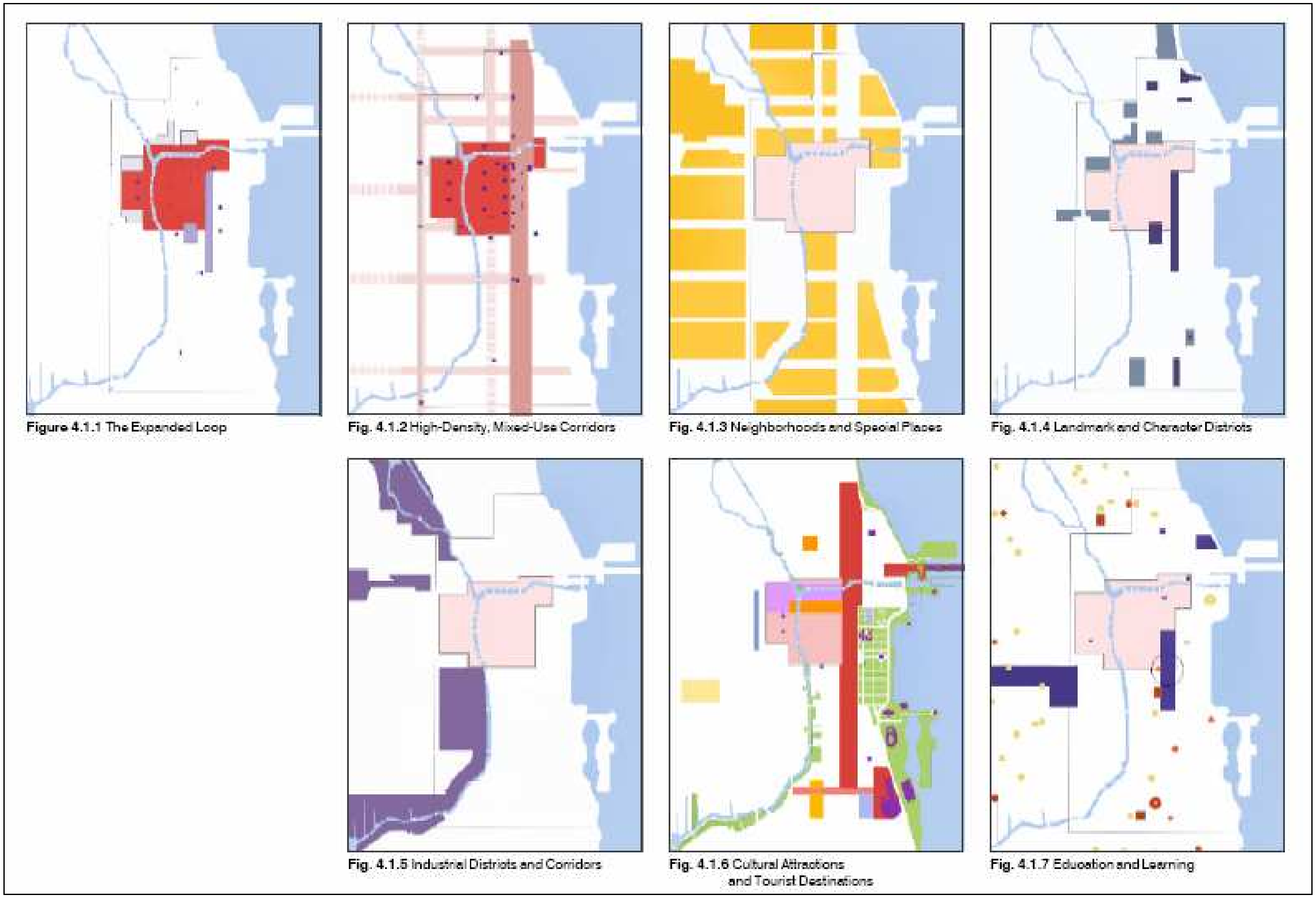

Figure 8.21. The guiding principles of the development framework guiding the growth of the Central Area were analyzed using overlay analytical capabilities of information systems such as the GIS, and were represented with 2D representations (CCAP 2003, p.44).

Figure 8.22. Using photomontage technique to test the visual impacts of the proposed extension of Chicago Central Area at the local level with a variety of scales and levels of detail (CCAP 2003, p.94, p. 99).

8.3.3 Discussion of findings and conclusions

This section discusses the findings of both analytical tasks. The assessment suggests that the designers may have been influenced by the modeling and IT tools to overcome common inadequacies of urban plans with respect to the coverage of the basic design aspects.

8.3.3.1 Findings and discussion of the first analytical task

Content analysis of CCAP found that the most-used modeling and IT functionality was the communication functionality followed in descending order by the navigation (visualization) analytical, and manipulation functionalities (see Table 8.6). Each functionality involved many IT and 3D modeling techniques, some of which have been effectively used in developing CCAP and were found to have made profound impact on the design outcome.

In the communication category, their techniques were extensively used as a communication tool within and across teams and also as an interface with the public at large. According to a senior designer who participated in the development of CCAP:

> …The model was used to make large exhibits in order to show ideas. We used it to communicate design concepts in different formats, such as saving views in PDF files or images and sending and discussing them with others, all of which were unavailable in physical model" (senior designer, Interview 2005).

In the navigation category, the most effectively used technique was generating 3D visualizations to represent the area's proposed development and growth at various scales yet with low level of geometric content (see Figures 8.16, 8.17, and 8.18). They were meant to visualize and assess its potential impact on the area's character and urban form such as shadow impact assessment and massing-spaces studies (see Figure 8.19). Another useful technique was creating eye-level views of streets, bridges and other urban elements to compare the existing setting with the proposed development (see Figure 8.20). One senior designer assessed the usage of visualization and representational techniques as follows:

> …It was a very effective presentation tool particularly when we presented the project to our client. It was not often used for conceptual development and analysis, but rather as a presentation tool and a study tool, and that's why I say it was used as a communication and visualization tool… (senior designer, Interview 2005).

In the analytical category, the powerful GIS analytical capabilities allowed creation of linkages between multiple data sets to create 2D visualizations for the main guiding themes of CCAP. The most effectively used technique was structured query and overlay analysis of different spatial data layers. The layering and delayering technique was applied to almost every level of representation to build a set of analytical switching capabilities. The layering structure was initially arrayed into three themes: development framework, transportation, and open space and waterfronts. At each layer, this technique allowed designers to isolate and view, at a strategic level, their main physical components such as high-density mixed-use corridors, neighborhoods, landmarks, character districts, and parks and plazas (see Figure 8.21) (CCAP 2003, pp. 44-53; 81-107).

In the manipulation category, the model supported the generation of a set of alternatives (senior designer, Interview, 2005). However, due to lack of real-time simulation capabilities, the most effectively used technique was superimposing photo-realistic renderings of the proposed improvements and projects on images of their urban context (see Figure 8.22).

This pattern and extent of usage of IT and modeling techniques was due, in part, to five factors: the model's type, plan's goals and objectives, design team's expertise in IT and modeling methods, IT tools integrated with the 3D model, and cost of model building, updating and usage.

First, the model's type, an iconic CAD model, determined to a large extent the analytical and representational styles and techniques. It allowed designers to generate only static 3D visualizations with low level of detail (see Figure 8.16). Such low level of detail did not significantly affect the model usage for analysis and manipulation because urban designers did not deal with the specific level of decision-making. Yet, it affected the model usage for visualization to communicate and present the design alternatives to the client and the public (senior designer interview 2005)

> It was very difficult to make a pretty picture of the 3D model, maybe due to the lack of details and degree of abstraction. (senior designer interview 2005).

Second, the focus of CCAP, an exemplary strategic urban design plan, was on the growth management of Chicago's downtown within a coherent urban form rather than on architectural details or 3D configurations of the urban environment (CCAP 2003, pp.ii-3). Hence, the design team believed that the model was appropriate to the level of decision-making in CCAP (senior designer interview 2005).

Third, the consultant's team involved designers with a variety of levels of professional expertise and capability in using IT and 3D modeling. Young designers were capable in creating 3D models but they were not enough trained to put together an urban design plan (senior designer interview 2005). Their mix of expertise allowed them to use the array of IT and 3D modeling functions consistently throughout all design phases and tasks yet with various extents of usage and effectiveness. However, since there were only a few people who know how to use the model, the usage of modeling was not very flexible because key designers have to ask for help in making the changes and must agree on a view or certain views (senior designer interview 2005). The consultant's team did not emphasize the analytical functions of IT and 3D modeling because designers believed that the knowledge of the physical environment of Chicago's downtown that they have acquired in developing earlier plans, particularly the 1983 plan, was adequate and may apply to the current plan.

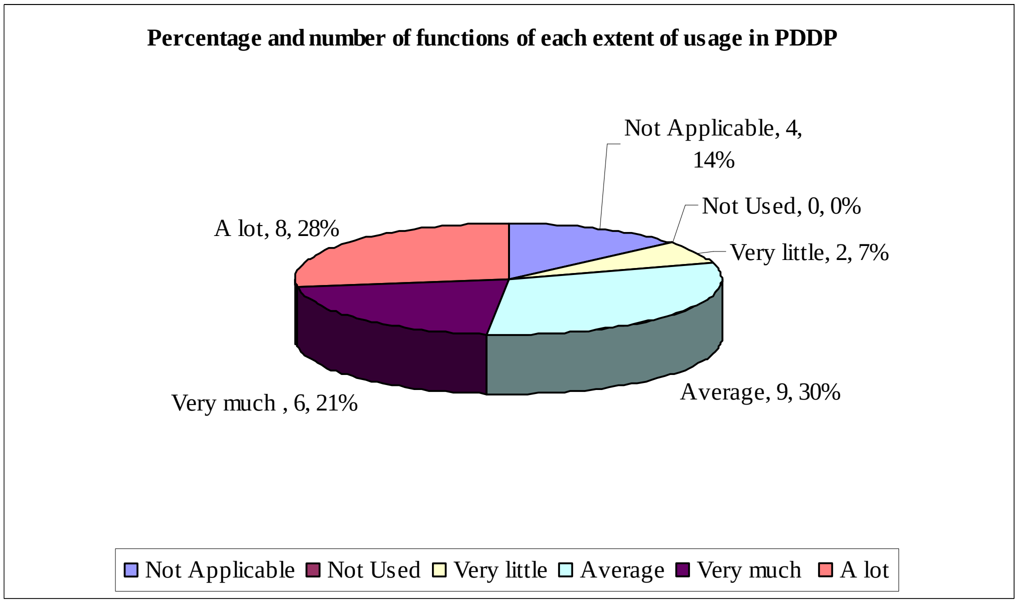

Figure 8.23.A. Percentage and number of functions of each extent of usage in PDDP.

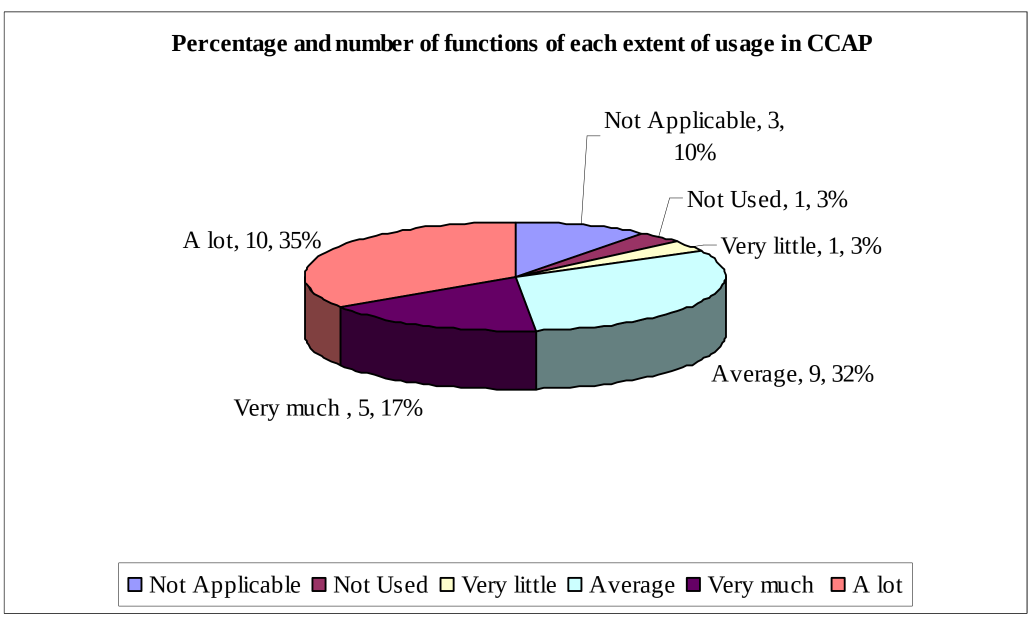

Figure 8.23.B: Percentage and number of functions of each extent of usage in CCAP.

Fourth, although GIS functions and databases were extensively used in the development of CCAP, they were isolated from the digital model due to technical difficulties that hindered their integration. Therefore, analytical tasks in CCAP involved using both tools, GIS and AutoCAD in isolation which, in turn, may have affected the effectiveness and output of the analysis process.

> …One of the major components of the plan was calculating how much zoning allowances change over the life of the plan. However, there were no databases linked to the model, so we were unable to calculate the quantitative basis of design (senior designer, Interview 2005).

Fifth, the cost of generating and rendering the models of the existing environment and of the proposed alternatives was fairly high. It was made in AutoCAD and then exported into 3D VIZ for rendering. Cost of building and using the model has limited the extent of its usage in analytical and manipulation functions.

> It is very time consuming to build a model. There was a major emphasis on building the model, and it took a great deal of time in planning and creating it. Therefore, to do a lot of design alternatives is not always cost effective, so we tend not to do a lot of design alternatives when we work with 3D modeling. Instead, we tend to arrive to design concepts and then build that in 3D model to test them in the 3D model. Yet the utility of the model in subsequent design plans may offset the initial cost... although it may be irrelevant to some small scale projects.
>
> Time and cost constraints in the design process did not allow designers to use it extensively for analysis but for visualization and representation purposes. The iterative style of design tend to be followed in design schools, but in profession it does not work that way because of cost and time constraints. (senior designer interview 2005).

The ratio of modeling functionalities used with above average usage to the total applicable modeling functionalities was 15/26 (58%), and the ratio of those used with average and above-average usage to the total applicable functionalities was 24/26 (92%)(see Figure 8.23.B compared to Figure 8.23.A). These figures indicate that modeling functionalities have been extensively used in the design process. These findings are inconsistent with the premise concerning the ineffective usage and inappropriate methods of using IT and digital urban models in developing urban design plans in US cities. They suggest that applications of IT and modeling functions may have effectively supported designers and thus have affected the quality of the design product. They also indicate that 42% of the applicable functions were either used with average or very little usage, or not used and thus were less effective in the design process and outcome. This suggests that a more effective usage of those functionalities and techniques could have further improved the decision-making and thus the quality of the design outcome. That may require the availability of other tools, particularly real-time simulation and 3D GIS. Those tools are likely to improve the capabilities of designers and public alike to comprehend design concepts. They may allow them to interactively analyze and visualize the potential impact of growth scenarios and to communicate the economic and environmental impact analyses.

In light of these findings, it may be argued that the effective usage of IT and 3D modeling may have improved the quality of the design outcome. Yet, this requires investigating the extent with which those applications have provided designers with support. This investigation will be conducted in the content analysis of issue two.

At issue two, content analysis and interviews with key designers and planners found that applications of the afore-mentioned functions have supported designers with various levels of effectiveness. The extent of support was very effective in two applications: visualization and decision-support. The quality of the 2D and 3D representations has significantly enhanced the modes with which key designers, decision-makers, and stakeholders communicated growth scenarios, design concepts and ideas, and thus allowed them to make informed decisions. The extent of support was effective in two other applications: analysis and collaboration. Effective and very effective support at decision-support and collaboration applications respectively was due, in part, to the role of digital model and IT in fostering the involvement of various levels of designers' expertise in design, creativity, and modeling in the design process. They have been used, yet to a less extent of usage, to generate, communicate, represent, and test the impact of design proposals. Due to the model's type, its functions were not applicable to simulation.

These findings are inconsistent with the premise that urban designers use 2D media to communicate the 3D urban spatial structure. These findings underscore the notion that design analysis is moving towards a new paradigm based on simulation rather than abstractions derived from legal professional rules and norms (Koutamanis 2002, p.245). Therefore, a comprehensive coverage of design aspects requires integrating and managing a hybrid of geometric, geographic, and annotative information and datasets and using advanced dynamic and scientific visualization.

8.3.3.2 Findings and discussion of the second analytical task

This section assessed the extent and pattern of design aspects coverage of CCAP using three criteria derived from the analysis results.

The first criterion is the quantity of design aspects at each coverage level. The plan has addressed 4, 4, and 1 design aspects with high, medium, and low coverage levels respectively. These figures indicate that 44.5 %, 44.5, and 11% of the design aspects were addressed with high, medium, and low coverage levels respectively (see Figure 8.8 and Table 8.5). These percentages, with one exception, are higher than their counterparts of the average computational plans, particularly in connections and movement network. Therefore, CCAP has a high overall coverage level according to the criteria adopted in Table 6.4

The second criterion is the extent with which CCAP has addressed certain design aspects. Content analysis of CCAP showed that the variety of effectiveness and levels of design aspects coverage may be related to their scale and scope of concern. It has showed that the plan involved high coverage of land-use and connection and movement issues (100%), both of which are 2D design elements that are concerned with the city/downtown level. It showed also a high coverage (66%) of townscape and public realm design aspects, and medium coverage (64%) of urban form, all of which are concerned with the characteristics of and structural and visual relations between urban elements at the city/ district level. Content analysis found also a medium coverage of landscape architecture (43%) and conservation areas (34%) aspects that are concerned with the 2D and 3D design issues of individual elements or groups of elements at the local level. Conversely, it did not address the elements and issues comprising architectural character with any significant or minimum coverage (see Figure 8.9). The trend lines of CCAP and the average computational cases are almost congruent along 3D urban –wide and local aspects. Yet, they diverge significantly at the urban-wide 2D design aspects, where the CCAP trend line becomes closer to that of PDDP (see Figure 8.10).

The third criterion is the effectiveness with which CCAP covered the entire list of design aspects. Content analysis found the difference between the highest and lowest percentage of coverage ranges from 100% to 0% respectively. This difference exceeds its counterpart in the average of computational plans where it ranges from 92% to 11% respectively. The wider difference in CCAP indicates that design aspects were addressed with a wide variety of coverage levels that range gradually from high to medium and to low (see Figures 8.9 and 8.24). Therefore, the effectiveness of coverage in CCAP is almost similar to the average attained across computational cases, yet its lack of coverage of the architectural character causes a gap in that effectiveness that is examined and discussed in the following section.

The pattern of coverage was assessed using two criteria. The first criterion was the trend with which CCAP covered the entire set of design aspects. The content analysis showed that 4 aspects (44.5 %) were addressed with high coverage level that ranged from 100%-66% and that 4 aspects (44.5 %) were addressed with medium coverage level that ranged from 64%-33%. There were a few non-covered design elements that range from 17%-33% of five aspects, but constitutes 100% of the sixth aspect, the architectural character.

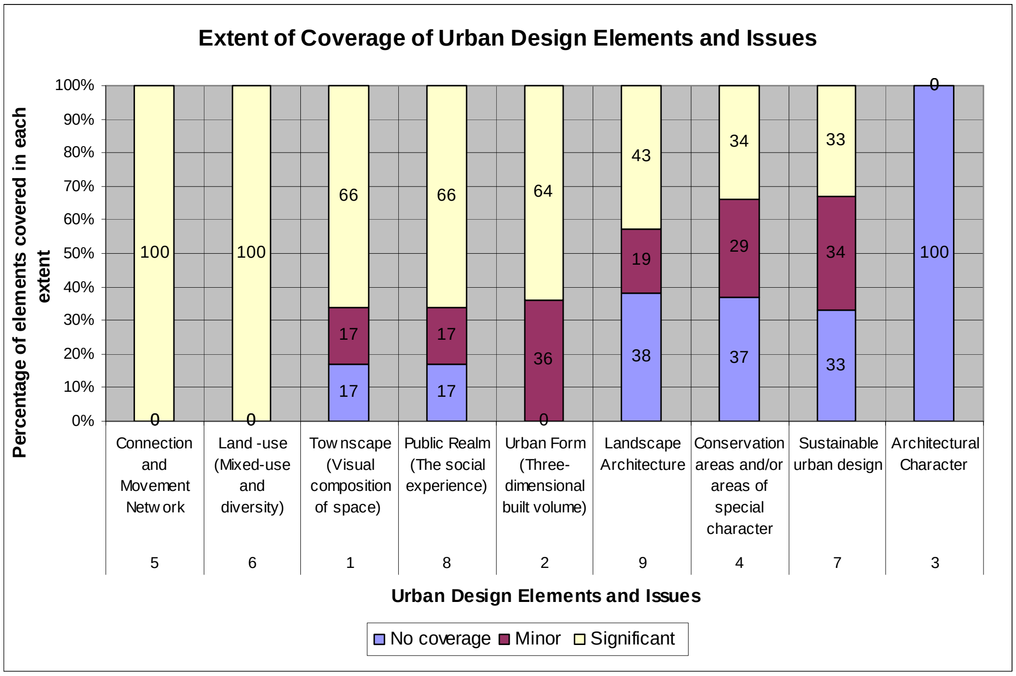

Figure 8.24. Extent of coverage of urban design elements and issues in CCAP

The trend line of CCAP neither mimics that of the average computational nor that of the PPDP. The gap that separates it from their trend lines varies along the list of design aspects which indicate that CCAP's emphasis on certain design aspects differs from that in PDDP and the average computational cases (see Figure 8.10). Therefore, the plan's trend of coverage may be considered variable (changing) coverage. This is inconsistent with the premise derived from the average computational cases that the trend of coverage is related to the plan's overall coverage level, i.e. high or low overall coverage plans address most design aspects with high or low coverage levels respectively.

The second criterion was the pattern of design aspects distribution in two models derived from the coverage of average computational cases. Their quantity and location in the four quadrants of both models indicate their coverage levels in CCAP, and how these levels differ from those in the average computational cases.

The first model illustrates their distribution in the four quadrants of low and high coverage and rank (see Figure 8.11.B). In CCAP, the design aspects are equally distributed between the high-coverage high-rank quadrant and low-coverage low-rank quadrants, and one design aspect on the edge separating high and low quadrants. Their uniform distribution in two quadrants and the irregular shape of the line linking them indicates the plan's tendency to emphasize addressing certain design aspects with the highest and most effective coverage levels according to the plan's statement of purpose, goals and objectives. The line linking them differs in shape and slope from its counterpart of the average computational plans, yet they largely fall within the same quadrants (see Figure 8.11.C). These findings provide further evidence of the high overall coverage of CCAP that was based on addressing certain design elements and issues with an above-average extent of coverage in response to the plan's statement of purpose as shown in the second model.

The second model illustrates their distribution in the four quadrants of urban wide and local 2D and 3D design aspects (see Figure 8.12.B). The location and extent of design aspects coverage with respect to the model's center, the point of axes intersection, indicates the pattern of emphasis on design aspects with certain scale and scope of concern.

The location of urban-wide 2D design aspects at the quadrant's edge indicates their priority in the plan's design strategies, and that they were more effectively covered than their counterparts in the average computational plans. The clustering of urban-wide 3D design aspects across the line that separates high and medium coverage zones of its quadrant indicates that they were less extensively covered compared to the urban-wide 2D design aspects and more effectively covered than their counterparts in average computational plans model. Similarly, the cluster of local 3D design aspects across the line that separates low and medium coverage zones differs from their locations in the low coverage zone of the average computational cases model. It indicates that CCAP has emphasized their coverage and addressed them with a coverage level that is higher than that attained in the average computational plans. The larger shaded areas indicate how the extent of coverage of local 2D/3D aspects differs from that of the average computational cases (see Figures 8.12.B and 8.12.C). The difference in the extent of shaded areas, particularly in the local 3D design aspects quadrant highlights that CCAP covers them more effectively than the average computational cases and supports the finding that computational cases address urban-wide 2D and 3D design aspects effectively and efficiently.

The distribution of design aspects in the four quadrants indicate that the design content of CCAP has emphasized the urban-wide 2D design aspect, followed in descending order by urban-wide 3D, local 2D, and local 3D design aspects. This order of priority of emphasis in the design content is consistent with the emphasis of the plan's goals and objectives on functional and visual design considerations. This may provide evidence that the usage of modeling functionalities has helped designers address the problem's area and fulfill the plan's statement of purpose.

The findings refuted to a great 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. These findings and the significant coverage of public realm are consistent with the earlier premise that current urban design strategies in US cities enhance the design content by linking the more detailed urban form, townscape, and public realm with the general matters. These findings support the research hypothesis that the effective usage of 3D modeling functionalities may increase the coverage of design aspects and thus improve the design content.

8.3.3.3 Empirical justification

The variety of levels with which CCAP has covered the entire array of design aspects is due, in part, to four factors: the model's type and the extent of its function(s) usage, the plan's goals, and objectives, the plan's methodological approach, and the extent of model's usage.

First, due to its iconic type, the model's most effectively used functions were explanation and management whereas other functions were less effectively used. Such type has limited the applicability of IT and modeling methods to only three applications: visualization, analysis, and communication. However, they were coupled with representations of various formats at multiple levels of details that may have allowed design participants to analyze and represent the attributes of and relationships between local and urban-wide design elements with various degrees of effectiveness (see Figures 8.19 and 8.22). This may explain the medium coverage of design aspects at the local scale as opposed to the high coverage of urban-wide 2D and 3D design aspects.

Second, the plan's explicit and foremost goals were managing Chicago's downtown growth within a coherent framework. Due to its strategic nature, CCAP was meant to form a significant part of the link between the overall plan strategy and detailed design policy and to manage the growth of Chicago City Center. These goals may explain the plan's emphasis on functional, visual and urban experience design considerations which has lead to high coverage of urban-wide 2D design aspects, namely land-use and connection and movement network design aspects. Such emphasis was reflected in analyzing and representing the design strategies at an urban scale with high-medium levels of abstraction rather than at a local scale and detailed level (see Figures 8.16, 8.17, and 8.18). It has lead to the high coverage of urban-wide 3D design aspects, public realm, townscape, and urban form. It has also lead to the medium coverage (43%) of landscape architecture compared to low coverage (33%) across computational cases.

Third, its methodological approach involved breaking down the key design strategy into sub areas and components (see Figure 8.16). It has also used the enabling guidance to control the process of growth and change in the urban environment. Therefore, the design policies were represented in a high to medium levels of abstraction to create a sound environment for subsequent detailed architectural design decisions (see Figure 8.17). This may explain the low coverage level of conservation areas, a local design aspect, and lack of coverage of the architectural character at any significant or minimum level (see Table 8.8 and Figure 8.9).

Fourth, CCAP exhibited an extensive usage of IT and modeling functions to address 2D and 3D design issues alike. Such extensive usage was coupled with using a combination of computational and conventional techniques and representation modes. According to three key designers, such combination and extensive usage have reflected their commitment to consider the impact of all planning and design decisions on the visual and spatial qualities of the built environment. They used those tools to facilitate communication within and across design and planning teams in various design phases and tasks, as well as with public at large to foster their wider involvement in the decision-making process (interviews with senior designers, 2005). The integration of both modes appeared to have enhanced designers' cognitive and analytical capabilities, and thus facilitated developing and considering a wider number of design aspects and design. These improvements and their impact on the design quality of CCAP are discussed the section 3.3.4.

Content analysis revealed that the CCAP design process employed multiple types of media, modes of presentation, and techniques to analyze and represent 2D and 3D urban design elements and issues. The most extensively used techniques were 3D visualization, photomontage and photorealistic renderings, and 2D visualizations of various data sets and at multiple levels of details and degrees of realism. In general, the content analysis revealed an effective usage of 3D modeling functions to analyze and represent all 3D- and most of the 2D-information elements and issues. These findings are inconsistent with the premise that modeling and information systems tools have been ineffectively used in developing urban design plans in US cities.

The extent of coverage of CCAP's design aspects was correlated to the effectiveness of combining multiple representation modes, formats, and techniques of representing their constituent elements and issues. The design aspects addressed with significant coverage involved extensive usage of 3D modeling and a combination of computational and conventional tools to represent the design in a variety of 2D and 3D formats and media. Conversely, design aspects with minimum coverage involved average usage of 3D modeling and average usage of a combination of 2D and 3D media to assess and compare the proposed improvements of urban areas against their existing situations. Design aspects with no coverage involved minimal usage of 3D modeling and combination of various representation formats and media.

These findings are consistent with the argument that multiple representations are significant to support collaborative urban design and planning practice (Batara, Dave, and Bishop, 2001, p. 204). They also support the hypothesis that scientific and dynamic visualizations may improve the quality of the design outcome because they allow designers to interactively generate and customize the type, media, and content of presentations in accordance with their professional role and backgrounds, design phases and tasks, and personal preferences.

8.3.3.4 Conclusions of CCAP case

The content analysis of CCAP demonstrates both an effective and intelligent usage of 3D digital modeling in the design 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 basic design aspects, particularly 3D aspects, and ineffective utilization of 3D information in developing urban design plans in US cities. The findings revealed that CCAP involved an effective usage of 3D modeling functions 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 or no coverage of other 2D and 3D design issues at the local scale (see Figure 8.12 B).

The extent of coverage of almost all design aspects was found to be correlated with two factors. First, the extent of usage of 3D modeling functionalities; second, the combination of computational and conventional tools and techniques with multiple types of media and modes of presentation to analyze and represent their respective elements and issues. These findings verify the hypothesis that the effective usage of 3D modeling would result in the effective coverage of design aspects. Although a single case cannot support general conclusions, the findings represent a data point. This case also provides a method that other researchers can replicate as they conduct additional case studies to increase the confidence in the conclusions.

The effective usage of most of the model’s functionalities and their applications in the design process appeared to have improved the quality of the decision-making through providing certain improvements and support to designers’ capabilities in performing core design tasks (see Figure 8.14). The primary support those tools provided was in navigation-visualization application. Yet improvements to designers' cognitive capabilities are likely to support analytical and decision-making applications that would ultimately affect the quality of the design outcome. These improvements are 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. Interviews with four designers and planners indicated that the 3D model was effective in improving their cognitive capabilities for two main reasons:
   a. The site area was so large, so the 3D model was effective in showing the area entirely.
   b. Showing the third dimension of design alternatives. With the model, designers were able to show the impact of proposed alternative design strategies and to visualize the impact of the proposed changes in zoning of Chicago city center.

2- Effective utilization of available 2D and 3D information in analysis functions which supported designers in analytical applications. This has improved the analytical content and results and thus facilitated the generation of well-spaced and diverse urban design strategies and growth scenarios. Designers gained new insights as a result of the usage of 3D modeling in analytical and visualization functions.

> Obviously, understanding the character of the urban environment in three dimension is the greatest insight. The insight is a more comprehensive understanding of the project. You get an overview of the project and see the result of the design decision fairly quickly without building a physical model." (senior designer interview, 2005)

3- Providing a platform for communicating design ideas among and across design teams. The design process was distinguished with clarity in communicating and presenting ideas (senior design interview, 2005). 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.

> I think that the 3D digital modeling has primarily affected presentation and communication of design concepts. It was really the only way to show that to every body… (senior designer interview, 2005).

4- Helped designers to link the lower (micro) and higher (macro) levels of planning, i.e. to address the relation between the decision making at CCAP and Chicago's urban planning.

> …Traditionally, we tend to move in the direction of designing in the single parcels of the city. The model helped in working the lower levels (70%) and the higher levels (30%) of the design task. (senior designer interview, 2005)

These improvements have affected the following elements of quality of the design outcome:

1- **Creativity, originality and innovation:** The usage of 3D modeling and information technology systems appeared to have encouraged experiments with new forms of information management, communication, and visualization to produce more imaginative design solutions that are a better fit to the design problem and a better translation of design and planning goals and objectives.

2- **Logic and workability**: The match between the proposed design solutions and alternatives and the problems that the plan is supposed to solve was another element of quality that resulted from the model usage (senior designer interview, 2005). The workability and the usage of methods that have proven to work over time were due to the clarity of the design process that resulted from using 3D modeling.

3- **Comprehensiveness of work:** Literature suggests that the content of a design in urban architecture is often built in several design levels, where each level meets its specific design problems (Westrik 2002, p. 434). The usage of a combination of interactive 2D and 3D views allowed designers to zoom at, explore, and communicate multi-dimensional spatial and temporal relations between design elements and issues at various scales of the urban environment. Such improvements appeared to have affected the thinking process by adding another level of the study that was otherwise unavailable. It has affected the extent to what the plan has covered the design aspects that may have an impact on the project (senior designer interview 2005).

4- **Professionalism:** The usage of 3D modeling has affected the professional basis, the quality of drawings, the craft of the project, and the quality of the materials that constitute the design outcome.

These impacts on the design outcome may have been further increased if the design process involved using advanced modeling, information, and networking technology. The usage of dynamic and scientific visualization techniques may allow designers to explore the design alternatives with various degrees of abstraction and details and to simulate and assess their impact on their urban context. Designers can make informed decisions and selections of the preferred design strategy (see Figure 4.13).

> …The next phase in 3D modeling is a more interactive model that carries the attributes of the objects like the GIS. The ideal model is a self-repairing model where a small change in data will show up in the 3D model." (Senior designer interview 2005)

Therefore, designers are more likely to comprehensively cover and fit together the various levels of 2D and 3D urban-wide and local design aspects into coherent design strategy with rich design content.

8.4 Comparison between the Design Content and Modeling Usage in PDDP and CCAP

This section compares the extents and patterns of coverage and usage of modeling functionalities of both plans, PDDP and CCAP, and highlights the factors that may have lead to their similarities and differences.

Although the overall coverage of both plans was high, yet the extent of coverage of PDDP is higher than that in CCAP according to three criteria (see Table 8.10.A). The first criterion was the higher number of design aspects addressed with high coverage in PDDP. The second was the larger number of design aspects addressed with significant coverage (6/9) in PDDP. The third was the gap between highest and lowest percentages in PDDP which was narrower than that in CCAP. Although the highest percentage in both cases was the same 100%, the significant difference between their lowest percentages indicates that PDDP has addressed a greater number of design aspects with a higher level of coverage. These criteria indicate that the effectiveness of design aspects coverage in PDDP was higher than that in CCAP. The various numbers and patterns of distribution of design aspects in the quadrants of the second model (see Figures 8.11.A and 8.11.B) illustrate and reflect the difference in their effectiveness of coverage. Linking the data points that represent the design aspects in each plan would yield different shapes and thus reflect a variety of emphasis on covering the entire array of design aspects.

The pattern of coverage in each plan involved certain differences. The trend of coverage in PDDP was predominantly static (constant) because it addressed most design aspects with high coverage level. Conversely, the trend in CCAP was variable (changing) because it involved three levels of emphasis on covering certain design aspects with high and medium levels and not addressing others such as the architectural character with coverage of any significance. The difference in their trend of design aspect coverage was reflected in their various quantities and patterns of distribution in the quadrants of the first model (see Figures 8.12.A and 8.12.B). Their uniform distribution in PDDP reflected the plan's trend of constant coverage as opposed to the clustered distribution in CCAP which reflected its emphasis on certain design aspects. Both cases involved high coverage of urban-wide 2D and 3D design aspects, and medium coverage of local 2D design aspects, yet with a variety of extents. In PDDP, local 3D design aspects were addressed with medium coverage and their uniform distribution reflects gradual degrees of emphases on their constituent elements and issues. Conversely, CCAP addressed them with low coverage in CCAP, and their cluster in a particular location reflects lack of emphasis on certain design aspects. Such lack, which may be necessitated by the plan's statement of goals and objectives, was coupled with lack of coverage of one of its design aspects, architectural character, which caused a gap in the design content.

Both plans involved various extents of using 3D modeling, in general, and of using certain modeling functionalities in particular (see Table 8.10.B). The findings indicated that 3D modeling in CCAP was slightly more effectively used than in PDDP. The development of CCAP and PDDP involved using 58% and 56% of applicable 3D modeling functionalities respectively with above average extent of usage. The extent of using navigation-visualization- and communication functionalities in CCAP was slightly higher than that in PDDP (see Figure 8.23.A and Figure 8.23.B).

The higher extent of using 3D modeling and most of its functionalities in CCAP compared to PDDP is due, in part to four major reasons. The first is the variety in scale of the project and the nature of the design problems, goals and objectives which was reflected in a variety of emphasis on design considerations and aspects. The significantly larger scale of the design area of CCAP, and the plan's emphasis on functional and visual considerations have lead the design team to use visualization functionalities extensively to support design tasks and decisions related to connection and movement network, land-use, and the townscape and public realm of Chicago city centre.

The second reason is the various and broader levels of expertise of CCAP's design team in using 3D modeling functionalities. These levels allowed the design team to use it more effectively and consistently during the design process. According to the CCAP urban design team leader, the rich information that they have already acquired through developing previous urban design plans of Chicago's central area in 1970 and 1985 has lead to allocating only 10% of the model's usage to analytical tasks. He also underscores the role of time and cost constraints in allocating as low as 10% of the model usage for manipulation tasks. Conversely, 50% and 30% of its usage were allocated to communication and visualization tasks such as representing and assessing alternative design strategies (senior urban designers' interviews, 2005).

Table 8.10.A. Comparison between the components of the design content of PPDP and CCAP.

PDDP			Substantive Aspects	CCAP		
			GENERAL APPROACH			
No Emphasis	**Minor**	**Significant**		**Significant**	**Minor**	**No Emphasis**
			Emphasis in the statement of purpose on design considerations			
		■	Visual considerations		■	
		■	Functional considerations	■		
	■		Environmental considerations	■		
		■	Urban Experience considerations	■		
	■		Specific design considerations	■		
		■	**Emphasis on breaking the plan into sub areas**	■		
			EXTENT OF DESIGN ASPECTS COVERAGE			
			Emphasis on design considerations in the design policies			
		■	Visual considerations		■	
		■	Functional considerations	■		
	■		Environmental considerations		■	
		■	Urban Experience considerations	■		
		■	Specific design considerations	■		
	Lowest %	**Highest %**		**Highest %**	**Lowest %**	
	34	100	**Range between highest and lowest percentage coverage**	100	0	
Low	**Medium**	**High**		**High**	**Medium**	**Low**
		■	**Overall plan's coverage**	■		
			PATTERN OF DESIGN ASEPCTS COVERAGE			
			Distribution in quadrants of the first model:			
0	0	2	Number and location of urban-wide 2D design aspects	2	0	0
0	0	3	Number and location of urban-wide 3D design aspects	2	1	0
0	1	0	Number and location of local 2D design aspects	0	1	0
0	2	1	Number and location of local 3D design aspects	0	1	2
Constant			**Pattern of coverage**	**Variable**		
Similar			**Shape of trend line wrt average computational cases' trend line**	**Different**		
			Distribution in quadrants and ranges of the second model:			
0	0	5	Number and location of design aspects in hi-cov. hi-rank quadrant	4	1	0
0	1	1	Number and location of design aspects in hi-cov. lo-rank quadrant	0	0	0
0	0	0	Number and location of design aspects in lo-cov. hi-rank quadrant	0	3	0
0	2	0	Number and location of design aspects in lo-cov. lo-rank quadrant	0	0	1
Uniform			**Pattern of distribution and shape of trend line**	**clustered**		

Table 8.10.B. Comparison between the extents of usage of modeling functionalities in PDDP and CCAP.

PDDP							CCAP					
						USAGE OF 3D MODELING and IT TOOLS						
Not Applicable	**Not used**	**Very little**	**Average**	**Very much**	**A lot**		**A lot**	**Very much**	**Average**	**Very little**	**Not used**	**Not Applicable**
						Extent of the usage of 3D modeling functionalities						
				■		Navigation functionalities		■				
					■	Communication functionalities	■					
			■			Analytical functionalities			■			
		■				Manipulation functionalities				■		
4	0	2	9	6	8	**Number of functionalities used at each extent**	10	5	9	1	1	3
14	0	7	30	21	28	**Percentage of functionalities used at each extent**	17	35	32	3	3	10

The third reason is the more advanced attributes of the digital model used in CCAP compared to the model used in PDDP such as the wider modeled area, lower degree of abstraction, higher degree of reality, and the availability of associated yet not fully integrated GIS databases.

The fourth reason is the type and ownership of the model. In CCAP, the 3D model was a CAD model created in the planning consultancy that led the design team. Accordingly, the model usage was associated with the usage of a variety of 2D and 3D conventional and computational media to analyze, represent and configure a variety of urban design elements and issues. In PPDP, it was a GIS model developed by a computer modeling specialist for the planning department and was made available to other consultancies on-line and on compact media. This may have affected the extent of its usage due to technical difficulties such as the long time required in loading and navigating the model. However, its integration and compatibility with the city's GIS database helped increase the extent of its usage.

However, it must be noted that although the extent of 3D modeling usage in CCAP was higher than its extent in PDDP, the design aspects coverage in PDDP was higher than that in CCAP. Such variety in extents of modeling and coverage supports the earlier conclusion in chapter VI and the theoretical premises that, besides the extent of 3D modeling usage, other substantive and procedural elements may also affect design content of urban design plans. These elements include the plan's statement of purpose, goals, and objectives; the design approach, model type and range of associated tools, and the design team's level of expertise in using 3D modeling functionalities. The elements were found to influence the extent and modes of 3D modeling usage which, in turn appeared to have affected the pattern and extent of design aspects coverage.

It was found that, in each plan, the levels of emphases on the design considerations in their statements of purpose, goals, and objective was similar to the level of emphasis on these design consideration in the plans' content. Such emphasis was reflected in relevant design policies which indicates that both plans were successful in translating their goals and objectives into relevant design policies. This may provide further evidence that the usage of modeling functionalities has helped designers address the problem's area and fulfill the plan's statement of purpose. These findings provide further evidence that supports the research hypothesis that the effective usage of 3D modeling functionalities may increase the coverage of design aspects and thus improve the design content.

8.5 Conclusions

Both cases had high overall coverage levels that slightly vary in extents and effective and efficient coverage of the entire array of design aspects yet with various patterns of emphasis. The extents of coverage in both plans were higher than the percentages attained in the average computational cases. Both plans involved also an effective usage of 3D modeling in general and visualization functionalities in particular to support the design and decision-making processes. The high extents of coverage were found to be correlated with the effective usage of 3D modeling functionalities. These findings support the research hypothesis that the effective usage of 3D modeling would increase the effectiveness of design aspects coverage in urban design plans.

The effective usage of modeling functionalities appeared to have improved designers' cognitive capabilities and consequently their communication and analytical capabilities. The analysis and designers' interviews of both plans suggest that, as discussed in chapter VI, the models of causal relation between the usage of 3D urban models and the design aspects coverage are correct. The mode with which such usage affected the design aspects coverage mimics the theoretical model illustrated in Figure 8.14. The following discussion attempts to use the theoretical model as a basis to track the mechanism with which the usage of 3D modeling functionalities in both plans supported the design tasks and affected the quality of their outcome, particularly their design content (see Figure 8.14).

The theoretical model was based on the notion that the usage of navigation-visualization functionalities becomes the driver for using communication and analytical functionalities, and in consequence supporting designers in multiple tasks. They may improve the intellectual tasks, theoretical thinking, analysis processes, and communication. Likewise, in both plans, navigation-visualization functions were used with an above-average extent of usage. Their improvements to designers' cognitive capabilities led designers to use communication functionalities more effectively that have ultimately affected the quality of the design outcome (see Figure 8.14). This may explain the extensive usage of both communication (decision-support) and navigation- visualization- functionalities in the planning process (see Table 8.1 and Table 8.6).

In communication functionalities (see Figure 8.14- Track 1), the apparent improvement to designers' cognitive capabilities have enhanced the modes with which they communicated with both design participants, planning and design consultancies, and the public at large. They have also improved public and designers' capabilities to comprehend and easily communicate design concepts. Designers were able to overcome communication problems between planning committees, stakeholders, consultants, and public and to foster a wider and more effective public involvement in the design process to reach consensus on the preferred planning and design strategies.

Analytical functionalities (see Figure 8.14- Track 2) allowed designers to use various analytical techniques, particularly zooming, layering and delayering, graphic reduction, and conceptual and thematic modeling to analyze the characteristics of and the structural and visual relations between urban design elements and issues. Such analyses allowed designers to generate and use information, particularly 3D information, in designing and covering the 3D design aspects comprising the spatial structure such as the urban form and townscape with significant coverage.

The usage of visualization functionalities appeared to have improved the quantitative and qualitative basis of the analytical content. This, in turn, helped address the area's specific characteristics and problems and achieve a better fit between the design content and the design problem. In each plan, this was reflected in emphasizing certain design considerations and aspects in the goals and objectives and design content consistently.

However, in a deviation from the sequence of the theoretical model, there was little evidence that modeling usage encouraged experiments with new forms of information management, communication, and visualization or produced any distinctive imaginative design solutions. This may be due, in part, to the model's iconic type, average level of expertise in 3D modeling usage, and lack of dynamic and scientific visualization. The graphical user interface can improve the analytical capabilities and thus the analysis processes. However, analytical functionalities were used with average level for different reasons in both plans. In CCAP, it was due to cost and time limitations, and the availability of analytical content of previous similar plans (senior designer interview 2005). In PDDP, most analysis was manual and was based on GIS and 2D media, the results of which were subsequently represented and communicated using 3D modeling (senior designers' and planners' interviews 2006).

The model in both plans lacked any interactive capabilities and, in CCAP, lacked effective integration with GIS databases. Such provision could have two further improvements to the communication and analytical capabilities. First, it could have enhanced their analytical capabilities with an improved access to and management of information, which may allow designers to retrieve and apply information, knowledge, and analytical content to the design problem at various design stages (senior designer interview 2005). Designers, as such, can avoid performing tedious, repetitive, time- and effort-consuming tasks and focus instead on pure creative tasks. They can reduce the cost and time factors that appeared to have affected the design process, and may allow designers to generate and evaluate a greater number and variety of alternative design concepts and strategies. This underscores the significance of integrating analytical tools and networking technology with visualization tools to help support designers throughout the entire design process.

Therefore, the causal relationship between the model usage and the coverage of 3D design issues in both plans differs from the theoretical model with respect to the potential improvements in analytical capabilities (see Figure 8.14-Track 2) due to 3D modeling usage. This track did not effectively contribute to the combined improvements of the analytical and communication capabilities as suggested in the theoretical model. This may have affected the expected impact on the quality of the design outcome, which may explain the few gaps in the design aspects coverage in both plans. It provides further evidence that, the high and above-average extent of design aspects coverage in both plans could have been further increased if the design process involved an effective usage of the entire array of modeling functionalities, particularly the analytical and manipulation functionalities.

Usage of a combination of interactive 2D and 3D views can allow designers to zoom at, explore, and communicate multi-dimensional spatial and temporal relations between design elements and issues at various scales of the urban environment. Usage of dynamic and scientific visualization techniques can allow designers to explore design alternatives with various degrees of abstraction and details and to simulate and assess their impact on their urban context. These modes of usage can lead designers to make informed decisions and selections of the preferred design strategy and, in consequence, to comprehensively cover and fit together the various levels of 2D and 3D urban-wide and local design aspects into coherent design strategy with rich design content.

CHAPTER IX

SUMMARY AND CONCLUSIONS

This chapter includes three main sections that synthesize the research findings and discuss their implications for widespread application in urban design practice in US cities. The first section includes a summary of the research problem, objective, and methods. The first section discusses the findings and compares them with the research hypothesis, and the theoretical models developed in chapters III through V. In the second section, the implications of the findings for application in urban design practice are discussed. This section addresses the obstacles and concerns that may prevent widespread implementation of 3D modeling in current practice. In the third section, recommendations that outline a framework of best practices of 3D modeling are explained and justified.

9.1 Research Summary

9.1.1 Research problem

Urban design gives form and definition to the full spectrum of cultural, ecological, political, social, and aesthetic forces that shape the built environment and the public realm. Urban designers synthesize these factors into plans, guidelines and regulations that shape the physical character across scales and geographical areas (A1A 2005, p.1). Urban designers, in this process, create an achievable strategic vision that considers design an overarching element that articulates the shape of the urban environment. An urban design plan, as such, is considered a three dimensional depiction of urban design policies (Shirvani 1985, p.144).

The design content of urban design plans is the coverage of the strategic vision, core design issues, and detailed and subject-specific design issues (Carmon, Punter, and Chapman 2002, p.29). The design content includes three interrelated tiers of substantive elements: design considerations, design policies, and design aspects.

In reality, however, there may be a discrepancy between what the urban design should be and what it actually is. In much urban design practice in US cities, a researcher has found that little consideration is given to three-dimensional aspects of design and few plans portray an explicit spatial design strategy (Punter 1999, p.12). More importantly, the plans that are developed lack adequate coverage of essential design aspects (Gosling and Gosling. 2003, p.8).

This problem may be a result of using 2D media to communicate spatial information and to design spatial structure. Designers may not utilize the growing volume of 3D spatial information to generate urban design strategies and visions. A need may exist for tools that support flow and management of spatial information and facilitate exchange and communication of design concepts and strategies among and across designers and professionals during the design process.

9.1.2 Research hypothesis, objectives and methods

Literature suggests that the increasing range and variety of information and communication technologies may represent a potential solution to this problem. This research focuses on 3D digital urban models as one promising type of digital tools. These models offer functions that are particularly powerful in visualizing the urban environment and in supporting information management during the design process.

This research was guided by a central hypothesis: if the urban design process employs digital 3D urban models and databases to support design tasks in developing urban design plans, then the plans will effectively address the basic design issues and aspects of the urban environment and will incorporate 3D design aspects efficiently. The research objective is to understand how the usage of 3D digital models affected the coverage of design aspects and the design content in urban design plans. This research has applied a novel perspective of examining both the methods of modeling used to support urban design and the quality (design content) of urban design plans to attempt to reveal a correlation or causal relation.

The research has used the mixed method that combined qualitative (case studies) and quantitative (questionnaire) methods sequentially to address issues of internal and external validity. The research included three phases: content analysis, structured interviews, and questionnaire.

In the first phase secondary sources have been reviewed. Theoretical proposition addressing the impact of 3D digital model usage were constructed. These propositions formed the basis with which analytical results were compared and constructed. In the second phase, 14 urban design plans (8 computational and 6 conventional) selected from six US cities were examined using content analysis to assess their design content and coverage of design aspects. The design of the content analysis method followed the methods described by Krippendorff (2004). The structure and development of the coding scheme has followed the prior research driven approach. The coding scheme of research on content in urban design plans that has been conducted and published by Punter and Carmona (1994 and 1997 a and b) was modified and adopted.

Among these plans, three plans were selected to pursue comparative detailed case studies by interviewing key contributing designers and planners. In the third phase, a questionnaire survey was conducted with designers and planners who participated in developing the computational cases was conducted to evaluate the utility and effectiveness of the 3D models.

The findings showed how the pattern and extent of design aspects coverage in computational plans differ from these in conventional plans. The findings highlighted the extents with which design aspects were covered in computational and conventional plans. These findings are summarized in the following section.

Based on the quantitative data from content analysis and the questionnaire survey, and the qualitative data collected from the interviews, this research drives conclusions about the impact of 3D models usage on the design content and design aspects coverage in urban design plans.

9.1.3 Research findings

Plans have exhibited a variety of overall coverage levels and degrees of emphasis in addressing the design aspects. Using both criteria to sort the plans, it was found that computational plans are superior and are associated with high and medium overall coverage level, with one exception. Conversely, conventional plans were superior to computational cases in only two cases, and were associated with medium and low overall coverage levels.

Plans of both types have exhibited the same trend of emphasis on 2D urban-wide design aspects rather than local 2D and 3D design aspects. However, the findings showed that the extent of coverage of design aspects in computational plans differs significantly from that extent in conventional plan. Computational plans address a large number of design aspects and wider range of scales with a greater extent of coverage. The greatest difference appears in 3D urban-wide design aspects, namely public realm, townscape, and urban form and to a less extent in 2D urban wide design aspects. Therefore, the pattern and extent of design aspects coverage in computational plans was more efficient and effective and thus is likely to yield better design content than in conventional plans.

These findings demonstrated that the overall coverage level of plans is correlated with the media or design methods used. These findings are consistent with the research hypotheses that 3D modeling usage enhances the extent of design aspects coverage and increases the design content.

The findings also revealed two patterns with respect to design aspects coverage across all plans. In the first pattern, some design aspects were addressed across all plans with either high coverage such as land-use and connection movement, or with low coverage such as architectural character, landscape architecture, and sustainable urban design. In the second pattern, design aspects were addressed across most plans with a variety of extent of coverage such as public realm, townscape, urban form, and conservation areas.

The findings also revealed three coverage levels with which design aspects were addressed: high, medium, and low. The coverage levels were correlated with the conceptualization, scale, and scope of concern. The design aspects concerned with 2D urban-wide quantitative controls and design guidelines were addressed with high coverage levels. The design aspects concerned with 3D urban-wide qualitative controls and design guidelines that configure the spatial structure physically and visually were addressed with medium coverage levels. The design aspects concerned with the 2D and 3D design attributes at the local level were addressed with low coverage level.

Each design aspect was examined to track any potential relation between its coverage level and the plan type and media. The level of coverage of each design aspect was found to be correlated with the plan's type. The average coverage level of any design aspect in computational plans was higher than that in conventional plans. This correlation is most obvious in three 3D urban wide aspects: townscape, urban form, and public realm. It is slightly less obvious in two 2D urban wide aspects: connections and movement networks and sustainable design. This correlation is less evident in two aspects, architectural character and conservation areas, both of which are concerned with the 3D attributes of the urban environment at the local scale.

The findings demonstrated that the overall usage of modeling functionalities was between *average* and *very much*. Yet, designers used these functionalities with a variety of extents. The communication and visualization functionalities were the most extensively used functionalities. Analytical and manipulation functionalities were less extensively used due to human and technical problems. The modeling functionalities were used inconsistently during the design process. The effectiveness of their usage during conceptual design phases such as generating design alternatives was greater than their usage during the initial design phases such as data analysis and formulation of design goals and objectives.

The findings demonstrated that 3D modeling functionalities have various extents of impact on designers' performance in core design tasks. The most significant impact appeared to be the improvement in communication of design concepts to a wider group of professionals. The least impact was reported to be the increase in time allocated for analysis and alternatives generation.

Similarly, 3D modeling functionalities have affected designers in designing the entire set of design aspects with various extents: high, medium, and low impact. Designers reported that the highest impact of 3D modeling functionalities was on designing the urban form and townscape, that are 3D urban wide design aspects, and on designing the architectural character and conservation areas that are 3D local design aspects. Designers also reported that 3D modeling functionalities have a medium impact on designing land-use and connections and movement networks that are 2D urban wide and on designing the landscape architecture which is a 2D local design aspect. Designers reported that the 3D modeling functionalities have a low impact on designing the public realm and sustainable urban design.

The findings showed that the majority of designers and planners use model areas that are smaller than a downtown scale and with medium degree of reality. The findings showed also a low extent of modeling usage by architects and landscape designers. The findings also showed that the public has a low level of accessibility to most models used.

9.1.4 Discussion of research findings

These findings discredited some theoretical premises and bolstered others. These findings were inconsistent with the assertion that urban design plans in US cities lack the coverage of 3D design aspects of the urban environment. The results are inconsistent with the assertion that American planning is dominated by the townscape philosophy, and that the adopted plans failed to positively shape the public realm (Punter 1999, pp.155-156). Yet, they bolstered the premises that those plans emphasize 2D land use and rigid zoning codes and regulations in controlling the urban form of US cities.

Computational plans were superior in addressing a wider range of design aspects with higher extent of coverage. These findings support the research hypothesis that usage of 3D modeling in design process will increase the design aspects coverage and enhance the design content. Such impact of 3D modeling usage has appeared in various extents across the design aspects. The greatest impact appeared obviously in 3D urban wide design aspects and to a less extent in 2D urban wide design aspects. Such an impact may lead to plans with comprehensive design content.

Therefore, the usage of digital modeling and information systems has provided a media that appeared to have enhanced the efficiency with which the spatial structure and 3D attributes of the physical environment were navigated, communicated, and designed. Such usage can facilitate performing design tasks at a wide urban scale that was otherwise difficult to attain with conventional 2D media. These findings were consistent with the theoretical model that illustrated the impact of the improvements of designers' cognitive capabilities on the quality of the design outcome.

The research provided counter evidence to these findings in a very few cases. First, computational plans were not exclusively superior to conventional plans. Second, they addressed architectural character with a coverage level lower than in conventional plans. Low coverage levels of 2D and 3D local design aspects such as architectural character can affect the coherence and unity of the townscape and urban form of the study area. Low coverage of landscape architecture may cause gaps in the design framework of open space network and public realm that represent key design elements of the spatial structure.

The findings of the questionnaire survey and structured interviews may provide explanations to the very few cases that were considered as counter evidence of the superiority of computational plans. Such counter evidence may have resulted from human and technical factors. These factors are: low extent of modeling usage by architects and landscape architects, the model's low level of reality, the low level of accessibility of public to the model, the plan's goals and objectives, and the adoption of the strategic urban design approach. Some inadequacies were found in the methods and extent of modeling usage. Underutilization of some modeling capabilities was found either in the variety of modeling functionalities used or in the extent with which they were used. Other inadequacies were due to lack of some essential modeling functionalities, and particularly manipulation and analytical functionalities. Technical improvements such as, integration of models with GIS databases and usage of advanced visualization techniques (VR) may help address these inadequacies and thus increase the effectiveness of designers' support.

Therefore, it can be inferred that certain procedural and substantive factors might affect the desired impact of 3D modeling usage on design aspects coverage and on the design content. These factors were investigated in chapter VIII in a comparative study between two computational plans of high overall coverage levels.

The findings of the comparative study were largely consistent with those derived from multiple case studies. The findings also helped refute certain premises and bolstered others. They helped to highlight how the mechanism of usage and impact of 3D modeling on the design content in practice differs from those in the theoretical models developed in chapter V.

The overall level of coverage was found to be correlated with the extent of usage of 3D modeling functionalities and with the effectiveness of combination of a variety of representational media, format, and types. These correlations support the research hypothesis that 3D modeling usage can increase the design aspect coverage and improve the design content. They also support the premise that multiple types, format, and media of representation are significant to support collaborative urban design practice. They refute the premise concerning the ineffective utilization of 3D modeling tools, functionalities and information in the design process. However, most designers emphasized the usage of modeling tools as a platform for communication and collaboration and as a tool for illustration and representation, while analytical applications were less effectively used. Digital urban models were also used as effective communication tools to foster a greater public participation in the urban design process. They were used as part of a learning system where it helped inform public how and why particular decision alternatives have been identified.

The various extents of usage of modeling functionalities was due, in part, to the model type and degree of reality, plan's goals, purpose, and objectives, accessibility of the pubic to the model, the design team's expertise in modeling methods, and cost of model building, updating, and usage. The various extents of usage may be due also to the variety of associate tools and networking technology. It was found that if the model's degree of reality were appropriate to its potential role and the associated tools support the design development process, then it may improve the designer's expertise in using its various functionalities and techniques extensively and efficiently. Such fit and extent of usage would ultimately affect the level of design aspects coverage.

Theoretically, the effective usage of modeling functionalities may improve the quality of the decision-making process through providing certain improvements to designer's capabilities in performing core design tasks. According to the theoretical model illustrated in chapter V, the improvements to designers' cognitive capabilities would become the driver to improve designers analytical and communication capabilities. The overall impact of the combined improvements is meant to provide solutions to the information management problems and communication problems that have lead to the gaps in the design content.

In practice, however, analytical functionalities were used with below average usage. There was little evidence that their usage has made any significant improvements in designer's analytical capabilities. Such deviation from the theoretical model was due cost and time limitations and limited understandings of the role and methods with which models can be used in initial design phases to improve the analytical content and thus to enrich the design content. This provides further evidence that the coverage level of computational plans could have been further increased if the entire array of modeling functionalities were used effectively and efficiently.

The mechanism of 3D modeling support to designers' capabilities in practice was inconsistent with that in the theoretical model. However, 3D modeling support has had significant impact on several elements that constitute the quality of the design content:

creativity, originality, and innovation; logic and workability; comprehensiveness of design outcome; and professionalism. The design considerations emphasized in the plan's statement of purpose were consistent with the design aspects emphasized in design content. Therefore, the modeling usage appears to have helped designers to match the design problem and design solution.

In conclusion, the results of the quantitative analysis and qualitative data support the research hypothesis that 3D modeling usage can significantly improve the entire array of design aspects, particularly 3D design aspects. In practice, 3D modeling tools were used largely as tools for communication, representation, and illustration. Computational plans were superior in addressing a wider range of design aspect with higher coverage levels. In the comparative study, computational plans have shown consistency between the design strategies and the design problem that they were meant to address. The questionnaire survey and interviews have explained how the usage of 3D modeling and IT tools improved designer's cognitive, communication, and to a less extent, analytical capabilities, and justified the resulting increase in the design content. If designers become aware of the role and impact of those tools in improving the problem of information management and spatial structure communication among and across design teams, it may be expected that the 3D modeling and IT tools would significantly affect the design content and become an effective tool in urban design practice.

9.1.5 Final conclusions

The usage of 3D digital models in design development of urban design plans appeared to have improved several elements of the quality of urban design plans. Computational plans, the plans developed using 3D digital models and IT tools, appear to have achieved, in general, higher levels of design content. Such higher levels that reflect the superiority of computational plans are found in two main attributes. First, computational plans are associated with high or medium overall coverage levels. They address a large number of design aspects and wider range of scales with a greater extent of coverage. Second, the design considerations they emphasize in the plan's statement of goals and objectives are consistent with the considerations that they emphasize in the design policies. In computational plans, design policies achieve a better fit to the design problem they are meant to solve and make a better translation of the design and planning goals and objectives.

Computational plans address urban wide 3D and 2D design aspects with high or medium extents of coverage. Such effective coverage of urban wide aspects may lead to plans with an explicit spatial design strategy that covers a broader array of the constituent elements and issues of the physical environment.

The improved design content was correlated to the effective usage of 3D modeling functionalities. Their usage appeared to have improved the designers' capabilities to visualize, represent, and study discrete relationships between urban elements as well as revealing obscured structural and visual relationships of the elements that constitute the urban form. Such improvements in designers' visual capabilities have lead to similar improvements in their communication capabilities and have lead to minor improvements in their analytical capabilities. The integration of GIS tools and the usage of advanced visualization and networking technologies may further increase the improvements they provide to designers capabilities.

Therefore, the usage of 3D modeling may provide a solution to the problems explained in the introductory chapter: the information-related problems, communication-related problems, and visualization-related problems. Yet, the design methodology should be driven by the usage of 3D modeling. Usage of 3D modeling and IT tools may lead to the best results when associated with a design methodology that is structured around using those tools consistently during all design phases.

9.2 Policy Implications

This research provides evidence to explain the role and impact of 3D modeling in urban design practice. 3D urban modeling improves designers' ability to visualize, analyze, and communicate 2D and 3D data sets and information. It helps designers navigate, design, and communicate the urban-wide 3D spatial structure at various scales, views, and perspectives. Thus 3D models improve designers' ability to manage increasingly collaborative multi-disciplinary urban design process, and to respond to the paradigmatic shift towards a strategic, performance-based design approach. Due to this advantage, this tool can address a wide variety of urban design elements, issues, and aspects at multiple levels of the physical environment, particularly 3D design aspects that would ultimately improve the design content.

The 3D modeling tools can be applied to several planning and design processes and tasks that require managing complex visual 2D and 3D data sets and information for decision-making. These applications include the following:

- Illustrating and communicating design strategies to the public at large;
- Assessing the visual and physical impact of design alternatives on the study area;
- Breaking the key strategy into such areas or themes;

- Manipulating the proposed changes, analyzing the visual and physical relations between urban elements; and
- Communicating design alternatives, and strategies among and across design teams as well as with clients and city authorities.

These advantages and applications suggest integrating the conventional design tools and methods with methods that are supported by a more sophisticated visual model. Such a model should illustrate the three-dimensional framework of the public realm at various scales and from various perspectives to help designers analyze and design its constituent design aspects.

However, widespread application of 3D modeling in urban design practice in US cities requires considering several related issues that may affect their implementation. These issues are concerned with the construction of 3D models, their integration with other IT tools, and employment in current local urban design practice in US cities. These issues are discussed in the following section.

9.2.1 Concerns for implementation of 3D urban modeling

In this section, the limitations that were found to hinder the usage of 3D models are reviewed. The main limitations are cost, operation and performance, and degree of reality.

9.2.1.1-Cost

One of the biggest obstacles that hinders the widespread usage of 3D modeling in current urban design practice is cost in terms of money and time. Most of the financial cost for constructing 3D models results from 3D modeling resources and software. Aerial photography has become an affordable resource of spatial data and information for local governments. Many local governments already possess aerial photography for urban planning and design purposes (Kim, 2005, p.161). Those aerial photos can be utilized for 3D modeling. In addition, three-dimensional visual and representation capabilities have been significantly improved in recent GIS packages. For example, ArcGIS, which is the most popular GIS package for use by local governments in planning practice, includes the *simulation viewer*, an extension that can be used for 3D urban simulation (Kim, 2005, p.161). Local governments can easily combine the 3D model to its GIS system if they are in compatible format. Such a combination, according to key designers, planners, and decision makers of the PDDP, has allowed them to visualize, represent, and navigate the entire design area from various perspective and viewpoints efficiently. In contrast, key designers of CCAP believe that if the 3D model was combined with GIS databases, then it may have increased the variety and extent of its usage.

Software for 3D modeling is not commonly used in local governments and may be the only additional financial cost for 3D model construction. Yet, modeling and visualization firms and research centers which already possess and use such software packages can build and deliver a 3D urban model to a planning department in a compatible format to the GIS. Such an option was neither considered in New York nor in Chicago although it would have helped overcome a large portion of the financial cost of 3D model construction.

Another cost issue is time and labor needed for planning, constructing, maintaining, and updating a 3D database that includes the 3D urban model and GIS layers. Many local governments have already built and managed their GIS data layers (Kim, 2005, p.162). Therefore, the time issue results primarily from the extensive time needed for planning, constructing, managing, and updating the 3D model (designers' interviews 2005 and 2006). Such time and thus cost is likely to be substantially reduced if a software package that has a user-friendly interface was used to build a geometric model with abstract objects. Time and cost may be further reduced if the model construction was a semi-automatic process (Dokonal, 2002 b, pp 410-416; Forstner 1999 pp 1-6). Conversely, texture mapping and photo editing are time consuming processes and can be a massive project for a larger urban area. Such process may be automated using new technologies such as oblique aerial photos, yet no research has provided any clear answer to that issue (Kim 2005, p.162). Therefore, planning departments and firms should consider cost when they select the appropriate degree of reality of 3D models.

Another cost issue is the cost of using 3D modeling during the design process. This cost results from the need to involve designers with various levels of skills and expertise in design and modeling. In this research, observations and interviews have shown that design development and alternative design strategies are developed, evaluated, and selected by senior designers. One alternative or a very few alternatives are subsequently constructed by junior designers who have certain capabilities in modeling those alternatives in 3D format. Theoretically, combining various levels of design expertise and skill should improve decision-making in the design process. In practice, however, it was found to increase the time required to develop, assess, and select design alternatives. This inadequacy is likely to be solved as there is evidence that urban design firms are hiring more senior designers who are well versed with 3D modeling, which may improve and change the design process (senior designer interview A, 2005).

Cost of design alternatives' modeling was found to limit the number of alternatives that designers may develop. This is consistent with the premise that most urban design practice does not involve developing a number of differentiated and well spaced design alternatives. Thus, this is inconsistent with the theoretical model developed in chapter V that illustrates the mechanism of 3D modeling impact on the design content. This model suggested that 3D modeling usage may facilitate developing, testing, and evaluating a larger number of design alternatives. It must be noted however that the advantages associated with 3D modeling for those alternatives may outweigh their high cost.

9.2.1.2-Operation and networking of 3D models

Another issue related to policy implications is the operation and networking of 3D models. The operation and speed of performance of 3D models are interrelated with several factors such as networking technology, computer hardware, and size of data that the 3D modeling tool handles. Empirical research has shown that approximately 7 to 8 city blocks can be fluently simulated with an average personal computer. However, in cases that used an abstract geometrical model, the same computer may simulate a much larger area such as a community or neighborhood (Kim 2005, pp 162-163). To improve its operation, current 3D modeling technologies may be used to allow for the option of switching between various levels of details. Such an option allows designers to switch from detailed texture-mapped views to more abstract views depending on the purpose of navigation, scale of the area examined, and the level of detail and focus with which the area is meant to be visualized.

Besides the model's performance, its operation requires efficient networking technology to meet the requirements of an increasingly multi-disciplinary collaborative and distributed design process and information. Such networking should ensure that 3D views and data are easily and efficiently managed and communicated among and across design teams. The current increase in bandwidth and in the usage of the Internet in design communication may provide solutions to these requirements. Therefore, computer hardware and networking technology should be carefully designed according to the size of data managed, anticipated number of users and extent of usage, and the role and applications of the 3D model.

9.2.1.3-Degree of reality of 3D models

Finally, the 3D model attributes, particularly degree of reality and modeled area are tailored or selected depending on their role in the design process. This research has shown that a low degree of reality of the 3D model has limited the extent and efficiency with which some of its functionalities were used. Such deficiencies in usage appeared to have affected the extent of coverage of local 2D and 3D design aspect that has ultimately created a gap in the design framework of the study area. The current trend of adopting strategic urban design approach emphasizes addressing urban-wide design aspects with significant coverage and addressing local design aspects with medium or low coverage (see section 3.3). The usage of a variety of conventional media and digital tools with 3D digital modeling tools may bridge that gap and help increase the level with which plans address local 2D and 3D design aspects. The usage of software with 3D modeling capabilities such as AutoCAD, Form Z, and Sketch-up may help bridge that gap. Their usage in the conceptual design phase may help designers configure and link local 2D and 3D urban elements with the elements that constitute the 3D spatial structure.

In addition, low level of reality may not foster a wider public involvement in decision-making, and may not support communication among and across design teams. It may not allow designers to switch their focus of attention between various scales and levels of emphasis of the physical environment. Increasing the level of reality without compromising the performance speed requires certain level of hardware and networking technology, and thus higher construction and operating costs. However, such costs may be overweighed by potential advantages such as larger number of applications and users and a wide range of scales and types of urban design plans. Such advantages may offset the costs associated with high level of reality.

In spite of these concerns for implementing 3D modeling, it may be successfully used by planning and development departments in city governments and by architectural firms and consultancies. Recent advances in information management, visualization, and networking technologies such as VR, GIS, and the Internet can support widespread incorporation of 3D modeling in current and future urban design practice.

9.3 Recommendations for Best Practices of 3D Modeling Usage in Urban Design Practice in US Cities

This research has provided evidence that efficient usage of 3D modeling functionalities can lead to improving certain designers' capabilities and thus improve the quality of the design product, particularly the design aspects coverage and design content. There were concerns for the widespread application of 3D modeling in urban design practice. However, there were several approaches that may facilitate the achievement of such goal. These approaches can also maximize the usage of 3D modeling tools and thus improve the designers' capabilities and skills of using those tools effectively in design practice. These approaches, as such, can also minimize the cost for constructing, managing, and updating the 3D modeling tools. In this section, these approaches are recommended and explained. The recommended approaches are meant to address the earlier mentioned concerns that affect the effective usage and widespread application of using 3D modeling in urban design practice.

9.3.1 Using existing 3D models

Field observations and interviews have shown that already existing 3D urban models were underutilized due to the lack of knowledge and coordination. There were many computer generated 3D urban models driven by commercial and/or public sectors (Batty et al. 2001). Most of the major US cities have a 3D city model. A list of those cities was developed based on the surveys conducted by Center of Advanced Spatial Analysis (CASA) at the University College London, and published in Batty et al (2000) and Shiode (2001). The list includes cities of greater than 1 million population which developed and used 3D digital urban models in their planning practice such as Boston, Philadelphia, New York, Los Angeles, and Chicago. In a few other cities such as Portland, New Orleans, and Denver wide urban areas were modeled (Batty et al 2000). For some of those major cities, multiple companies and research institutes have put their own efforts to build 3D urban models (Kim 2005, p.165).

However, these existing models are underutilized and the number of projects that utilize them remains limited. In two computational plans examined in this research, the planning firms did not utilize existing 3D models that were effectively connected with GIS databases. Instead, these firms developed abstract, less efficient 3D computer models that modeled the entire central areas of those cities. This may be due in part to lack of awareness of two main issues. The first is a lack of knowledge and awareness of the existence of these models and a lack of collaboration efforts to avoid the duplication of efforts. The second is lack of awareness on the role of 3D modeling as an effective tool for urban design practice in those cities and on its potential impact on the quality of the design product. Research has proven that, by putting efforts that convert those existing 3D models to GIS compatible formats and that incorporate with cities' GIS systems, cities governments can construct 3D urban modeling tools (Kim 2005, p.165).

9.3.2 Three-dimensional urban simulation as a spatial database

This research provided evidence that the analytical functionalities were less effectively used than other functionalities. The mechanism with which they support designers' analytical capabilities in real word practice was inconsistent with the one that was illustrated in the theoretical model. That inconsistency may affect the potential impact of 3D modeling usage on the design content of urban design plans. Usage of 3D urban modeling can significantly improve designers' analytical capabilities by organizing city-wide 3D information in a geo-relational or object-oriented database that integrates 3D objects with related attribute data.

The work of Urban Simulation Team (UST) at the University of California Lost Angeles illustrated that approach in constructing organized large scale 3D models and databases (Ligget and Jepson, 1995). The work involved building a photo realistic model of the entire Los Angeles basin, an area of several hundred square miles (see section 4.4) (Delaney, 2000). The model is stored in a database structure that facilitates the real-time query of a GIS database in the three-dimensional environment to support various design and decision-making tasks. Therefore, if databases are linked with 3D models and allow designers to update and manage the model, then they may be used more effectively and efficiently in core designs tasks and thus provide significant support to designers analytical and visualization capabilities (senior designers' interviews A and B 2005).

9.3.3 Constructing city-wide digital urban models

Literature review, field observations, and interviews have shown that 3D models that cover a few blocks or a neighborhood are less likely to be re-used in other projects and thus are not cost-effective (senior designer interview A, 2005; Whyte 2002, p.134). A city-wide 3D urban model that covers larger built-up areas has several advantages that may lead it to be a more economic decision-support and design support tool in urban design practice.

The first advantage is that it facilitates linking design decisions at various scales and thus improves the coverage of local 2D and 3D design aspects (see chapters VI and VIII). It allows designers to switch their levels of emphasis between various levels to relate urban design decisions with local and city-wide guidelines. The second advantage is the potential reduction in time, effort and cost associated with building independent small-scale models. Small-scale models are often tailored to fit the specific goals of the projects for which they were constructed and thus are less likely to be used for a wider scope of applications and functionalities or to be re-used for subsequent projects (managing director interview A, 2005). Conversely, building and managing city-wide 3D models in the same way as any other 2D GIS layer may facilitate extracting and using the 3D model of any community or neighborhood in the city from the cities' data for different kinds of urban design and planning applications (Kim 2005, p. 166). Third, literature suggests that city-wide models may minimize the conflicts in terms of data exchanges, formats, and compatibilities. As a whole database, the 3D urban model can be managed, updated, and reused and integrated in the city's planning process (Kim 2005, p.166). Literature and observations have shown similar urban-wide 3D models in US cities such as the models of Lower Manhattan, Boston, Philadelphia, and Chicago.

9.3.4 Using a variety of advanced modeling and IT tools

To enhance the level of design coverage and in turn the design content of urban design plans in US cities, a variety of tools are recommended to support designers in core design tasks throughout the design process. These tools may help designers analyze, design and represent urban design aspects and their constituent elements with various types and formats of digital and conventional 2D and 3D media. Such variety is essential to address complex datasets and multiple levels and perspectives of the physical environment. The emerging capabilities of digital tools and technologies such as the interactive real-time VR modeling and the Internet GIS are likely to address that complexity. They allow designers to change areas of emphasis of the physical environment and thus cross link between the multiple levels of the urban design and planning process. Designers are more likely then to effectively cover the local 2D and 3D design aspects and other ineffectively covered design aspects.

Visual and qualitative guidelines are central to design control in urban design. However, this research has bolstered the premise that quantitative and 2D design guidelines dominate most urban design plans. Such inadequacy leads to a recommendation to use digital technologies, particularly scientific and dynamic visualizations. These tools allow designers to enhance the modes with which they visualize and interact with the visual characteristics of the spatial structure and its constituent elements. The steadily growing utility of scientific and dynamic visualizations in architecture and urban design and planning may help overcome that inadequacy and inefficiency in coverage. Scientific visualization may help designers to effectively use and integrate the multiple and complex spatial and non-spatial datasets. Dynamic visualization may help designers in interactive visual exploration, analysis, and communication of the spatial structure's elements at various scales. Therefore, these capabilities may become a means to establish an efficient cross linkage between the increasingly-adopted strategic urban design approach and other scales of design control. Such linkage may help designers to equally address urban-wide and local design aspects and thus to bridge the gaps inherent in the design framework of some plans.

9.3.5 Using 3D digital models for pubic participation

The utility of 3D digital models to improve communication between designers and public may support their interaction at various stages of, and degrees of involvement in the design process. Their realistic and interactive views may enable the public to participate in exploring the area or design problem, to explore and experiment with one or more of suggested design alternatives and in some cases, to formulate design decisions (Carver et. al 2000, p.162).

Digital models that are meant to foster a wider involvement should be more realistic and interactive. They may be used for explaining design to other parties and to explore aesthetic considerations, as well as to foster public interaction (Whyte, 2002, pp.1221-122). However, such an educational role of 3D models depends upon using combined and/or integrated representation methods, conventional and digital, to communicate urban design projects to the public. This can ensure that multiple viewpoints and different issues are better communicated and that more accurate and thorough understanding of the projects' impact could be reached. Advanced networking technologies are also important to facilitate designers' interaction with the public at large.

Usage of digital models in the urban design process may foster public participation in various ways. First, it improves social inclusion because it provides an easy access to all public willing to participate regardless of any barriers, except of course those of access to digital technology. Wider public involvement may enrich the debates with multiple and various perspectives and viewpoints. Second, it improves the public ability to comprehend different representation modes that represent the design alternatives. Such an improvement may eliminate a barrier that is likely to impede their effective inclusion in the design process. Third, digital models provide a wide and unprecedented scope for interaction. They can become the basis for social interaction. People can enter the virtual environment and communicate with designers and other interested parties. Digital models have the potential to break down the psychological barriers to participation that the public may face when expressing their points of view at public meetings.

9.3.6 Educating architectural and planning students

This research documented ineffectiveness in either using the variety of applicable modeling functionalities, or in the extent with which they were used. Such ineffectiveness was due, in part, to the limited understanding of the impact that these tools can have on the design quality, and to the inconsistent usage during the design process.

Architectural and planning schools and departments can contribute to improving the afore-mentioned inadequacies and in meeting the requirements of slow yet gradual increase in the usage of digital technology in urban design and planing practice. It is highly recommended thus to incorporate courses that are primarily concerned with digital urban modeling in urban design with architectural and planning schools curricula. Through seminar courses, students can learn theoretical knowledge underlying the impact of effective usage of digital modeling in core design tasks on decision-making, and thus on the quality of the design product. Such courses should emphasize the emerging perspectives and design paradigms as a result of using digital modeling for analytical, communication, and representation purposes in urban design practice. Studio projects may allow students to integrate that knowledge into their design projects. More importantly, studio projects should emphasize using appropriate digital modeling and associated IT tools consistently during the design process.

The curriculum of the Graduate School of Architecture, Planning and Preservation at Columbia University, for example, includes seminar courses that are primarily concerned with digital urban modeling for urban design. These courses are meant to deploy an array of digital platforms to document and then re-represent the students' notions of New York City. Another example is the courses offered at the School of Architecture at Carnegie Mellon University. These courses are primarily concerned with computer modeling and digital speculation. The work of Sheffield Virtual Urban Model (SUCoD) that involved building an urban model for the historic center of Sheffield, UK represents another approach to integrate modeling with education. It allowed students to gain practical experience in constructing, managing, and using virtual environments for a variety of applications (Peng, et al 2002).

Urban modeling research centers that are affiliated with academic institutes and universities may also contribute in the education process. These centers, such as the Urban Simulation Team (UST) at the University of California at Los Angeles (UCLA) can help bring their staff expertise and knowledge into the classroom environment. They can also disseminate their knowledge through courses, workshops and internship programs that allow students to learn using appropriate modeling methods and techniques in urban design practice.

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APPENDIX A

1- COVER LETTER

2- QUESTIONNAIRE SURVEY FORM

3- STRUCTURED INTERVIEW PROTOCOL

4- LIST OF INTERVIEWEES

Dean's office
College of Architecture
Texas A&M University
College Station, TX, 77843-3137

June 16, 2004
Attention: Mr.
Department of City Planning
New York City
Dear Mr. ………………….,

Subject: Questionnaire Survey

I would like to ask for your participation in an important survey dealing with the impact of using 3D digital urban models upon urban design in US cities. This survey is part of research work being conducted by Firas A. Salman Al-Douri who is a Ph.D. student at Texas A&M University. His research will document and critically examine the methods used in designing selected plans in US cites. He hopes to suggest a new set of rules or a methodological framework for usage of 3D digital models in urban design. The ………… is one the cases he examined in this research. There is no intent to draw any comparison between the quality of design plans at different planning departments surveyed in this study.

The results of this research project will be of widespread value not only to educators but to urban designers and planners as well. To assure success of the research, please complete the questionnaire by clicking on the link below.

Mr. Al-Douri will contact you by telephone in a few days. He may wish to interview you in more depth. Your assistance to him will be greatly appreciated

I highly appreciate the time and effort required to complete this survey. Thank you for your help in conducting this important subject.

Here is a link to the survey:
http://www.surveymonkey.com/s.asp?A=130544180E3022

Thanks for your participation,

Sincerely,

Dr. Mark J. Clayton

Associate Executive Dean

1- This section includes closed-ended questions that attempt to determine the extent to which designers use 3D digital models' functionalities in the development of urban design plans.

Question 1: To what extent you use each of the following functionalities in the development of urban design plans?

No.	Categories of Functionalities	Extent of Models' Usage					
1		**Not Used**	**Very little**	**Average**	**Very much**	**A lot**	**Not Applicable**
1	***Category 1: Navigation-Visualization- Functions***						
1.1	Viewing the visual configuration of an existing urban pattern						
1.2	Visualizing the impact of proposed urban design						
1.3	Providing spatial data through the GIS						
1.4	Extruding spatial features in 2D GIS maps to create 3D perspectives						
1.5	Generating 2D Visualizations (e.g. maps & perspectives) at various levels of realism						
1.6	Generating 3D visualizations						
1.7	Generating 3D VRML models at several levels of realism						
1.8	Representing the study area at different geometrical and geographical scales						
1.9	Representing the study area with different types of media.						
2	***Category 2: Decision-support (communication) Functions***						
2.1	Communicating project-specific design data and information within the design team						
2.2	Communicating design concepts-or scenarios- within the design team						
2.3	Assessing the proposed development(s) within the design team						
2.4	Communicating and assessing the proposed development with city authorities						
2.5	Carrying out the major reviewing process to city authorities						
2.6	Selecting the best design alternative-scenario.						
3	***Category 3: Analytical Functions***						
3.1	**Modeling and testing** spatial/structural relationships between physical components						
3.2	**Analyzing the study area systems** (circulation, Land-use, site analysis, etc.)						
3.3	**Analyzing the visual/3D characteristics** (townscape, skyline, building views, etc.)						
3.4	**Graphic reduction**: Isolating visual information to reveal certain structural and spatial relationships.						
3.5	**Layering and delayering:** Synthesizing multiple sets of spatial relationships						
3.6	**Structured query** of data to generate new layers of data and information						
3.7	**Overlay analysis** of different spatial data layers						
3.8	**Thematic mapping** of various design aspects						
4	***Category 4: Manipulation Functions***						
4.1	Representing the proposed design with different levels of details.						
4.2	**Modeling and testing** proposed guidelines for newly developed areas.						
4.3	**Visual impact assessment:** Assessing the impact of different design alternatives or scenarios with their context						
4.4	**Simulating** pedestrian movement/vehicular traffic						
4.5	**Impact analysis:** Testing specific economic and physical impacts of a proposed design.						
4.6	**Scenario analysis:** Comprehensive analysis of the many implications of a planning scenario such as infrastructure, land-use policy, and accessibility.						

2- This section includes close-ended questions that measure in a scale of (1-5) the extent to which designers use 3D models in each major phase of the urban design process.

<u>Question 2:</u> Identify to what extent designers used 3D models in each of the following design phases?

No.	Design Phases	Extent of Models' Support				
		No Impact	Low Impact	Medium Impact	High Impact	Not Applicable
1	Data collection, survey of existing conditions-natural, built, and socio-economic conditions					
2	Data analysis, identification of all opportunities and limits					
3	Formulation of goals and objectives					
4	Generation of alternative concepts					
5	Elaboration of each concepts into workable solutions					
6	Evaluation of alternative solutions					
7	Translation of solutions into policies, plans, guidelines, and programs					

3- This section includes close-ended questions that measure in a scale of (1-6) the impact of 3D models usage on designers' products and output.

<u>Question 3:</u> On the scale shown below, to what extent you believe 3D models usage has affected the following products and output of the afore-mentioned design phases?

No.	Impacts of model usage	Assessment					
		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
1	Provided a better access to data and information						
2	Organizing the quantitative base of the urban design process						
3	Analyzing the study area at multiple levels						
4	Increased the time allocated for analytical tasks						
5	Helped generate a larger number of design alternatives						
6	Increased the time allocated for generating design alternatives						
7	Improved the communication of design concepts and alternatives						
8	Helped underpin design alternatives with analytical content						
9	Considering a greater number of alternative scenarios						
10	Avoiding communication deficiencies among designers						
11	Communicating design concepts to a wider group of professionals						
12	Improved the designers' confidence in the decisions made						
13	Addressing a greater number of design aspects in the urban design plan						
14	Helped organize multiple scales of design control (Metropolitan, city-wide, District)						

4- This section includes close-ended questions that measure in a scale of (1-5) the impact of 3D models usage on designing the design aspects addressed in the urban design plan.

<u>Question 4:</u> On the scale shown below, to what degree has the 3D models usage affected designing the following design aspect addressed in the urban design plan?

No.	Design Aspects	Assessment				
		No impact	Low Impact	Medium Impact	High Impact	Not Applicable
1	**Sustainability-Energy and resource management**					
1.1	Traffic management and alternative transportation					
1.2	Ecology and nature conservation					
1.3	Energy conservation					
2	**Townscape (Visual composition of space)**					
2.1	District character and identity					
2.2	Views, vistas, and overlooks					
2.3	Skyline					
2.4	Continuity of spaces, streetscape, and streetscene					
3	**Urban Form (Three-dimensional built volume)**					
3.1	Density					
3.2	Scale (height and massing)					
3.3	Space system: urban and open space structure					
3.4	Visual qualities of open spaces and streets					
3.5	Urban pattern and layout					
4	**Public Realm (The social experience)**					
4.1	Vitality: Economic vitality and maintenance of downtown vitality					
4.2	Social interaction					
4.3	Security, public perceptions, and sense of community					
5	**Land -use (Mixed-use and diversity)**					
5.1	Diversity and mixed land-use					
6	**Connection and Movement Network**					
6.1	Accessibility to open spaces (for pedestrians and motorists).					
6.2	Street network: accommodation of traffic					
6.3	Pedestrian network: pedestrian routes, links to parking					
6.4	Parking: accommodation of parking, access to parking					
7	**Architectural Character**					
7.1	Architectural form: bulk, character, height, massing, scale					
7.2	Elevations: Design vocabulary and design style					
7.3	Elevations' details: detailing, fenestrations, color, texture, and materials.					
8	**Landscape Architecture**					
8.1	Overall landscape design: open space network and topography.					
8.2	Soft landscape design: Water, landscape layout and improvements					
8.3	Hard landscape design: Street furniture and lighting					
9	**Conservation areas and/or areas of special character**					
9.1	Urban form and townscape					
9.2	Architectural form: bulk, character, height, massing, and scale					
9.3	Elevations: Design vocabulary, design style.					
9.4	Elevations details: detailing, fenestrations, color, texture, materials					

5- This section probes the attributes of the 3D model used in the design process.
Question 5: Identify the attributes and adaptability of the used model.

1- The extent of the study area modeled by the 3D digital urban model:
- ☐ one district
- ☐ more than one district
- ☐ Downtown-city center
- ☐ City wide
- ☐ City region

2- The level of details:
- ☐ Detailed architectural model including fenestration
- ☐ Detailed elevation
- ☐ Major details of building elevations
- ☐ Accurate building volumes
- ☐ Roofscapes
- ☐ Prismatic block models –coarse massing

3- The ability to convert file format to other standard formats**:**
- ☐ Convertible
- ☐ Non Convertible

4- Model's compatibility with other tools:
- ☐ Compatible to all other current tools and agencies
- ☐ Compatible to some other current tools and agencies
- ☐ Non-compatible to any other current tool and agencies

5- Accessibility of the model to the public (check all that apply):
- ☐ public
- ☐ design team
- ☐ city authorities
- ☐ Urban planning and design consultancies
- ☐ All other engineering and infrastructure consultancies

6- For how long the firm has been using the model in the design and decision-making process?
- ☐ Less than 2 years
- ☐ 2+-3 years
- ☐ 3+-5 years
- ☐ 5+-8 years
- ☐ More than eight years

7- Who uses the model in the planning department/ firm?
- ☐ Urban planning/ design team
- ☐ Engineers
- ☐ Surveyors
- ☐ Landscape planners and designers
- ☐ Planning department head
- ☐ Others:

8- Which of the following best describes the change in design methodology due to 3D models usage?
- ☐ Conventional methodology without any change

- ☐ Conventional methodology but supported with digital technology
- ☐ Modified methodology to fit the models' usage

6- This section includes open-ended questions to investigate the methods of using 3D models in supporting core design tasks in the process of urban design plans development.

<u>Question 1:</u> What design tasks have models supported in developing the urban design plan?

<u>Question 2:</u> To what extent they were adequate in supporting designers in core design tasks?

<u>Question 3:</u> To what extent have designers relied on their support and output in developing the urban design plan?

<u>Question 4:</u> For which functions they were inadequate in supporting designers and why?

<u>Question 5:</u> What other tools and software should be integrated with the 3D models to support these functions adequately?

3- Structured Interview Protocol

1-Imapct of Models on Design Methodology

How did 3D models usage affect the design methodology followed in developing this urban design plan? Please address the following aspects:

- Generating and testing alternative design strategies
- Number of design alternatives
- The relation with the other levels of the hierarchical scale of design control
- The models functions most used

2- Impact on the Design Team

- What new insights have designers gained due to 3D models usage?
- Do they rely on their output in their decisions and why?

3- Impact on Design Outcome

How did 3D models usage affect the quality of the design outcome of basic tasks in the design process?

4-Effectiveness of Support

- To which extent models were adequate in supporting designers in these tasks?
- What other tools and software has to be integrated with the 3D models to support them adequately?

4- List of Interviewees:

The following is a list of the initials, titles, and affiliations of the informants interviewed concerning the plans of Chicago, New York City and Pittsburgh. Information shown in this table defines their titles and affiliations at the time those plans were developed and published.

No.	Informants' initials	Title/Position	Affiliation
A- Interviews at Chicago (CCAP)			
1	L. O.	Director	Okrent Associates-for computer modeling and animation.
2	J. J. & R.D.	Designers	Okrent Associates
3	B.H.	Director of Urban Design and Planning	Department of Planning and Development-City of Chicago
4	S.A.	Deputy Commissioner-Urban Design and Planning	Department of Planning and Development-City of Chicago
5	R.N.	Architect	OWP/P Architects
6	L. T.	Architect	SOM LLP-Chicago Office
7	Y. L.	Urban Designer	SOM LLP- Chicago Office
8	P.K.	Senior Urban Designer	SOM LLP- Chicago Office
9	Dr. B. R.	Assistant Professor	City Design Center-University of Illinois at Chicago
11	S. R.	Planner &Computer Model Developer	SOM LLP (Shanghai office-China) Telephone Interview
B- Interviews at New York City			
12	M. K.	Director	Environmental Simulation Center, LTD
13	G.J	Executive Director	Environmental Simulation Center, LTD
14	C.S.	Associate	Beyer Blinder Belle Architects and Planners LLP
15	J.O.	Planner	Department of City Planning, City of New York
16	M.V.	Senior Urban Designer	Department of City Planning-City of New York
17	M.R.	City Planner	Department of City Planning-City of New York
18	P.W.	Senior Urban Designer	Department of City Planning-City of New York
C- Interviews related to Pittsburgh Downtown Development Plan (PDDP) (Telephone interviews)			
19	M.H.	Director, Department of City Planning	Department of City Planning-City of Pittsburgh
20	J.D.	Associate	Zmistowski Design Group, LLC
21	S.K	Urban Designer	Department of City Planning-City of Pittsburgh
22	M.S.	Project Director and Urban Designer	Department of City Planning-City of Pittsburgh/Project team
23	J.F.	Project Manager	Department of City Planning-City of Pittsburgh

APPENDIX B

A LIST OF URBAN DESIGN PLANS AND THEIR HOST CITIES

No.	City	Title of the urban design plan	Year	Type of the plan	Code in content analysis	URL source
1	New York	New York city's vision for lower Manhattan district	2004	Computational	A1	http://nynv.aiga.org/nynv_book.pdf
		Hudson Yards Master Plan	2005	Computational	A8	http://www.nyc.gov/html/dcp/html/hyards/proposal.shtml
		Far West midtown. A framework for development	2001	Conventional	B1	http://home.nyc.gov/html/dcp/pdf/pub/fwmt.pdf
2	Pittsburgh	The Pittsburgh Downtown Development plan. A blue print for the 21st century	1998	Computational	A2	http://www.city.pittsburgh.pa.us/dt/
		The Riverfront Development plan. A comprehensive plan for the three rivers	2001	Conventional	B2	http://www.city.pittsburgh.pa.us/rfp/
3	Chicago	The Chicago Central Area Plan. Preparing the central city for the 21st century.	2003	Computational	A3	http://www.uic.edu/cuppa/upp/people/faculty/wiewel/CCAPinvite.pdf
		A Vision for State street, Wabash Avenue and Michigan Avenue. Chicago historic downtown core	2000	Conventional	B3	Google Search: State, Wabash and Michigan Plan
4	Philadelphia	North Delaware Riverfront. A long-term vision for renewal and redevelopment	2001	Computational	A4	Comprehensive Redevelopment Plan for the North Delaware Riverfront
		Extending the Vision for South Broad Street: Building Philadelphia's Avenue of the Arts for the 21st Century.	1999	Conventional	B4	http://www.philaplanning.org/plans/avearts.pdf
5	Milwaukee	Milwaukee Downtown Plan	1999	Computational	A5	http://www.mkedcd.org/downtownplan/index.html
		Park East Redevelopment Plan	2004	Conventional	B5	http://www.mkedcd.org/parkeast/index.html
6	Boston	The Fort Point District -100 Acres Master Plan	2004	Computational	A6	http://www.cityofboston.gov/bra/Planning/PlanningInitsIndividual.asp?action=ViewInit&InitID=33
		A Civic Vision for Air Rights in BostonVision	2000	Computational	A7	http://www.cityofboston.gov/bra/Planning/PlanningInitsIndividual.asp?action=ViewInit&InitID=43
		The East Fenway Neighborhood Strategic Plan	2003	Conventional	B6	http://www.cityofboston.gov/bra/Planning/PlanningInitsIndividual.asp?action=ViewInit&InitID=8

APPENDIX C

CONTENT ANALYSIS CODING MANUAL

GOALS AND STRUCTURE OF THE CONTENT ANALYSIS

GOALS OF THE CONTENT ANALYSIS

The content analysis of urban design plans is meant to discover the following:

- The coverage of design aspects in the individual urban design policies;
- The emphasis on three-dimensional aspects of the design;
- The cross-referencing between design policies at various scales of intervention; and
- The level of detail of design intervention (guidance).

STRUCTURE OF THE CONTENT ANALYSIS

The content analysis is organized into four major sections as follows:

1. General approach, which embraces approaches to design, the stated purposes for producing the plans, site analysis upon which design plans are based, structure of the plan, and type of design guidance.
2. Design content
3. Hierarchy of policies
4. Plan expression and presentation

1-THE GENERAL APPROACH:

The general approach of the plan embraces the following:

a- Purposes of producing the plan
b- Site analysis
c- Structure of the plan
d- Type of design guidance

1.1- PURPOSES:

The statement of purpose summarizes the plan's main functions and draws attention to design matters to ensure that they are formally acknowledged as valid requirements (Turner 1994, P.304). The goal is to assess the consistency between the stated purposes and the actual content of the plans, and to assess the emphasis placed on design aspects generally, and 3D design aspects in specific.

Question 1: What are the main stated purposes of the urban design plans?

1	
2	
3	

Question 2: With what degree of emphasis the statement of purpose emphasize any of the following design considerations?

Design considerations	**Degree of Emphasis**		
	Non existent	Minor	Significant
Visual Considerations			
Functional considerations			
Environmental considerations			
Urban Experience(public perception)			
Specific design considerations			

1.2- SITE ANALYSIS

The plans will be examined in order to note the frequency with which reference was made to the analysis criteria throughout the plan, and to assess the level or type of site analytical content within each plan. The level (or type) of site analysis is a key variable affecting the quality of design of the development on a particular site (Turner 1994, p.293).

According to Punter and Carmona (1997), three elements were identified *a priori* as forming the basis for appraisal: analysis of the fabric of the locality, analysis of development pressure leading to particular design problems, or analysis of public concerns (Punter and Carmona 1997, p.122). Four levels of analysis were identified from the content analysis: explicit, implicit, integral, and no evidence of analysis. Explicit analysis is evident in the plan and provides a clear analytical basis for policy making. The plans that involve this type of analysis respond directly to local conditions, often tailoring policies specifically to individual localities and often including details of the analysis within the plan. Analysis that is integral to the plan sets future directions for development, although it tends to be largely descriptive, and rarely develops clear design principles. In implicit analysis, plans provide evidence of careful analysis. Some plans show no evidence whatsoever of analysis of the locality.

Question 1: What is the type (or level) of site analysis within the plan?

	Type of Analysis			
Analytical Element	Explicit	Implicit	Integral	No evidence
Land-use and transportation				
Architecture, streetscape, and open space				
Socio-economics factors				
User perception and behavior				
Natural factors				
History				

The above-mentioned analytical elements are listed below with their constituent sub-elements. This list is modified according from the list developed by Southworth (1989) in his content analysis of 70 urban design plans in US cities (Southworth 1989, pp377-79).

Land-use and transportation

Land-use:
1. Existing conditions and possible improvements
2. Impact of land-use changes
3. Housing characteristics
4. New major office development
5. Growth Projections
6. Spatial/functional organization of downtown activity centers
7. Effects of past land-use policy

Location of public facilities and spaces:
1. Location of parks, bikeways, trails, scenic parkways

Vehicular traffic and parking:
4. Existing conditions
5. Impact of traffic changes

Densities:
3. Floor-area ratio
4. Current densities
5. Zoning/height limits

Infrastructure:
1. Inventory of street Utilities
2. Sidewalk and street widths
3. Utilities and water supplies

Pedestrian circulation:
1. Sources and routes

Land-use and transportation problems:
1. Problem intersections
2. Parking and circulations problems

<u>Architecture, Streetscape, and open space</u>

Streetscape:
1. Character of streetscape(lighting, paving, signage, fences, etc)
2. Quality of streetscape
3. Existing street patterns
4. Streets (width, slope, alignment)
5. Landmark building locations
6. View corridors
7. Critical skylines and shorelines

Open space quality:
- Trees, walls (light and shade, density, type, height)

Landscape districts

Architectural character:
- Residential Character
- Building heights
- District character
- Survey of good and bad architecture
- Significant buildings and architectural quality
- Visual quality
- Location of gateways

Building types and conditions

<u>Socio-economic factors:</u>

Population:
- Population change and projections
-

Economic Analysis:
- Demands for various types of space
- Land values
- Socio-economic characteristics

Forces directing change:

Market Analysis:
- Change in retail/commercial activity
- Needs of existing businesses

Fiscal impacts:
- Cost/benefit of alternative plans

<u>User perception and behavior</u>

Imageability:
- Views, view orientation
- Road experience
- Scenic route framework
- Walking experience
- Sense of continuity, movement, rhythm, sequence
- Relation between mode of travel, perception, use and design of trails

Sense of community
- Livability survey
- Plan's contribution to sense of community

Users behavior and attitudes:
- Use of region
- Preferred places and most frequented places
- Use of open space (type, amount)
- Variations in open space use as function of age, sex, weather, time of day, location

Noise

<u>Natural Factors</u>

Topography
Climate and solar exposure

Prominent natural features
Environmental hazards

<u>History</u>

History of place
History of architectural styles

Buildings and sites of architectural and historical interests

Question 2: What is the number with which reference was made to the analytical content and elements throughout the plan?

<u>1.3 -STRUCTURE OF THE PLAN</u>

The plans document will be examined in order to find evidence that any of the plans had been prepared by breaking the key strategy map into numerous sub-area maps.

Question: what evidence is there for breaking the key strategy map or key design strategy, into numerous sub-area maps?

- ☐Significant
- ☐Minor
- ☐No evidence

<u>1. 4- TYPE OF DESIGN GUIDANCE</u>

The plans will be examined to assess which elements of guidance are more likely to influence the design development on the site, and to note any particular emphasis on either prescriptive or enabling guidance. According to turner (1994), three broad types of design guidance are identified. The first, highly prescriptive guidance, contains fixed requirements for mix/density, sets out a road layout, and provides an indicative site layout. The second, enabling guidance, place most emphasis on design and the relationship between buildings, vehicles, and the landscape, with minimal restriction on layout and access position. The third, neutral/framework, is neither prescriptive nor enabling but providing guidance and suggests a framework within which the designer might work (Turner 1994, p.297).

Question: what is the type of design guidance given throughout the plan?

- ☐Highly prescriptive guidance
- ☐Neutral/ framework guidance
- ☐Enabling guidance.
- ☐A combination of two or more types.

TYPE A: HIGHLY PRESCRIPTIVE GUIDANCE

<u>Mix/density prescribed</u>

Restricts developer/leads developers to a certain density and leaves little opportunity for density to follow from design and site constraints.

<u>Indicative layout</u>

Suggests a 'correct' solution, leads lazy developers to comply with security that permission will be granted

<u>Access prescribed</u>

Provides a definite constraint to layout but is often unavoidable

<u>Traffic routes prescribed</u>

Often unnecessary - severely restricts layout design and reduces number of possible solutions

<u>Pedestrian and/or cycle</u>

As above, in a minor way routes prescribed

<u>Detailed landscape</u>

Prescribes indigenous vegetation - this is laudable but when taken section to extreme detail may restrict creative input from developers' landscape architect

<u>Retain/reinforce landscape often boundary</u>

May not always be appropriate for example, when the integration of a development with surrounding area might be considered

Type B: NEUTRAL/FRAMEWORK GUIDANCE

<u>Mix/density range given</u>

Offers flexibility and allows mix/density to respond to the design

<u>Firm landscape framework</u>

Broad guidance which should not be too constraining,

<u>Advice offered regarding materials/colors</u>

Influences design but generally in 'framework' way

<u>Layout - description Layout - diagram</u>

Less than prescriptive, but may not be enabling - neutral

<u>Reference to 'secure by design'</u>

A framework of current thinking on this issue – will influence design but not prescriptive

<u>Reference made to design</u>

Focus on good design rather than prescriptive advice of parking

Type C: GUIDANCE WHICH ENABLES CREATIVITY/ENCOURAGES GOOD DESIGN
Form/character
Suggests architectural character which the design might take- encourages thought and consideration in this area of the design.
Scale/height
As above - encourages sensitivity to the site
Emphasis on design of walls and fences to be part of overall design concept
An important pointer to good design practice - with plenty of scope for creativity
Advice which directs the designer towards good practice
Note that design/layout of buildings should relate to typography/landscape
Note that open space should be designed as such rather than a series of unusable left over areas
Reference to views/visual links
As above
Reference to requirement for sensitive/high standard/ quality of design
Raising awareness of the importance of design

2- DESIGN CONTENT

The design content embraces three tiers as follows:

1. The first tier: Design considerations
2. The second tier: Design policies of the urban design plan
3. The third tier: Design aspects addresses (covered) in the policies, and the degree of emphasis on each design aspect.

2.1- DESIGN CONSIDERATIONS:

Design considerations express the qualities that urban design, as a process, seeks to achieve (Rowley, A. 1994, p.182).

Question: With what degree of emphasis did the plan content emphasize the following design considerations?

Design considerations	Degree of Emphasis		
	No emphasis	Minor	Significant
Visual Considerations			
Functional considerations			
Environmental considerations			
Urban Experience			
Specific design considerations			

2.1.1- Visual Considerations:

Visual considerations range from design and siting of a single object on a space, to a concern for buildings seen in their immediate context, to city-wide concern for the skylines to siting of high buildings or other landmarks. They encompass such issues as:

- Aesthetics
- Environmental psychology and perception
- Urban form
- Spatial definition and composition

- Serial vision
- Color, texture, and decoration
- Landscaping

2.1.2-Functional Considerations:
They include issues such as:

- Layout and capacity of road network
- Car parking provision
- Refuse collection facilities
- Layout, safety, and convenience of pedestrian network or routes
- Design of open space (in connection with movement and use)
- Mix, intensity, and compactness of activities and uses
- Privacy
- Protection and security against crime

2.1.3- Environmental considerations:
They include issues related to the ecological impact and "green" considerations of urban design such as:

- Provision of natural light, sun, and shade in spaces
- Avoiding noise, glare, air pollution, and wind
- Designing with the micro-climate
- Energy efficiency
- Wildlife support and nature conservation
- Pollution and waste control
- Sustainability

2.1.4-The urban experience (public perception):
They include issues related to attributes of place rather than physical space. The keywords are: complexity, diversity, activity, surprise; public perceptions, associations, and meanings, and the history and genius loci of settlements. These issues include:

- Diversity of architecture and other visual stimuli
- The amenities
- The open spaces for active and passive recreation
- Social interaction of diverse people in these spaces

2.1.5- Specific design considerations:
In addition to the considerations of the built environment, a range of specific design concerns should infuse the remainder of the plan to ensure that design quality is considered in relation to all policy areas. Such concerns apply over and above the issues already included in design-specific policy. An indicative range of such considerations is listed by policy area below:

- The rural environment
- Transport and infrastructure
- Employment and local economy
- Town centers and retail development
- Housing
- Sports, leisure, and community facilities (Carmona, Punter, and Chapman 2002, p.30)

2.2-DESIGN POLICIES OF THE URBAN DESIGN PLAN

The design policies identify the key factors that designers should take into account. A suggested agenda for urban design policies include the following policies:

- Sustainable urban design
- Townscape (visual composition of space)
- Urban form (three-dimensional built volume)
- Public realm (the social experience)
- Mixed use and tenure
- Connection and movement
- Architectural character
- landscape architecture
- Conservation areas and listed buildings (Carmona, Punter, and Chapman 2002, pp.60-61).

2.2.1-Sustainable urban design:

Sustainable development, according to Carmona, Punter, and Chapman (2002), should be a principal goal of urban design at all scales-buildings, spaces, quarters, and settlements (Carmona, Punter, and Chapman 2002, p.60).

Question: What is the degree of emphasis on each aspect of sustainability as a design strategy?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Alternative transportation			
Control of pollution: noise reduction			
Drainage: drainage systems, maintenance of drainage systems			
Ecology: Preservation of outstanding natural features, nature conservation			
Energy: Energy conservation, orientation			
Materials			
Micro-climate			
Resources: avoiding overload on resources			
Site design and layout			
Traffic management			
Urban form			
Water: water fronts, water conservation, water quality			

2.2.2-Townscape (visual composition of space):

Townscape policies should be used to embrace a concern with three main design issues:

1. The visual relationships of a development to its site and wider setting
2. Defining the appropriate townscape role of a development including its relationship to and provision of visually interesting public spaces and buildings
3. The protection of both local and strategic views, particularly where topographic or historic factors have combined to create particular assets of the skyline or the natural setting of a settlement (Carmona, Punter, and Chapman 2002, p.60).

4. Enhancing the streetscape in new development and provision of high quality hard landscape (Carmona, Punter, and Chapman 2002, p.60; Punter and Carmona 1997, p.156)

Question: What is the degree of emphasis on each aspect of townscape as a design strategy?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Buffers: treatment of interface between commercial and residential uses			
Character: district character, neighborhood character, character maintenance, improvement to character.			
Context: Connections among districts and city, visual links to context			
Continuity of streetscape and streetscene			
Eyesores			
Identity: genius loci, unique identity			
Intrusions			
Landmarks			
Morphology			
Sense of place			
Setting: expression of natural setting, enhancement of natural form			
Skyline protection			
Topography			
Views: View corridors, views to hills, bay, lake, and ocean			
Visible framework of public facilities			
Vistas and overlooks			
Visual orientation: to gateways, approaches, and landmarks			

2.2.3-Urban form (three-dimensional built volume):

Urban form policies should include and seek the following design considerations:

1. Appropriate scale of development through control of building envelope incorporating density, height, and massing concerns, but emphasizing the creation of human scale consistent with the context.
2. Key character-giving elements such as:
   - relative enclosure of public spaces
   - continuity of the building line
   - diversity and pattern of the established urban grain, and block and plot sizes.
3. Tailored density allocation (in existing urban areas) to the existing character of the area and to the relative accessibility, and should not override other key contextual considerations.
4. Considerations of sunlight, daylight, and microclimate to ensure good living and working conditions, comfortable public spaces, and energy conservation.

Question: What is the degree of emphasis on each aspect of the urban form as a design strategy?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Bulk of buildings			
Character: Contemporary architectural character			
Daylight/Sunlight: Controlling sense of enclosure, controlling shadow impacts through daylight and sunlight standards			
Density defined by visual principles, privacy			
Density: Habitable room per acre used for residential density, plot area ratio, units per acre			
Height			
Massing: rhythm, urban pattern, grain , and texture			
Richness and visual interest: spatial complexity, variety of spatial experiences			
Scale: human scale, pedestrian scale			
Space system: urban & open space structure			
Unsightly nuisances			
Urban image:			
Urban streetscape character:			
Visual qualities of streetscape and open spaces: Sense of enclosure, definition of open spaces and streets corridors			

2.2.4-Public realm (the social experience):

Public realm policies emanating from social perspectives can complement townscape and urban form policies. They embrace concerns with the following issues:

1. Encouraging legible, comfortable, stimulating, and safe streets and public spaces (e.g. active frontages at ground level whenever possible).
2. Incorporating public perceptions of the identity and quality of the built environment such as:
    a. Permeability of blocks and neighborhoods
    b. Vitality
    c. Comfort
    d. Environmental quality
    e. Public art (to create visually rich public realm)
3. Embracing design-against-crime (safety) principles including:
    a. Consideration of the defensible space
    b. Surveillance
    c. Visibility
    d. Lighting
    e. Other security measures

- Functional concerns such as:
    - Parking
    - Servicing
    - Disabled access considerations
    - Relationship between public and private spaces

Question: What is the degree of emphasis on each aspect of the public realm as a design strategy?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Functional concerns: Parking, servicing, disabled access considerations, and relationship between public and private spaces			
Public perceptions of the identity and quality of the built environment, sense of community, street level interest			
Security and design against crime			
Sense of urbanity			
Social Interaction: social places, gathering places, opportunities of social interaction			
Vitality: economic vitality, maintenance of downtown vitality			

2.2.5-Mixed use and tenure

The mixing of uses should be a fundamental policy objective in order to create more sustainable living and movement patterns, and more vital and viable urban centers. It would also aim at the provision of adequate and attractive amenity spaces in residential developments.

Question: What is the degree of emphasis on each design aspect comprising the mixed use and tenure as a design strategy?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Diversity: diversity of business types and services, cultural and economic diversity			
Mixed land-use: Mixing of uses in urban areas			
Provision of adequate and private amenity spaces in urban areas			

2.2.6-Connections and movement

Accessibility considerations will be important to the detailed design of public spaces. Policies should seek to achieve the following:

- Promote walking and cycling (as the most sustainable modes of transport)
- Ensure the quality of walking and cycling (frontage controls and enhancements)
- Maximizing the local autonomy of residents
- Structuring the development around energy-efficient movement networks
- Prioritizing safe, easy, and direct pedestrian movement
- Creating a network of attractive and well-connected public space.

Question: What is the degree of emphasis on each aspect of connections and movement as a design strategy?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Accessibility by public transportation			
Accessibility: Accessibility to open spaces, accessibility toy all (pedestrians, motorist, bicyclists)			
Cycling environment: bicycle access			
Efficiency: efficiency in traffic flows, congestion reduction			
Efficiency: efficiency in transportation network			
Parking: accommodation of parking, access to parking			
Pedestrian network: Pedestrian routes, link to parking, pedestrian -vehicle conflict			
Streets network: accommodation of traffic			

2.2.7-Architectural character:

The architectural character involves three hierarchical levels of design considerations:
1-Coverage of architectural form considerations;
2-Coverage of elevational considerations; and
3-Coverage of elevational detail considerations.

2.2.7.1-Coverage of architectural form considerations:

Question: What is the degree of emphasis on each aspect of the architectural form as a design control consideration?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Building spacing			
Bulk			
Design character			
Form			
Height			
Massing			
Scale			
Size			

2.2.7.2-Coverage of elevational considerations:

Question: What is the degree of emphasis on each aspect of the elevational considerations as a design control mechanism?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Contemporary design			
Design Vocabulary: relation of design vocabulary with surrounding environment			
Style			
Richness and visual interest			

2.2.7.3-Coverage of elevational detail considerations:
Question: What is the degree of emphasis on each aspect of the elevational detail considerations as a design control mechanism?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Materials			
Roofscape			
Proportions			
Fenestrations			
Detailing			
Color			
Rhythm			
Silhouette/ Profile			
Vertical / horizontal emphasis			
Texture			

2.2.8-Landscape Architecture:

The landscape architecture character involves three hierarchical levels of design coverage:

1. Coverage of strategic landscape considerations;
2. Coverage of soft (green) landscape considerations; and
3. Coverage of hard landscape considerations.

2.2.8.1- Coverage of strategic landscape considerations:
Question: What is the degree of emphasis on each aspect of the strategic landscape as a design control consideration?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Boundaries			
Existing vegetation			
Landscape survey			
Open space			
Topography			
Urban edge			

2.2.8.2- Coverage of soft (green) landscape considerations:
Question: What is the degree of emphasis on each aspect of the soft (green) landscape as a design control consideration?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Soft landscape			
Trees			
Species			
Buffers			
Water			
Landscape layout			

2.2.8.3- Coverage of hard landscape considerations:
Question: What is the degree of emphasis on each aspect of the hard landscape as a design control consideration?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Floorscape			
Hard landscape layout and planning			
Street Furniture			
Lighting			

2.2.9-Conservation areas and listed buildings:

2.2.9.1-Coverage of considerations of conservation of urban form and townscape:
Question: What is the degree of emphasis on each aspect of urban form and townscape characteristics of the conservation areas?

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
1-Urban Form			
Building line			
Character: Maintenance of original -historic-character, creation of an authentic character			
Density			
Grain			
Morphology			
Urban space			
2-Townscape (visual and functional relationship with the locale)			
Landmarks			
Setting: Maintenance of authentic setting			
Skyline			
Topography			
Views			

2.2.9.2-Architectural form and detail of the development in conservation areas:

a-Coverage of architectural form, grain, and morphology aspects:

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Scale			
Height			
Massing			
Form			
Bulk			
Size			

b-Coverage of elevtional considerations:

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Contemporary design			
Style			
Richness and visual interest			

c-Coverage of elevational detail considerations:

Design Aspects	Degree of Emphasis		
	No emphasis	Minor	Significant
Materials			
Roofscape			
Proportions			
Fenestrations			
Detailing			
Color			
Rhythm			
Silhouette/ Profile			
Vertical / horizontal emphasis			
Texture			

d-Coverage of listed buildings policies:

Design considerations	Degree of Emphasis		
	No emphasis	Minor	Significant
Rehabilitations			
Preservation/conservation			
Extensions			
Adaptive re-use			
Infill development			
Renovations			

3- HEIRARCHY OF POLICIES

The hierarchy of design policies embraces two components:

1. The scales (or levels) of intervention (district, city, city region, regional); and
2. The cross-referencing of the multiple levels of design intervention.

3.1- THE SCALES (OR LEVELS) OF INTERVENTION:

There are three levels of design interventions:

a. Level 1: Strategic urban design at the city/conurbation level.
b. Level 2: Strategic urban design at the city/district level.
c. Level 3: Urban design at the level of individual spaces or groups of spaces.

The levels of intervention will be determined according to two factors (Frey 1999, p.21):

1. Issues addressed at each design level; and
2. Scope of intervention of each design level.

Question: What is the degree of emphasis on each level of design intervention in the urban design plan?

Level of Design Intervention	Degree of Emphasis		
	No emphasis	Minor	Significant
Strategic urban design at the city/ conurbation level.			
Strategic urban design at the city/district level			
Urban design at the level of individual spaces or groups of spaces.			

3.2- CROSS REFERENCING OF THE MULTIPLE LEVELS OF DESIGN INTERVENTION

This embraces the cross-referencing of design policies at different levels within the same plan, or the link between the overall design strategy and detailed design policy.

Question: What is the degree of emphasis on linking the overall design plan with detailed design policies?

1. ☐No emphasis
2. ☐Minor
3. ☐Significant

4-PLAN PRESENTATION AND EXPRESSION

The content analysis should include a brief general analysis of plan presentation with the design or design-related sections of the plan. The plan presentation and expression embraces three major components:

1. Means of communicating and techniques to convey information such as:
   1.1. Availability of illustrations and maps
   1.2. Availability of 3D illustrations and modeling
2. Approach of presenting the design strategies
3. Their contribution towards comprehensive, readable, lively, and attractive documents.

4.1- AVAILABILITY OF ILLUSTRATIONS AND MAPS

Issues of illustrations usage	Assessment		
	Unavailable	Minor	Significant
1-Reference to illustrations in the text			
2-Explicating the analytical content			
3-Explicating the purpose of the plan			
4-Using illustrations to illustrate any specific design policy such as :			
4.a-The spatial design strategy			
4.b-The location of conservation areas			
4.c-The areas of townscape differentiation			
4.d-View corridors			
5-Providing a source of contextual information to the reader			

4.2- APPROACH OF PRESENTING THE DESIGN STRATEGIES:

Question: Did the design plan adopt any of the following approaches to present the design strategy?

Presentation approaches	Assessment		
	Unavailable	Minor	Significant
Breaking the key strategy map into numerous sub-area maps			
Superimposing the suggested design alternative (2D) map on the study area map			
Superimposing the suggested design alternative (3D) model on the study area (3D) model			
Breaking the key strategy map into numerous themes or categories according to certain criteria			
Using the layering and de-layering technique			
Combining design policies in one overall design map			

4.3- Techniques of Presenting Urban Design Policies

Presentation Modes	Computer models w/ final design solution(s)	Computer models (existing situation)	3Dimensional maps	Physical Models	Perspective drawings	Photographs	2Dimensional maps	Thematic maps	Schematic maps	Surface maps	Figure ground	Diagrams	Tables
Design Policies													
1-Sustainable urban design													
2-Townscape													
3-Urban form													
4-Public realm													
5-Mixed use and tenure													
6-Connections and movement													
7-Architectural character													
8-Landscape Architecture													
9-Conservation areas and listed buildings													

APPENDIX D

SAMPLE OF A CONTENT ANALYSIS CODING FORM DOCUMENTING THE DESIGN CONTENT OF ONE COMPUTATIONAL PLAN

1	TITLE OF URBAN DESIGN PLAN:	THE FORT POINT DISTRICT 100 ACRES MASTER PLAN
2	City:	Boston, MA
3	Name of City Department:	Boston Redevelopment Authority
4	Year of development:	2003-2004
5	Firms developing the plan:	
		BOSTON REDEVELOPMENT AUTHORITY
		BOSTON TRANSPORTATION DEPARTMENT
		BOSTON ENVIRONMENT DEPARTMENT
6	Date of the analysis:	From : April 11 To: April
7	Type of plan:	Computational Plan
8	Comments:	Four years of collaboration between several groups
		Six existing planning initiatives have included the 100 acres area and provided the planning basis for its development
		Followed LEED criteria and standards of sustainable development

STRUCTURE OF THE CONTENT ANALYSIS

The content analysis is organized into four major sections as follows:

1. General approach, which embraces approaches to design, the stated purposes for producing the plans, site analysis upon which design plans are based, structure of the plan, and type of design guidance;
2. Design content;
3. Hierarchy of policies; and
4. Plan expression and presentation.

1-THE GENERAL APPROACH:

The general approach of the plan embraces the following:

1. Purposes of producing the plan;
2. Site analysis;
3. Structure of the plan; and
4. Type of design guidance.

1.1- Purposes:

Question 1: What are the main stated purposes of the urban design plans?

1	**Guide the transformation of the area from industrial use to mixed use.**
2	**Create a harbor plan and public realm more in keeping with Boston's urban character and mixed-use economy than would have resulted under the strict application of the State's Waterways Regulations.**
3	**Provide the basis for reevaluating the area's outdated zoning provisions.**
4	

Question #2: Does the statement of purpose emphasize any of the following design considerations?

Design considerations		Degrees of Emphasis		
		No emphasis	Minor	Significant
1	Visual considerations			X
2	Functional considerations			X
3	Environmental considerations		X	
4	Urban experience			X
5	Specific design considerations			X

1.2- Site Analysis

Question #1: What is the type (or level) of site analysis within the plan?

No.	Analytical Element	Type of Analysis			
		Explicit	Implicit	Integral	No evidence
1	Land-use and transportation			x	
2	Architecture, streetscape, and open space			x	
3	Socio-economics factors		x		
4	User perception and behavior				x
5	Natural factors	x			
6	History	x			

1.3-Structure of the plan

Question: what evidence is there for breaking the key design strategy into numerous sub-area maps?

a-Significant		b-Minor		c-No evidence	X

1. 4- Type of design guidance

Question: what is the type of design guidance given throughout the plan?

e- Highly prescriptive guidance		f- Neutral/ framework guidance	X
g- Enabling guidance	X	h- A combination of two or more types.	X

2- DESIGN CONTENT

2.1-Design considerations:

Question: With what degree of emphasis did the plan content emphasize the following design considerations?

Design considerations		Degrees of Emphasis		
		No emphasis	Minor	Significant
1	Visual considerations			X
2	Functional considerations			X
3	Environmental considerations			X
4	Urban experience			X
5	Specific design considerations			X

2.2-Design policies of the urban design plan

Question: What is the extent of coverage of each of the following design aspects and their constituent elements in the plan's document?

		Extent of coverage			
Number	Design aspects and issues	Location in plan	No coverage	Minor	Significant
1	**Townscape (Visual composition of space)**				
1	**Buffers:** treatment of interface between commercial and residential uses.	1			x
2	**Character:** district character, character maintenance and improvement	2			x
3	**Context:** Connections among districts and city, visual links to context	3			x
4	**Continuity** of streetscape and streetscene	4			x
5	Eyesores		x		
6	**Identity:** genius loci, unique identity	5		x	
7	Intrusions		x		
8	Landmarks		x		
9	Morphology	6		x	
10	Sense of place	7			x
11	**Setting:** expression of natural setting, enhancement of natural form	8			x
12	Skyline protection	9			x
13	Topography		x		
14	**Views:** View corridors, views to hills, bay, lake, and ocean	10			x
15	Visible framework of public facilities	11			x

16	**Vistas and overlooks**	12			x
17	**Visual orientation:** to gateways, approaches, and landmarks	13			x
2	**Urban Form (Three-dimensional built volume)**				
1	**Bulk** of buildings	14		x	
2	**Character:** contemporary architectural character	15		x	
3	**Daylight/Sunlight:** controlling sense of enclosure, controlling shadow impacts	16		x	
4	**Density** defined by visual principles, privacy		x		
5	**Density**: residential density, plot area ratio, units per acre	17		x	
6	**Height**	18			**x**
7	**Massing:** rhythm, urban pattern, grain , and texture	19			x
8	**Richness and visual interest:** spatial complexity, variety of spatial experiences	20			x
9	**Scale:** human scale, pedestrian scale	21		x	
10	**Space system**: urban & open space structure	22			x
11	**Unsightly nuisances**		x		
12	**Urban image:**	23		x	
13	**Urban streetscape character:**	24			x
14	**Visual qualities of streetscape and open spaces:** sense of enclosure, space definition	25			x
3	**Architectural Character**				
1	*Architectural form:* Building spacing		x		
2	Bulk		x		
3	Design character	26		x	
4	Form	27		x	
5	Height	28			x
6	Massing	29		x	
7	Scale		x		
8	Size		x		
9	*Elevations:* Contemporary design	30		x	
10	**Design Vocabulary:** relation with surrounding environment	31		x	
11	Style	32		x	
12	Richness and visual interest		x		
13	*Elevation details:* Materials		x		
14	Roofscape		x		
15	Proportions		x		
16	Fenestrations		x		
17	Detailing		x		
18	Color		x		
19	Rhythm		x		
20	Silhouette/ Profile		x		
21	Vertical / horizontal emphasis		x		
22	Texture		x		
4	**Conservation Areas and/or areas of special character**				
1	*Urban form and townscape:* Urban form	33			x
2	Building line	34		x	
3	Character: Maintenance of original -historic-character, creation of an authentic character	35			x
4	Density	36		x	
5	Grain	37			x
6	Morphology	38		x	
7	Urban space	39			x
8	*Urban form and townscape:* Townscape	40			x
9	Landmarks	41		x	
10	Setting: Maintenance of authentic setting	42			x
11	Skyline	43			x
12	Topography		x		

13	Views	44			x
14	*Architectural form and detail: Scale*		x		
15	Height	45			x
16	Massing	46		x	
17	Form	47		x	
18	Bulk	48		x	
19	Size		x		
20	*Elevations considerations:* Contemporary design, design vocabulary		x		
21	Style	49		x	
22	Richness and visual interest		x		
23	Materials		x		
24	Roofscape		x		
25	Proportions		x		
26	Fenestrations		x		
27	Detailing		x		
28	Color		x		
29	Rhythm		x		
30	Silhouette/ Profile		x		
31	Vertical / horizontal emphasis		x		
32	Texture		x		
33	*Listed buildings policies: Rehabilitation*		x		
34	Preservation/conservation		x		
35	Extensions		x		
36	Adaptive re-use		x		
37	Infill development		x		
38	Renovations		x		
5	**Connection and Movement Network**				
1	**Accessibility** by public transportation	50			x
2	**Accessibility:** to open spaces, to all (pedestrians, motorist, bicyclists)	51			x
3	**Cycling environment:** bicycle access		x		
4	**Efficiency:** efficiency in traffic flows, congestion reduction	52			x
5	**Efficiency:** efficiency in transportation network	53			x
6	**Parking:** accommodation of parking, access to parking	54			x
7	**Pedestrian network:** Pedestrian routes, link to parking, pedestrian -vehicle conflict	55			x
8	**Streets network:** accommodation of traffic	56			x
6	**Land -use (Mixed-use and diversity)**				
1	**Diversity:** diversity of business types and services, cultural and economic diversity	57			x
2	**Mixed land-use:** Mixing of uses in urban areas	58			x
3	Provision of adequate and private amenity spaces in urban areas	59			x
7	**Sustainable Urban Design**				
1	Alternative transportation	60		x	
2	**Control of pollution**: noise reduction		x		
3	**Drainage:** drainage systems, maintenance of drainage systems		x		
4	**Ecology:** Preservation of outstanding natural features	61			x
5	**Energy:** Energy conservation, orientation	62		x	
6	Materials		x		
7	Micro-climate	63		x	
8	Resources: avoiding overload on resources	64			x
9	Site design and layout	65		x	
10	Traffic management	66			x
11	Urban form	67		x	
12	**Water**: water fronts, water conservation, water quality	68			x
8	**Public Realm (The social experience)**				

1	**Functional concerns:** Parking, servicing, relation between public and private spaces	69			x
2	**Public perceptions** of the identity and quality, sense of community, street level interest	70			x
3	Security and design against crime		x		
4	Sense of urbanity	71		x	
5	**Social Interaction:** social places, gathering places, opportunities of social interaction	72			x
6	**Vitality:** economic vitality, maintenance of downtown vitality	73			x
9	**Landscape Architecture**				
1	*Strategic landscape considerations:* Boundaries	74			x
2	Existing vegetation	75		x	
3	Landscape survey		x		
4	Open space	76			x
5	Topography		x		
6	Urban edge	77		x	
7	*Soft landscape design:* Soft landscape improvements	78			x
8	Trees and greenery	79		x	
9	Species		x		
10	Buffers	80			x
11	Water	81			x
12	Landscape layout	82		x	
13	*Hard landscape design:* Floorscape	83		x	
14	Hard landscape	84			x
15	Street furniture	85			x
16	Lighting	86			x

3- HEIRARCHY OF POLICIES

3.1- The scales (or levels) of intervention:

Question: What is the degree of emphasis on each level of design intervention and the cross referencing between those levels in the urban design plan?

		Degree of Emphasis		
Number	**Cross Referencing between Levels of Design Intervention**	**No emphasis**	**Minor**	**Significant**
1	**Scales (or levels) of intervention**			
1	Strategic urban design at the city/conurbation level.			**x**
2	Strategic urban design at the city/district level			**x**
3	Urban design at the level of individual spaces or groups of spaces.		**x**	
2	**Cross referencing of the multiple levels of design intervention**			
1	Cross referencing of the multiple levels of design intervention			**x**

4-PLAN PRESENTATION AND EXPRESSION

4.1- Availability of illustrations and maps

Question: To what extent were the illustrations made available and used in the plan?

		Extent		
Number	**Availability of Illustration Issues**	**Unavailable**	**Minor**	**Significant**
1	**Issues of illustrations usage**			
1	Reference to illustrations in the text			x
2	Explicating the analytical content			x
3	Explicating the purpose of the plan			x
4	Using illustrations to illustrate any specific design policy such as:			
5	a-The spatial design strategy			x
6	b-The location of conservation areas			x
7	c-The areas of townscape differentiation			x
8	d-View corridors			x
9	Providing a source of contextual information to the reader			x

4.2- Approaches of presenting the design strategies

Question: Did the design plan adopt any of the following approaches to present the design strategy?

		Extent		
Number	**Presentation approaches**	**Unavailable**	**Minor**	**Significant**
1	Breaking the key strategy map into numerous sub-area maps	x		
2	Superimposing the suggested design alternative map on the study area map (2D)	x		
3	Superimposing the suggested design alternative model on the study area model (3D)			x
4	Breaking the key strategy map into numerous themes or categories according to certain criteria			x
5	Using the layering and de-layering technique		x	
6	Combining design policies in one overall design map		x	

4.3- Techniques of presenting urban design policies

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
1	Townscape	x	x				x	x	x						
2	Urban form	x					x	x	x					x	
3	Architectural character						x		x	x					
4	Conservation areas		x				x	x	x	x					
5	Connections and movement							x	x	x					
6	Land-use (Mixed use and diversity)	x	x					x	x						
7	Sustainable urban design		x					x	x	x					
8	Public realm		x					x	x	x					
9	Landscape Architecture							x	x	x					

[1] P.36;p.52; P.61
[2] P.42; P.62
[3] P.32; p.49;p.52
[4] P.42;p.50;p.52; P.55
[5] P.42;p.49
[6] P.42; P.62
[7] p.42;p.49;p.52
[8] P.50
[9] P.32;p.40;p.64
[10] P.40, p.42;p.50
[11] P.49
[12] P.32; p.40; p.42;p.50
[13] P.32;p.40; p.42;p.50
[14] P.32; p.33
[15] P.66
[16] P.36;
[17] P.36; P.62; P.63
[18] P.32; P.63; p.64
[19] P.42; p.64
[20] P.50;p.52
[21] P.33;p.42
[22] P.32;p.40;p.49; p.50;p.52
[23] P.52
[24] P.49;p.50;p.51; P.55; P.66
[25] P.42;p.49;p.51; P.55; P.66
[26] P.66
[27] P.40

[28] P.66
[29] P.40
[30] P.66
[31] P.66
[32] P.66
[33] P.50
[34] P.51; P.66
[35] P.33;p.40;p.42;p.50; P.62; P.66
[36] P.62
[37] P.42
[38] P.42;p.50; P.62
[39] P.33; ;p.49; P.62
[40] p.42;p.50
[41] p.42
[42] P.33;p.40;p.42;p.50; P.62; P.66
[43] P.40; p.64
[44] P.40; p.42
[45] P.33; P.66
[46] P.33;p.40
[47] P.33;p.40
[48] P.33;
[49] P.66
[50] P.48
[51] P.40; p.42;p.49;p.50
[52] P.40; p.45; PP.69-71
[53] P.40; P.42; p.45, p.48; P.68; PP.69-71
[54] p.47
[55] P.40; p.42; p.45; p.46;p.49;p.50; P.54
[56] P.40; P.42; p.45; P.68; PP.69-71
[57] P.36;P.40; P.62; PP.70-71
[58] P.36; p.40; P.61; p.62; PP.70-71
[59] P.33; P.36;p.40; P.61; p.6; PP.70-71
[60] P.46-49
[61] P.67
[62] P.67
[63] P.35;
[64] P.35; P.67
[65] p.65; P.67
[66] P.46-49; P.62; PP.69-71
[67] p.65
[68] P.35;p.49; P.66
[69] P.33;p.50; P.55
[70] P.49;p.50; P.55; P.62
[71] P.49; P.62
[72] P.49;p.52
[73] P.52; P.61; P.62
[74] P.49;p.52; P.54
[75] P.52
[76] P.32;p.49;p.52; P.54
[77] P.32
[78] P.50;p.51;p.52; P.54
[79] P.50;p.52;p.54; P.55
[80] P.54
[81] P.49
[82] P.50;p.52
[83] P.54
[84] P.54

[85] P.54; P.55
[86] P.54; P.55

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EDUCATION

Baghdad University, Department of Architecture, B.S. Architecture, June 1982.
Baghdad University, Center of Urban and Regional Planning for Graduate Studies, M. S. Urban Planning, January 1989.
Texas A&M University, Department of Architecture, Ph.D. Architecture, August 2006.

TEACHING EXPERIENCE

2002-2006: Graduate Assistant, teaching and research, Department of Architecture, Texas A& M University.
1989-1996: Full-time Lecturer, Department of Architecture, University of Technology, Baghdad, Iraq.
Courses taught: Seminars: Theory of Urban Design; Site Planning and Design; and Architectural Programming. Design Studios: upper-level undergraduate Architectural design studios; graduate level Architectural design studios; and urban design studios.

PROFESSIONAL EXPERIENCE

1996-2001 Senior Architect/Urban Designer, Dubai Municipality, United Arab Emirates.
1990-1996 Architect-Urban Designer, Part-time, Engineering Consulting Office, University. of Technology and Baghdad University, Baghdad, Iraq.
1986 & 1988-1989 Architect, Ministry of Housing and Construction, Baghdad, Iraq.

RESEARCH INTERESTS

Applications of 3D digital modeling, visualization, and information technology in architectural and urban design practice; urban design practice; and urban renewal, conservation, and preservation of historic cities.

PUBLICATIONS

1989-2006: (Author) Eight papers in proceedings of peer-reviewed conferences and symposia.
1993-1996: (Co-Author) Urban Design: Methods and Techniques (Text book).
1993-2006: (Author) Three articles in peer reviewed journals.

FELLOWSHIPS, SCHOLARSHIPS, AWARDS, AND RECOGNITIONS

2002-2006: four academic excellence awards, three academic fellowships, and two graduate scholarships from Texas A&M University.
2005: AIA/AAF Fellowship for Advanced Study and Research.