A CAD-Based Modeling for Dynamic Visualization of Urban Environments in Piecemeal (Incremental) Growth

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I dedicate this work to the loving memory of my mother , Senay Alper.

ABSTRACT

Visualization is inherent to the conduct of urban design as a direct connection between the designer and three dimensional reality of urban settlements. Visualization of urban environments and urban design projects is vital, since most designers prefer to understand place and context through visualization. The reasons for visualization in urban design can be classified under three headings: ‘visual thinking, design communication and testing mechanism’.

‘Digital revolution’ has improved computer use in urban design, as in many other fields. Dynamic computer models can present an ideal environment to visualize the change in respect to time. Digital tools are much more efficient than conventional methods in explaining the growth and change of urban environments. Especially, incremental growth requires features not found in ‘static/analog’ media. Christopher Alexander and his colleagues, in their book *‘A New Theory of Urban Design’*, tried to justify their ideas about piecemeal growth by an experiment. The analog methods, such as physical models, two-dimensional diagrams, have been used to conduct the experiment and to convey their ideas about the design process. This thesis tries to produce a ‘dynamic/digital‘ model that could be utilized in their experiment instead of static/analog methods.

Spatial data should be considered as dynamic, or changing identities rather than as simple, static features. Time is an example of a dynamic component of a spatial data set. Recent technological developments are increasing computer hardware and software capabilities so that this dynamic aspect of data can be accounted for by today’s systems. Dynamic data have not been a great concern in digital technologies for many years, but today changing patterns and dimensions are becoming more important.

ÖZ

Tasarımcılar, kentsel çevreleri algılamakta ve anlamakta genellikle görsel araçlardan faydalanmaktadırlar. Dolayısıyla kentsel çevrelerin ve kentsel tasarım projelerinin görselleştirilmesi büyük önem taşımaktadır. Tasarımcı ile yaşam çevrelerinin üç boyutlu gerçekliliği arasındaki doğrudan bağın kurulması açısından da görselleştirme kavramı kentsel tasarımın ayrılmaz bir parçası haline gelmiştir. Görselleştirmenin kentsel tasarım alanında gerekliliği üç başlık altında toplanabilir; görsel düşünme, tasarımın anlatımı-ifadelendirilmesi ve tasarımların sınanması.

Dijital teknolojideki gelişmeler, kentsel tasarım alanında bilgisayar kullanımının yaygınlaşmasını sağlamıştır. Dinamik bilgisayar modelleri, zamana bağlı olarak değişimin görselleştirilmesi için ideal bir ortam sunmaktadır. Dijital ortam, kentsel çevrelerdeki büyüme ve değişimi ifade etmekte geleneksel yöntemlere gore çok daha verimli olabilmektedir. Özellikle parçacı büyümede, statik/analog araçlarda bulunmayan bir takım özelliklere ihtiyaç duyulmaktadır. Christopher Alexander ve çalışma arkadaşları, *‘Yeni Bir Kentsel Tasarım Kuramı’* adlı kitaplarında, parçacı büyümeyi deneysel bir çalışma ile anlatmaktadırlar. Bu deneysel tasarım çalışmasında fikirlerini anlatmak ve test etmek üzere maket, iki boyutlu çizimler gibi klasik araçlardan faydalanmışlardır. Tez, bu deneysel çalışmada yer alan araçların yerine kullanılabilecek dinamik/dijital bir model geliştirmeyi amaçlamaktadır.

Mekansal veriler dinamik ve değişken olarak ele alınmalıdırlar. Zaman, dinamik mekansal kurgunun en önemli elemanlarından birisidir. Bilgisayar donanımı ve yazılımındaki gelişmeler, mekanın bu dinamik boyutunun da günümüz sistemlerinde yer almasını sağlamaktadır. Na yazık ki, dijital teknolojide uzun yıllar dinamik veri kavramı yer bulamamıştır , ancak günümüzün değişen koşulları ve yeni yaklaşımlar bu alana büyük önem vermektedir.

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INTRODUCTION

> *"Time is the vehicle of measurement for change in formative processes. In assessing human settlements, change can be viewed as a constant, occurring in periods or rhythms differentiated as distinct and emerging realities that, when perceived, are already changing into other and different realities. Planners and designers can miss opportunity and information if they view 'place' as a finished product, without the dimension of time as a measure (and determinant) of change. Place can become an isolated piece of the built pattern, an artifact out of context and disconnected from the other realities of human settlement patterns if time is not recognized as a patterning force, something that represents the changes in a specific rhythm…"*
>
> (Kasprisin and Pettinari 1995, p.111)

The 'information age' has been presenting specific and convenient digital tools for various applications in many disciplines and fields, as well as the general use of computers in our daily life. Naturally, designers benefit from a variety of technological advances offered by computers in creating urban environments. Among these developments, digital visualization techniques have been of special interest to urban designers, who are in quest for three-dimensionality and visual feedback in the design process.

Potentialities presented by 'state-of-the art' digital technology resulted in widespread use of computers in urban design. New visualization techniques influenced the design process. However, digital visualization tools produced for the use of related disciplines, such as urban planning, architecture and landscape design, have not met the requirements and criteria of urban design.

1.1 Aim of the Study

Computer use in urban design is distinguished from the applications in other related fields, due to the necessity of a mixture of ”geometric, geographical, and annotative information”. This difference requires opportunities for “collaboration, needs for data integration, and examples of the increasing importance of rich datasets as a basis for design work” (McGullough and Hoinkes 1996). For instance; planning requires visualization of information on a two-dimensional map; or typically, in architecture, perspective rendering of a single building is considered.

Visualization can be defined as ‘the ability to create mental pictures which lead to the manifestation of a design solution’ (Dong and Gibson 1998, p.4). Visualization of urban environments and urban design projects is vital, since most designers prefer to understand place and context through visualization. Visual thinking is an important characteristic of a designer. Designers also need to communicate their ideas to themselves, to decision-makers and other members of the public. Presentation of these ideas effectively, improves the level of communication between all interests in the design process. The produced images can also be utilized for testing of ideas in relation to urban policies and regulations.

Urban design is very much engaged with the visual form of the city. Therefore, visualization is inherent to the conduct of urban design, not just as a representative media, but as a direct connection between the designer and three-dimensional reality of human settlements. (Kasprisin and Pettinari 1995, p.112) The need for three-dimensionality suggests effective utilization of digital graphics in the field and increases the importance of computer-aid in urban design.

The city does not have a static character and urban settings cannot be seen as finished products of a single design process. Places certainly change; and this change can be explained as a function of time. Urban designers can utilize ‘time-patterning’ technique as “a learning process, studying historic patterns, and formative processes that created them, and translating and interpreting these patterns through graphic diagramming techniques as a key part of the design process”(Kasprisin and Pettinari 1995, p.112). Adding the fourth dimension to three-dimensional models can be a helpful tool to explain the growth and change in urban design environments.

Dynamic computer models can present an ideal environment to visualize the change in time. The thesis aims to prove that digital tools are much more efficient than conventional methods in explaining the growth and change of urban environments. Especially, incremental growth requires features not found in ‘ **static/analog** ’ media. Christopher Alexander and his colleagues, in their book *‘A New Theory of Urban Design’*, tried to justify their ideas about piecemeal growth by an experiment. The analog methods, such as physical models, two-dimensional diagrams, have been used to conduct the experiment and to convey their ideas about the design process. This thesis will try to produce a ‘ **dynamic/digital** ‘ tool that could be utilized in their experiment instead of static/analog methods.

1.2 Goals and Objectives

This thesis, first of all, has a goal to draw attention to potential areas of study in computer-aid in design related to aspects particular to urban design. However, the field of urban design is extremely broad to include all of its aspects and criteria in a single research. Throughout the chapters, these aspects will be mentioned, directly or hidden between the lines. But, to be more specific, the study concentrates on the issue of ‘change of place and context in time’ in three-dimensional computer models.

Secondly, the efficiency of computer software should be improved in meeting the urban designers’ wishes and in being familiar to the way they design. The computer systems, configured by computer professionals or software engineers, would not normally match the professional needs and expectations of an urban designer. Research suggests that, contributions of urban designers will be appreciated in the area of digital graphics. The elements, criteria and aspects of urban design should be well-integrated to computer systems. The traditional urban design process should also be revised to go with the new technological conditions.

Next, there is a need in creating an interactive design environment where urban designers do not have to be specialized in computers. This interactive environment should be flexible enough to include factors like ‘customization, scalability, collaboration and productivity’. Different types of human-computer interaction techniques should be employed in computer-aided urban design systems. This study tries to avoid the unsatisfactory results of poor human-computer dialogue.

Theory of urban design has paid special attention to ‘the change of place in time’. Piecemeal or incremental theory was significant in the growth of cities. For ages, urban environments have developed piece by piece to form a meaningful and organic whole. To study this type of growth by the help of digital graphics would normally contribute to the development and explanation of the theory. Dynamic computer models can present an ideal environment to visualize the incremental growth. As in other fields, dynamic visualization should not only mean the user’s or participator movement as in ‘animated walk-throughs’. Instead, dynamic modeling of the environment, itself, with its elements, which are increments in this case, is considered as a major result of the thesis.

1.3 Scope of the Thesis

Actually, the term ‘visualization’ can include all kinds of graphic communication techniques such as ‘traditional drawings, maps, perspectives, three-dimensional physical scale models, computer-generated models, and scientific visualization’. The type of visualization mentioned in the scope of this thesis is that produced by computer modeling tools, mainly three-dimensional with reference to two-dimensional data, and in terms of the concepts such as ‘accuracy, abstraction and realism’.

This thesis tries to cover all the contemporary researches conducted in the field of digital visualization of urban environments, within the limits of all available resources. Moreover, in the area of research, it makes an effort to locate itself as a valuable source, containing up-to-date information. The fact that this kind of a research is new to our country, makes this research more important for its contributions in the area of computer-aided urban design. It also aims to create new subjects for other researchers and for future studies.

It should be noticed that computer visualization technology is developing rapidly. During the background studies for this research, many studies and researches were being carried in different countries all over the world. Hence, the information included here has been revised, again and again, just to be able to capture the latest technological advances. Still, this study can only be a snapshot of technological developments in the flow of time.

The scope of this study does not include the issue of computer programming. Here, it is important to present the subject from an urban designer’s point of view, rather than to see the subject as a task to be carried out by software engineers. But, in order to understand the logic of the systems and tools, computer hardware and software systems have been examined in detail. As a result of eight years of practice in the field of computer-aided design, the experiences and information gained by the author have also assisted in the composition of the thesis.

1.4 Thesis Organization

Although the digital systems are in the scope of this thesis, urban visualization modeling has been considered with references to analog techniques. The thesis has been structured in a way that it begins with the fundamentals and needs for urban visualization, develops through digital systems individually and relatively; and then explains the theory of incremental growth; finalizes with application of the systems for piecemeal growth.

In Chapter Two, the importance of visualization for urban design and how it can be utilized in different stages of design process is discussed. Various concepts emerging in computer visualization techniques are presented from the past to the future. The digital tools, developed for 3-D modeling and visualization of urban environments, include Urban Geographic Information Systems (Urban-GIS), Computer Aided Design (CAD), Virtual Reality Aided Design (VRAD) and Web-based applications. The capacity of these systems and their uses in digital visualization have been examined.

The Third Chapter focuses on the recent technological advances in computer systems, in terms of hardware and software. Contemporary trends emphasize the need for integration of diverse systems and tools. However, a complete integration could not be succeeded yet because of the limitations in hardware and software power that are widely available for professionals. Depending on these developments, the second part of this chapter presents a collection of outstanding digital visualization samples and case studies in the field of research.

In Chapter Four, the dynamic character of urban environments is examined. The incremental growth model and spatio-temporal change are explained. In this part, the subject is studied according to the theory of urban design. With the help of the theory, development of a computer model is explained in the fifth chapter. The experiment made by Christopher Alexander and his colleagues is re-evaluated by the assistance of digital tools. The design process is represented in virtual environment.

The thesis is concluded with the discussions of the major results of the study in Chapter Six. A set of researchable questions that could extend this work or address future related topics is also presented.

1.5 Original Discussions of the Thesis within the Related Disciplines

Urban design can be defined as “the attempt to give form, in terms of both beauty and function, to selected urban areas or to whole cities. Urban design is concerned with the location, mass, and design of various urban components and combines elements of urban planning, architecture, and landscape architecture.” (Simon 1986, p.560)

Urban designer does not have a clear area of activity. Critics have always argued the relationship between ‘City planner – Urban designer – Architect’ :

> ”An urban planner, was someone who was primarily concerned with the allocation of resources according to projections of future need. Planners tend to regard land use as an allocation of resources problem, parceling out land, for zoning purposes, without much knowledge of its three-dimensional characteristics, or the nature of the building that may be placed on it in the future. The result is that most zoning ordinances and official land use plans produce stereotyped and unimaginative buildings. Architect, on the other hand, design buildings. A good architect will do all he can to relate the building he is designing to its surroundings, but he has no control over what happens off the property he has been hired to consider. There is a substantial middle ground between these

> professions, and each has some claim to it, but neither fills it very well. Land use planning would clearly be improved if it involved someone who understands three-dimensional design. On the other hand, someone is needed to design the city, not just the buildings. Therefore, there was a need for someone who could be called an urban designer." (Barnett 1974, p.11)

Thus, in order to interpret the subject better for urban design, it is necessary to discuss the developments and ideas in relevant disciplines:

1.5.1 Urban Planning

Planners have always looked for new tools to enhance their analytical, problem-solving, and decision making capabilities. (Mandelbaum 1996; Nedovic-Budic 2000) The use of computers in urban planning dates back to 1950s; that can be accepted as the earliest computer applications in a design-related field. Tasks performed during planning process; such as demographic and economic analysis, land use and transportation studies, etc., require huge data collection and manipulation. Planners' work, which mostly depends upon the collection, analysis and presentation of information, is supported by the power of computing (Arbeit 1988, p.112-5)

However, computer use in planning cannot be limited to data management. Especially, with the development of microcomputers by the late 1970s, computers have become widely available for desktop use, thus fundamental tools of planning practice in various types. Computer applications for urban planning can be named as:

- Database Management
- Electronic Spreadsheets
- Presentation Graphics
- Statistical Analysis
- Mapping and Geographic Information Systems
- Computer Aided Design

- Project planning and management
- Artificial Intelligence
- Specialized Programming

Computer technology has given planning practice depth by increasing its data analysis and modeling capabilities. Nowadays, urban planners have the opportunity to apply spatial information technologies in all aspects of planning process. (Nedovic-Budic 2000, p.82). The applications include:

- GIS database development for planning related analysis
- integration of geospatial technologies with urban models
- building of planning support systems
- facilitating discourse and participation in the planning process;
- evaluation of planning practice and technological impact.

Visualization of existing urban-related processes and phenomena and simulation of outcomes of proposed plans and policies is in the core of planning practice. Further developments in three-dimensional modeling, virtual reality, incorporation of images, easy graphical manipulation of various urban components, movement through space, changing perspectives, linking with planning and policy documentation and descriptive statements, and annotation tools for dialog and commentary will enhance the communication capacity of urban planners. As with all applicable technologies, to make the visualization tools useful for planning practice, their customization and integration into the planning practice will be a necessary aspect of the development(Nedovic-Budic 2000, p.86). And finally Hall suggests that:

> “The importance of computer visualization for planning practice lies in its potential for the improvement of the quality of decision-making by virtue of its ability to avoid misunderstandings in the negotiation of the outward form of development.” (Pietsch 2000, p.522)

1.5.2 Architecture

Architects have the responsibility to design not only individual buildings but groups of buildings and the open spaces in between them. (McCullough 1995, p.115) Urban design field is in upheaval and conflict. The position of the architect is being questioned now and it is not surprising that he has become a member of a complex urban design team (Lynch 1974, p.533). Research suggests that digital technologies have made noticeable contributions in communicating architectural projects more effectively (Neto 2001;Ojeda and Guerra 1996;Larson 1996;Boryslawski 1996). Potentialities of the digital technology have also “forced architects to think more clearly in three dimensions and gain a better understanding of connections and form.” It also allows visualizing complex shapes, which are impossible to describe with conventional media (Larson 1996, p.14).

Figure 1.1 Hyper-realistic digital rendering - Tokyo International Forum by Rafael Vinoly Architects (Ojeda and Guerra 1996, p.37)

Generally speaking, for architects, computer use means all kinds of CAD applications, including two-dimensional drafting, three-dimensional modeling, hyper-realistic perspective renderings, and animated ‘walk-throughs’. The dominance of CAD systems in architectural practice has become so apparent and noticeable that, the technology had to specialize and differentiated with the use of the term ‘CAAD’, which stands for ‘Computer-Aided Architectural Design” (Goodfellow 1996; Voisinet 1987)

> “CAAD is characterized by an ingrained prejudice against the conventional two-dimensional drawings that represent the bulk of existing architectural documentation. By propagating novel-design representations for the generation of designs and photorealistic three-dimensional images for presentation, CAAD has done little to promote the analysis of orthographic projections like floor plans, sections and elevations.” (Koutamanis 1997, p.1)

J Rabie suggests that, by using traditional architectural drawings, it is not possible to succeed an effective way of communication between local authorities and architects. And this would result in a lack of consistency in the perception of urban developments:

> “Architects extrapolate from experience those elements which they have left invisible in this partial and abstract representation. However, because this is the way in which they draw, it follows that the documents prepared for those less initiated – client, city authority, the public – are similarly presented. These people do not share their facility, the abstraction baffles and the reduced image compares poorly with the future reality which it is meant to evoke.” (Rabie 1991, p.64)

In response to the ideas supporting the advantages of visualization, some architects might still believe that making these environments perceptible by others does not add much to their design. Bill Jepson, head of the ‘Virtual LA’ project at UCLA, believes that architects object to the technology mostly supported by urban developers:

> “Jepson says in most cases … he is hired by developers to create simulated models of architectural plans in order to make them more communicable to the layperson. But this role has raised the ire of some designers. ‘The architects don’t like what we do. They feel it impinges on their independence,’ says Jepson. But the developers love us’ because the simulator allows the developer to work with the urban-simulator team to alter the architects’ designs. “ (Bennett 1999, p.12)

Figure 1.2 CAAD visualization - Office development ‘101 Second Street’ by Skidmore, Owings & Merrill (Ojeda and Guerra 1996, p. 91)

The general use of architectural models is to communicate or market a development which has had all of its designs finalized. They are often crafted to a very high level of detail, which is fine for marketing purposes but has been found to be detrimental to the participatory process.

> “In fact the more detailed a proposal model the more criticism it invites. This is because the potential user of the facility likely interprets the finely drawn and constructed models to suggest that everything has been decided and the only role available to them is to accept or reject the proposal. This demotion to role of spectator on the part of the user invokes strong criticism of particular design features. Far too often this criticism results in the developer removing the controversial feature, but failing to replace it with anything. This outcome can actually be less favorable to the public at large, but due to lack of quality participation this often occurs. In fact detailed architectural models have been found to reduce public participation. The models themselves tend to intimidate the participants for fear of experimenting with the finely detailed and often delicate models; for instance in the case of the Green Machine housing study hundreds of adults refused to make changes to a finely detailed model even when urged to by the designers.” (Goodfellow 1996)

1.5.3 Landscape Design

As in other related fields of design, computer applications have become popular in all aspects of landscape architecture. Computers are utilized for “bookkeeping and correspondence, land use and resource inventories, various kinds of analysis, land use allocation problems, site engineering tasks, and the production of working drawings”. Computer-aided techniques for landscape design include computer-aided land planning or geographic information system (GIS) applications. (Gionet 1988, p.130-7)

In terms of computer modeling, the creation of virtual landscapes demands highly complex structures. The need for large data sets pushes the limits of software and hardware systems in landscape visualization. “Instead of manually modeling the environment, which is the traditional CAD approach, a GIS-based approach is pursued.” (Lange 2001, p.163) This is the case for most of the computer applications in landscape architecture, also preferred by many other professionals.

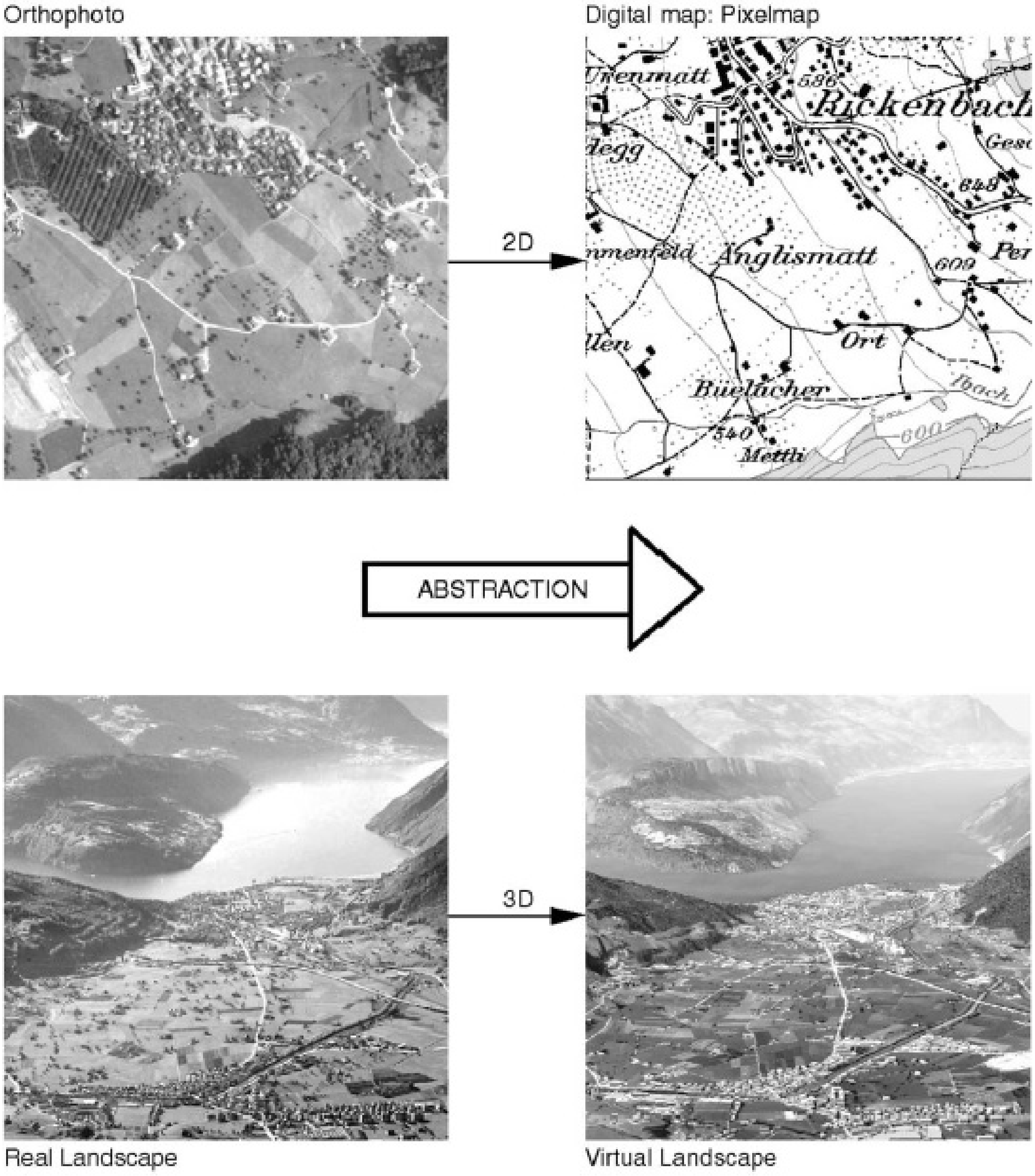


Figure 1.3 Digital techniques in landscape visualization (Lange 2001, p.168)

The basic elements of landscapes to be represented in virtual environment are; terrain, built objects and vegetation. For computer visualizations, the study area is modeled by using various elements like digital terrain model, digital images and land use data is integrated.

Mandelbrot reacts to the idea of realism in digital landscape visualizations: “Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line.” (Lange 2001, p.165) However, 3D digital representations are excellent for viewing detailed geographical areas and require little interpretation by the user on the form of the landscape. In an experiment made about perception of virtual environments; firstly 2D images of the site were shown to the students and problems occurred in their understanding of landscape features. In the second case, oblique views and 3D visualizations of the same data were presented and their perception improved.(Barstow et al. 2000) 3D landscape visualizations also gives opportunity “to directly compare landscape form(elevation) with derivative measures of that landscape (e.g. aspect, slope) simply by draping an 2D image of the derivative over the 3D landscape model.” (Morrison and Purves 2002, p.167)

In today’s technology, digital landscape visualizations mainly occur in three types :

- Image draping; a widely used technique by applying image layers (satellite data, digital aerial photographs, etc.) over a 3D representation of the terrain. Expected output should be as ‘still images’, but rarely animations can be generated.
- Photorealistic rendering; an artistic approach in which images of landscape features are utilized for a realistic visualization. Still images and animations are possible forms of output.
- Virtual Worlds; an interactive environment created for the user to explore a virtual landscape. (Appleton et al. 2002, p.144-147)

Chapter 2

THE CONCEPT OF DIGITAL VISUALIZATION IN URBAN DESIGN

> *“The form of the environment can be influenced in a number of ways. The most obvious, to a designer trained in architecture, is simply to specify the environment in a set of drawings. This is rarely possible... Most urban designs are diagrammatic. They refer, not so much to the exact form of things, as to the character or spatial effect intended, the clusters of behaviour expected in the spaces provided, the image structure, the basic circulation and activity location, and the types of management of control... A diagrammatic model, a control document, a series of slides, or a film may be better than a plan, section or elevation. Showing how a place will develop over time is more effective than drawing what its final form wil be.”*
>
> (Lynch 1974, p.274-5)

2.1 The Need for Visualization in Urban Design

Visualization of urban environments, whether existing or proposed, is vital and an integral part of design process. Besides usual ‘project presentation to client’ purposes, many rational reasons can be found for visualization of an urban setting, in comparison with an industrial design product or a single building.

Due to its inter-disciplinary character, urban design “attempts both to measure the consequences of visual moves, such as design improvisations, and to visualize the consequences of measured moves, such as socio-economic policies.” It requires to work with a wider variety of data and to involve more participants during the design process. (McCullough and Hoinkes 1995)

Visualizations can be accepted as works of art, since they are created with tools and techniques; not only decoration and renderings, but interpretations and translations using the elements and principles of art as integral parts of the design process. (Kasprisin and Pettinari 1995, p.51)

Research suggests the need for visualization in urban design for various reasons. The reasons for visualization in urban design can be classified under three headings: ‘visual thinking, design communication and testing mechanism’.

2.1.1 Visual Thinking

The practice of urban design is an intentional act of integrating culture, biological environs, artifact and functional needs; and especially focuses on the visual qualities of urban environments. (Barnett 1982; Kasprisin and Pettinari 1995, p.xiii; Relph 1982, p.229) Visualization assists the designer in visually perceiving and evaluating the underlying conditions and changes. Visualization can be used as ‘a mental tool’ to be able to study the urban issues :

> “Visualization is inherent to the conduct of urban design, not as a representative media, but as a direct connection between the designer and the three dimensional reality of human settlements and ... the most cognitive process useful in exploring spatial relationships.” (Kasprisin and Pettinari 1995, p.xiii)

However, visual thinking is not only applicable to the field of design. In scientific visualization, special emphasis is given to the relationships between formalization and the aspects of cognition and communication that makes it possible to be used successfully in a problem solving context (Cassettari 1993, p.183). It includes several techniques of analysis and display in a technically precise way. For instance, scientist Albert Einstein used visual images to deal with complex problems in physics. His following statement explains his visual thinking process: "…elements in thought are certain signs and more or less clear images which can be voluntarily reproduced and combines…This combinatory play seems to be the essential feature in productive thought before there is any connection with logical construction in words or other kinds of signs which can be communicated to others." Dramatist John Dryden, when writing his famous *The Rival Ladies*, suggests that his mind moves from a mass of confused thoughts: "…the sleeping images of things towards the light, there to be distinguished, and then either chosen or rejected by the judgment". For many professionals from different fields and disciplines, visualization becomes "a mental tool to create and solve problems". (Dong and Gibson 1998, p.4)

Visualization assists the designer in the interpretation of complex urban patterns. The use of visualization as a cognitive process can be generative, since spatial relationships are formed and evolved as a result of the process. Rudolph Arnheim, in his book *Visual Thinking*, points out that "…cognitive operations called thinking are not the privilege of mental processes above and beyond perception but the essential ingredients of perception itself … active exploration, selection, grasping of essentials, simplification, abstraction, analysis and synthesis, completion, correction, comparison, problem solving, …combining, separating, putting in context". (Arnheim 1969, p.13) And he states that "Shapes are concepts … what matters is that an object at which someone is looking can be said to be truly perceived only to the extent to which it is fitted to some organized shape." (Arnheim 1969, p.27).

The use of three-dimensional drawings can give a better opportunity to integrate urban information into a meaningful context. The invention of the perspective, during the Renaissance, enabled the designer to use a drawing in perspective as an optical device, to be able to perceive before it exists, a feature reality obeying Euclidean geometry, to calculate measurements, to create effects, to propose virtual realities. Since Leonardo da Vinci, the aim of the model has been simulation: Simulation for evaluating 'convenience, solidity, beauty' , to have an image of a design with a basis in reality, a reality that we can control and determine, visualize, qualify an image that is objective and complete. (Quintrand 1994, p.93)

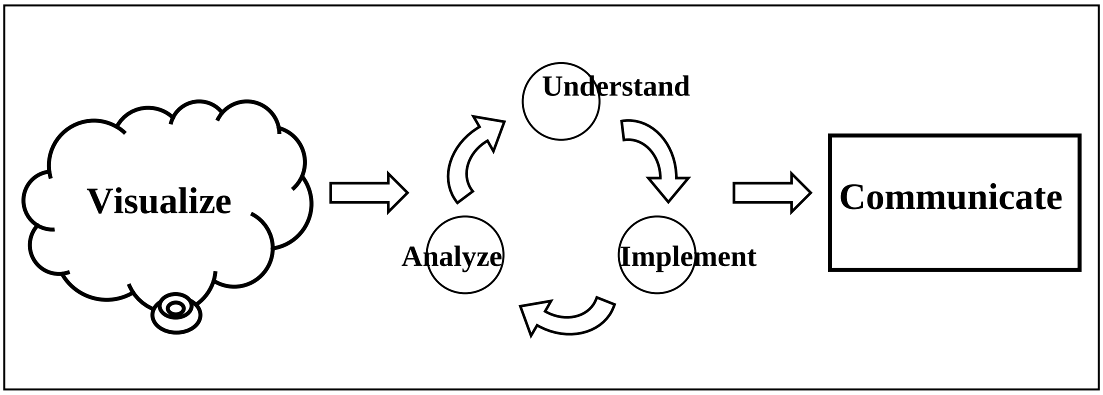


Figure 2.1 Visualization-communication model (Dong and Gibson 1998, p.4)

Visualization can be described as “the ability to create mental pictures which lead to the manifestation of a design solution”. (Dong and Gibson 1998, p.4) Visualization is a starting point for converting “data into provocative, spatial, connected differentiations” that allows the designer to explore more connections or ideas. (Kasprisin and Pettinari 1995, p.50)

Visual presentation of a design problem is closely linked with its solution (Dobilet 1984, p.140). Through artistic inquiry, the designer states a position, describes a philosophy, explains a set of values. The principal means of this act is visualization - as a language for analyzing and revealing the order of things. Through visualization, the designer tries to "simplify complexities and, by simplifying and diagramming, to express essential sensory relationships in the form of design" (Trancik 1986, p.228).

The urban design process can be systematized in five steps : (Schmitt 1988, p.5-6): *“(1).Problem and Design Objectives Definition: Drawing the limits of the problem, decomposition of the problem into parts, its analysis, including constraints and resources, determining design objectives; (2). Development of Alternatives: Studying several solutions and developing possible alternatives; (3). Evaluation: Rating of alternatives by using design evaluation criteria; (4). Selection; (5). Communication: presentation to the client / public / authority / professionals etc.”* In defining problems and design objectives, ‘understanding place and context through visualization’ can be extremely helpful, and can provide new opportunities to the designer. Visualization also assists the designer in creating and studying alternatives., since it is the inner voice that asks, “What if?”

In a similar approach, Steger defines a general set of activities in urban design studies, with four basic phases and some sub-phases (Steger 1995, p.144-5) : *“(1). Analysis: (a)Gathering of basic information, (b)Visual survey, (c)Identification of hard and soft areas, (d)Functional analysis; (2).Synthesis; (3).Evaluation; (4).Implementation.”* Visual survey is considered as a standard part of any urban design study. And it surely is a tool for designers to communicate their perceptions of the structure and organization of a city. Visual survey examines and identifies urban components; such as the location, view of landmarks and activity nodes. (Steger 1995, p.146)

In every step of the urban design process, visualization modeling becomes an important tool. Design can be defined as "the fundamental skill required to structuring urban space-a skill that distinguishes from other activities of planning and engineering the built environment” (Trancik 1986, p.225). And in this distinguished task, visualization assists the designer, not only with its communication potentials, but also in creating a method to understand, analyze and implement design decisions.

2.1.2 Design Communication

The urban design process involves ‘the exchange of ideas between multiple minds’, and that requires ‘high-quality communication’. David Gosling sees urban design “not to be a series of statutory proposals but rather a prospectus to engage the interest of the existing community, local authorities and potential investors in promoting a rational and imaginative development” (Rowland 1995, p.3). Moreover, Wilford suggests that “a clear physical expression of the community’s hopes and intentions through the medium of urban design is essential for the communication of a consensus image of the city of the future” (Rowland 1995, p.3).

The need for public participation is not exclusively required by the scale of the design and development, but rather is due to the vast interests and skills of the community members. “Circumstances differ from country to country, but never in history have there been so many reasonably educated people, collectively armed with so incredible a range of knowledge. Never have so many enjoyed so high a level of affluence, precarious perhaps, yet ample enough to allow them time and energy for civic concern and action. Never have so many been able to travel, to communicate, and to learn so much from other cultures” (Goodfellow 1996). This statement is telling us that community members are taking the time to ask questions and become involved in development of their community. If an appropriate method to do so is not formulated then the public would likely become agitated and would generate resistance to any change proposed.

The participation of the community can also aid the development of projects where the designer and client may be of a different cultural group than that of the user. This situation often occurs in the case of government funded projects. The government is not the end user, but they are the paying client. If both the client and the designer fail to understand the needs of the user then the development can be a failure.

Collaboration is the main theme of urban design work. "Urban design is a hands-on experience that seldom occurs behind closed doors. It requires multidisciplinary teamwork at the professional level, exposure to community groups and users at the social level, and often involvement with governmental institutions at the political level" (Trancik 1986, p.231)

“Urban design decisions are made daily through a complex, often politically driven process involving a plurality of interests.” (Nedovic-Budic 2000, p.81) Actually, urban design affects everyone in their daily lives. Therefore, the designer should carry a great deal of responsibility to the community. In a decision-making process, it’s essential that various groups participate. Naturally, the designer motivates himself to work for more, so that final users can also be involved in the decisions. According to Lynch, this implies “complex and sometimes cumbersome communications, and causes frequent recycling of design.” (Lynch 1974, p.523)

Designers can use many methods to be able to communicate their ideas to themselves and others. The most common ways can be named as ; sketching, modeling, and detailing. In order to achieve all these tasks, one should develop his skill for visualization. (Dong and Gibson 1998) CAD and visualization technology can offer a common meeting ground for negotiation among all concerned parties; such as city officials, property developers and members of the community (Levy 1998) :

> “It might be interesting to consider the computer as a bridge between the perceptual experiences and expectations of different groups participating in the elaboration of an urban project. “ (Rabie 1991, p.70)

Far too often urban citizens suffer from feelings of alienation and isolation. The process of participation can minimize activities such as vandalism, by bestowing a sense of ownership of the area on the community. This is accomplished by involving everyone including the wealthy, poor, employed, unemployed, old and young.

The public are not as a whole professional designers. What can we expect the public to be able to do? Generally the public at large can be expected to possess the following skills.

- Excellent non-verbal communication, despite education.
- Highly developed internal model of their environment
- Capacity to put themselves in hypothetical situations.

By effectively utilizing these skills one can bring the public into the design process as valuable contributing members, despite their lack of design training. The inherent general skills of the public allow participants to effectively participate in the setting of design goals and development character, without the need to actually create a physical design. Contributions of this nature are extremely valuable to the design process, especially when guided by a design professional, who can translate those goals and characteristics into a physical environment.” (Goodfellow 1996)

Communication role of visualization, rather than presentation, is an important ingredient of urban design as an ongoing visual story for designers and communities of their conditions, directions and options. Presenting complex ideas and information to the public in a context, orientation, and in a format that is familiar and direct, can be extremely useful. Visualization can bring “improvement to the quality of decision-making and to the confidence in these decisions by applicants, politicians, and the public at large” (Pietsch 2000, p.524)

2.1.3 Testing Mechanism

Among various definitions and aspects of urban design, Lynch states that “Urban design deals with the form of possible urban environments” (Lynch 1974, p.511). In a typical urban design process, the designer produces several alternatives and tries to study on these to test their appropriateness and suitability according to the regulations. Rowland suggests six interdependent parts of design process: ‘Establishing Goals; Urban Design Audit; Urban Design Framework; Design Briefing; Urban Design Guidelines; Creating a Vision’ (Rowland 1985, p.6) In the process the need for some form of guidance is emphasized. Urban Design Guidelines help to improve the quality of our built environment, therefore after determining these guidelines, there is a need to check forthcoming projects under the guidance of these rules.

Using visualization as a part of the design process can be the *‘testing mechanism’* that spatially demonstrates the on-the-ground implications of proposed policies, regulations, guidelines, private agendas, and plans (Kasprisin and Pettinari 1995, p.xiv). It's common to use visualization modeling to insure that buildings do not exceed height limits and setbacks or to evaluate the space assigned for a specific use. (Levy 1998)

The City of Toronto has successfully utilized visualization technology as ‘a testing mechanism’. The visualization model has been completed and now it forms ‘a base for testing urban design policy, carrying out the development reviewing process, modeling and comparing density allocations, testing built form envelopes for specific sites, modeling and testing open spaces and view corridors, and testing sun access for streets and open spaces’ (Jacunski 1993, p.40). Visualization modeling can also serve for the visual and qualitative evaluation and analysis of mutual shading among buildings. (Shaviv and Yezioro 1997, p.83-6)

2.2 Computer Visualization Tools for UD

Since the computer does not have the advantage of organic freedom found in traditional media, early critics rejected it as an adequate medium for the creation of art and design (Dong and Gibson 1998, p.1). First digital graphics application is accepted as the '*Sketchpad*' system, which was developed by Ivan Sutherland at the Massachusetts Institute of Technology (MIT) in 1962 (Bertol 1997, p.69). It allowed the computer screen to be used as an electronic drafting board and also tried to create an interface for realizing man-machine interaction. At the beginning, only some recognized the birth of this new art form and design process. The initial cost for implementing the computer graphics systems was another factor that prevented them to be widespread in commercial use at that time.

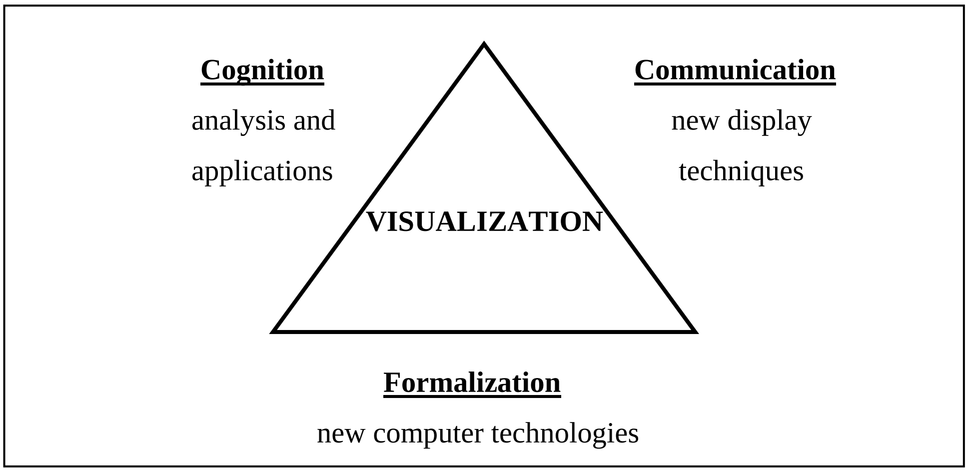


Figure 2.2 Components of visualization (Cassettari 1993, p.183)

Computer visualization is not only a technical advance; but a 'historical landmark of technological mutations'; as the new digital images give us a new dimension in our ways of perception and designing. (Quintrand 1994, p.93) Although computer generated images have demonstrated their maturity and capacity as methods of representation, their use in design have not reached its full potential. Limitations for its development have been: the difficulty of using these methods in the initial phases of design, high costs of data preparation and modeling, the need for powerful hardware and software, and finally lack of reliable interface between the new tools and conventional methods. (Quintrand 1994, p.94)

Technological advances enabled the use of 3D digital models and visualization tolls for many in the field of design:

> "Any given design idea holds an infinite number of possibilities depending on what medium is used to express it. A painting expressed as a sculpture is indeed not the same as the original painting, but rather, the literal and figurative reflection of a new dimension of the original. By the same token, a set of two dimensional (2D) drawings or a mental image, expressed as a three-dimensional (3D) digital model, has the ability to spark a new and potentially greater understanding of the original." (Dong and Gibson 1998, p.9)

Three issues are critical for the visualization modeling; abstraction, accuracy, and realism (Pietsch 2000, p.521):

a.) Abstraction : the selection of information included in the creation and presentation of computer visualization modeling

b.) Accuracy : the correctness of the information utilized, modeled, and depicted.

c.) Realism : the mimicry of the physical environment in a virtual setting

In the use of visualization modeling, the blend of abstraction, accuracy and realism is strongly related with the purpose and audience.

The capacity of computer visualization technologies such as computer-aided design (CAD), geographic information systems (GIS), and interactive multimedia has reached a sophistication where detailed representations of urban forms and systems may be practically manipulated. (McCullough 1995, p.115)

2.2.1 Urban-GIS

Two types of information system can mainly be identified according to the tasks performed (Maguire 1994, p.10) :

- Transaction Processing Systems; emphasis is placed on recording and manipulating the occurrence of operations. are based on clearly defined procedures.
- Decision Support Systems; the emphasis is on manipulation, analysis and, particularly, modeling for the purposes of supporting decision makers. need to be able to operate in a flexible manner.

Fundamentally, the information in the system has to be organized in a way that "it will have utility when retrieved; access to information in the system must be managed and carefully regulated; there must be continued support and maintenance of the information and technology within the system over time; and staff and users need to be encouraged and educated”. (Maguire, p.10)

Geographical Information Systems (GIS) can be described as “a computerized system that deals with spatial data in terms of” collection, storage, management, retrieval, conversion, analysis, modeling and display (Davis 1996, p.23). Mahoney explains GIS as "a computer based tool for modeling and analyzing existing data and events in the context of their geographical location". (Mahoney 1998, p.45-46)

However, GISs have a broad range of applications in many fields. This widespread utilization by various professionals presents an unclear area of activity; thus GIS becomes hard to define from time to time. Many authors from various disciplines tried to describe GIS in the most comprehensive way. In order to understand these systems better, it’s important to check various definitions in the field of research (Maguire 1994, p.10-11) :

“a system for capturing, storing, checking, manipulating, analyzing and displaying data which are spatially referenced to the Earth.” (DoE 1987,132):

“any manual or computer based set of procedures used to store and manipulate geographically referenced data.” (Aronoff 1989,39)

“an institutional entity, reflecting an organizational structure that integrates technology with a database, expertise and continuing financial support over time” (Carter 1989,p.3)

“an information technology which stores, analyses, and displays both spatial and non-spatial data” (Parker 1988, p.1547)

“a special case of information systems where the database consists of observations on spatially distributed features, activities, or events, which are definable in space as points, lines, or areas. A GIS manipulates data about these points, lines, and areas to retrieve data for ad hoc queries and analyses” (Dueker1979,p.1)

“a database system in which most of the data are spatially indexed, and upon which a set of procedures operated in order to answer queries about spatial entities in the database” (Smith et al. 1987, p.13)

“an automated set of functions that provides professionals with advanced capabilities for the storage, retrieval, manipulation, and display of geographically located data” (Ozemoy, Smith and Sicherman 1981,92)

“a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world” (Burrough 1986, p.6)

“a decision support system involving the integration of spatially referenced data in a problem-solving environment” (Cowen 1988, p.1554)

“a system with advanced geo-modelling capabilities” (Koshkariov, Tikunov and Trofimov 1989,p.259)

“a form of MIS (Management Information System) that allows map display of the general information” (Devine and Field 1986, p.18)

"a computer-based information system that enables capture, manipulation, retrieval, analysis and presentation of geographically referenced data." (Worboys 1995, p.1)

In spite of the fact that so many definitions of GIS have been produced, none of them is complete enough to cover all aspects of it. These various definitions can be presented in the form of three distinct but overlapping views of GIS :

- Map,
- Database,
- Spatial analysis.

The ‘map view’ deals with cartographic aspects of GIS, while the ‘database view‘ focuses on the importance of a well-organized and implemented database. The ‘spatial analysis’ view perceives GIS as a spatial information science, including analysis and modelling.

To have a better understanding, GIS can also be disintegrated into parts by the help of the terms it involves (Davis 1996, p.21):

- Geographic : the spatial realities; the geography
- Information : data and information; their meaning and use.
- Systems : the computer technology and support infrastructure.

The basic elements of GIS for operation can be named as : “computer hardware, computer software, data-information and liveware (people and organization)”. These components form the infrastructure of the system. In order of importance, liveware is the most important part of GIS; without organization and people, GIS would not work. Information can be accepted as the “heart of GIS”, since there will be no meaning or purpose without it (Davis 1996, p.15).

GIS is used in a variety of disciplines and applications such as geology, civil engineering, resource and waste management, geology, military applications, disaster management and planning. GIS cannot be limited to one of these fields, since it is multidisciplinary. Urban applications have marked the concept of ‘Urban-GIS’.

Urban-GIS applications are mostly distinguished with its quest for three-dimensionality. A key assumption in GIS applications is that all spatial data handled are referenced to a 2D Cartesian coordinate system (Raper and Belk 1994, p.299). Users have traditionally relied on 2D GIS databases for applications such as census mapping, vehicle routing, land-use analysis and planning, natural hazard assessment, etc. (Lang 1989, p.38) However, GIS should be more than just a map (Lais 2001, p.60). By adding the third dimension to GIS, the data is much easier to process and much more efficient than using contour lines, the traditional method of capturing a 3D representation.

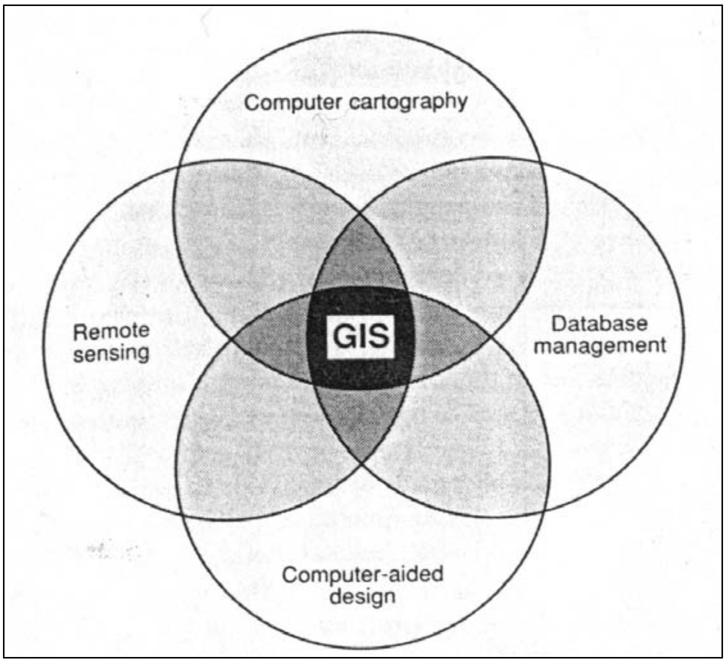


Figure 2.3 The relationship between information systems from GIS' point of view (Maguire 1994, p.13)

The capacity of computer systems now enables the advanced analysis called 'modeling'. Models can be defined as the "representative versions of the world and its processes" (Davis 1996, p.49). Models put data in order and can make generalizations . They help us to make general statements on how things exist and operate by summarizing data and analysis.

Computer graphics are generally configured to display information of a visual nature but a GIS has to offer more than purely graphics processing. Although visualization is a significant component of GIS, there is an evenly important collection of non-visual components to geo-data. As Burrough suggests: "Good computer graphics are essential for a modern geographic information system but a graphics package is by itself not sufficient for performing the tasks expected, nor are such drawing packages necessarily a good basis for developing such a system" (Worboys 1995, p.4). In today's world, the importance of data visualization is increasing, and GIS tries to become a leading technology in this movement. Digital systems develop their visualization capabilities by integrating new tools and techniques for transferring data into charming and understandable graphic display. Visualizing data can be effective and convenient in understanding and communicating complex information. In geographic information systems, visualization means "the presentation of data in graphic form" (Davis 1996, p.13).

Urban-GIS systems have been configured to deal with three dimensions. Three-dimensional modeling and visualization capabilities of GIS systems are developing (Sullivan 1998; Mahoney 1998). For instance, the leading GIS software *‘Arcview’* has an improved 3D plug-in to visualize and query data in three dimensions (Batty 2000, p.484). New forms of representation have been developing based on 3D vector and raster data structures, which can index spatial form and process, and support complex 3D queries. (Raper and Kelk 1994, p.299)

2.2.2 Computer Aided Design (CAD)

Computers, with the developing CAD technology, have gradually become part of the design process. As well as their use for drafting purposes, these systems are important tools of three-dimensional modeling and visualization. CAD systems allow designers “to think of drawings as combinations of individual data elements that can be stored independently and retrieved in any combination for display purposes” (Arbeit 1988, p.131).

Mahoney explains CAD as ‘a tool for creating new information in the form of geometrical representations of actual or potential structures’ (Mahoney 1998, p.45). In the most comprehensive way, computer-aided design (CAD) can be defined as “the use of a computer for the creation, manipulation, analysis, and communication of an idea” (Dong and Gibson 1998, p.2). However, expectations from CAD systems have always been too high :

> "The term CAD causes a lot of misunderstanding. In our opinion CAD software has to give to the designer a maximum of support, (not restricted to the graphical presentation of a design and the interaction on it only) also the software must warn the user against constructing non-logical relations and furthermore the software should give information about the quality of design." (Zelissen 1988, p.253)

Unfortunately, advances in CAD technology have not gone that far. CAD systems, available today, are mostly appreciated with their drafting benefits and visualization modeling capabilities. The term ‘CADD’, which stands for *‘Computer Aided Design and Drafting’*, may point out a system in a broader sense. It is also possible to find *CAAD* in literature that is used to describe *‘Computer Aided Architectural Design’.* However, all of these terms; CAD, CAAD or CADD, basicly illustrate the same technology. The technology may include many applications from drafting an architectural project by using computer equipment, to writing a proposal in a word-processor or searching the Internet for product information. Drawings are represented in the computer by point coordinates and vertices. Advanced CAD applications will allow for the construction of three dimensional models of nearly any object. “CAD is intended to make the computer accessible to nonprogrammers.” (Voisinet 1987, p.3)

The AEC (Architecture, Engineering and Construction) market has been invaded by all kinds of CAD applications, “from the design of buildings to the layout of telecommunications facilities to the development of highway proposals”. (Mahoney 1998, p.45) Professionals working in architectural practices, mechanical design, computer game development, and the entertainment industry try to utilize the advanced tools offered by CAD. One advantage that CAD has over the traditional manual techniques of drafting and model construction is that changes can be easily made, which can not be easily done using manual techniques. A basic understanding of the purpose and use of CAD is important in this paper for the eventual utilization of computer technology in collaborative design requires a degree of CAD proficiency to assemble an accurate model of the development environment. CAD can be utilized in many aspects of planning design/research projects. (Goodfellow 1996)

CAD software should be seen as a productivity tool. Its main function is "to embrace graphically an entire design cycle, including the overall systems environment and specific component representation" (Miles 1992, p.66). The emphasis in CAD systems is on the interaction between the designer and computer-generated model, so as to reach to an acceptable design. CAD systems have the potential to simulate tests of the properties of the design; such as structural properties of a building (Worboys 1995, p.4).

“CAD is not necessarily adaptable to every job function. Also, the design process itself is creative and personal and tends to be secretive.” (Voisinet 1987, p.10)

> “As the field of computer-aided design has developed over the last thirty years or so, three clear paradigms have successively emerged. First, designing was conceived of as a problem-solving activity. Then, as the limitations of this view became increasingly apparent, designing was seen more as a knowledge-based activity. Now, there is a growing consensus that designing must be treated as a fundamentally social activity - a matter of multiple, autonomous but interconnected intelligences in complex interaction.” (Mitchell 1994, p.239)

For the purpose of this study, it will be more useful to narrow the scope of CAD technology and focus on the following properties of CAD: three-dimensional modeling, digital rendering, imaging and animation.

Many CAD systems, including the leading program AutoCAD, are general-purpose packages and are designed to meet demands from various domains. One result is that these systems can be applied in almost any application but can hardly meet all demands from a given application domain. Fortunately, most CAD systems come with an open system architecture and developing environment. No doubt that AutoCAD is one of the systems with most powerful developing environments.

Research suggests that incorporating 3D technology in the design process has the potential to reduce project cycle tmes by as much as 70% (Jenkins 1998, p.27). Once a CAD model is generated, images ban be created to present concepts at any scale or format including elevations, plans and sections as well as animations and VR environments with little additional effort (Levy 1998, p. 5-?). And this resulted in the multiple representations of designs :

> “Multiple representations of a problem…enable the user to view information in several different contexts thus offering the potential to generate alternative approaches to a problem…In this manner users have the ability to visualize situation from several different perspectives in order to gain a better understanding of the information conveyed” (Shiffer 1992, p.711)

CAD has been quickly getting better in producing larger, better-linked models of extensive form. No doubt that that the vast amount of data sets needed for urban design applications in CAD can be a tough and costly task to prepare but they have the advantage of being reusable, extensible, and transmissible. (McGullough 1995, p.119) Thus; in general, it is practical and pays for itself quite well in time.

2.2.3 Virtual Reality Aided Design (VRAD)

Virtual Reality (VR) can be defined as “a computer-generated world involving one or more human senses” and produced in real-time by the user’s actions. (Bertol 1997, p.67) VR can be seen as ‘a final aspect of visualization’ (Cassettari 1993, p.191). Numerous applications of Virtual Reality can be found in many fields and disciplines. ‘Visual feedback’ and ‘three-dimensionality’ are important features of VR for the fields such as architecture and urban design, where ‘visualization based on three-dimensionality’ is essential. VR also gives the advantage to be ‘inside’ the problem, rather than observing it from the outside. (Bertol 1997, p.70)

Virtual Reality is a term that has been used in the media to describe a number of different technologies. Some technical professionals don't believe a system is virtual reality unless there are head mounted displays involved. This however is a narrow interpretation of the technology and for the purpose of this paper virtual reality will include systems both with head mounted displays and those relying on conventional monitor technology. The key underlying factor is that the technologies deal with the presentation of three dimensional data in a nonlinear format. Sherman and Judkins have identified five characteristics that identify a system as a virtual reality system. Those characteristics are as follows:

Intensive:

In Virtual Reality the user should be concentrating on multiple, vital information, to which the user will respond.

Interactive:

In Virtual Reality, the user and the computer act reciprocally through the computer interface.

Immersive:

Virtual Reality should deeply involve or absorb the user. Immersion can be illustrated by Myron Krueger"s "duck test", if someone ducks away from a "virtual stone" aimed at their head, even while knowing the stone is not real, then the world is believable. This is also known as "immersion".

Illustrative:

Virtual Reality should offer information in a clear, descriptive and (hopefully) illuminating way.

Intuitive:

Virtual information should be easily perceived. Virtual tools should be used in a "human" way.

One of the basic principles behind virtual reality is to improve the user / computer interface so that it is more intuitive. This would allow even a computer novice to navigate a three dimensional computer environment. Humans navigate through three dimensional space on a daily basis and thus the movement within a similar computer space should result in a minimum of disorientation. The technical issues of computer input and output-devices will certainly be developed by computer specialists and ergonomists to ensure the comfortable and simple control of these systems. (Goodfellow 1996)

Too often people hear the term virtual reality and immediately think of video games. This, however, would not be using the technology to its full potential. Virtual Realty has progressed from manual simulation techniques up to present day computer simulations. Kate Mc Millan has constructed a timeline that traces the development of virtual reality:

Late 1920s;

Edwin Link worked on vehicle simulation, arguably the first forerunner of virtual reality technology.

1940s;

Tele-operation technology began

1954;

"Cinerama" was developed using 3-sided screens.

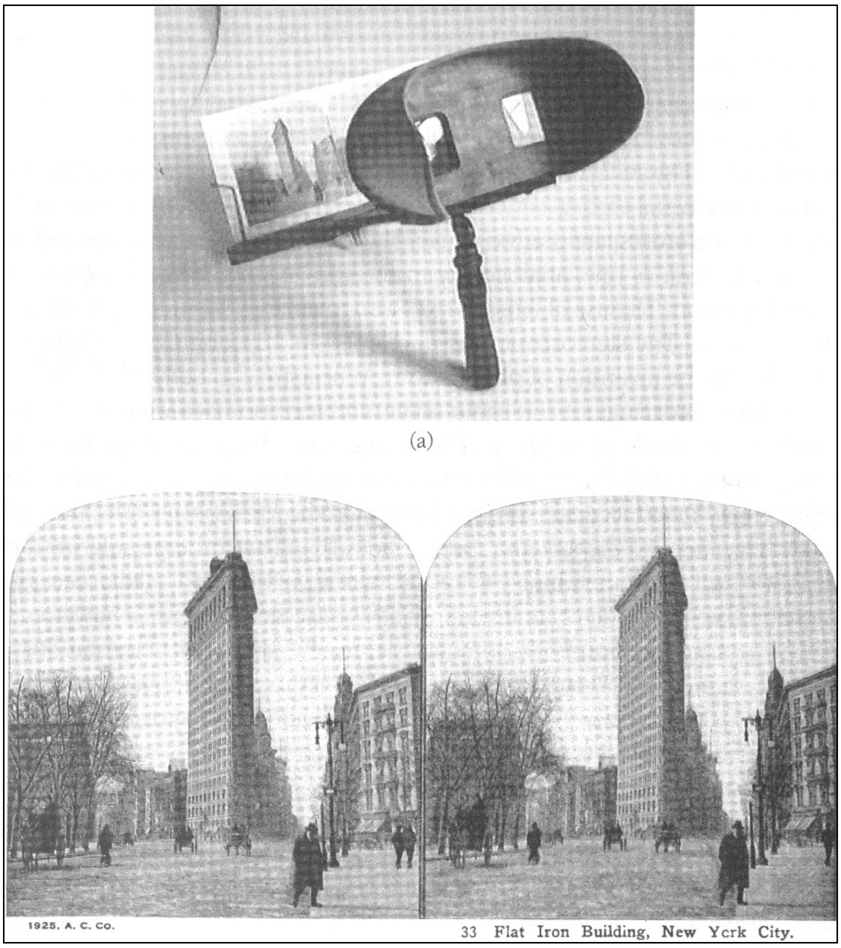


Figure 2.4 Stereoscope developed by Charles Wheatstone in 1833 (Bertol 1997, p.38)

Early 1960s;

Development of teleoperation displays using head-mounted, closed-circuit television systems by Philco and Argonne National Laboratory. Morton Heilig's ill-fated "Sensorama."

1966;

Flight Simulations, NASA.

Late 1960s;

Development of synthetic computer-generated displays used for virtual environments, pioneered by Ivan Sutherland.

Mid 1970s;

Krueger coined the term "Artificial Reality".

1984;

William Gibson published the term "cyberspace" in his book, "Neuromancer".

1989;

Jaron Lanier, founder of VPL Research, coined the term "VIRTUAL REALITY" to encompass all of the "virtual" projects e.g. "virtual worlds",. "virtual cockpits", "virtual environments" and "virtual workstations".

1990s;

Continued research for the specific use of VR in modeling, communication, information control, arts and entertainment.

It is expected that this technology will be very slow to be adopted by the urban design community as there are still many technical issues to resolve. Currently, to simulate a realistic environment requires very powerful expensive computer systems. This will, however, change as computers become more powerful and less expensive. Significant progress in computer technology has been made in the past 10 years and should accelerate in the future.

Currently the limits of our computer power restricts the amount of realism we are able to develop in our virtual environments. Many researchers have been investigating techniques to overcome these limitations and have developed interesting theories on the subject. Some believe that we can trick the human brain into thinking it has been exposed to more information than it really has. Physiologists and computer scientists are researching what symbolic features could be used to trick the mind into seeing more than what is really there. This technique is currently being used in the development of video game animations. The animator only creates the minimum number of frames necessary to convey motion. The game player's brain then fills in the gaps to create a smooth action. (Goodfellow 1996)

Other techniques used to simplify the task of navigating virtual environments for the computer are based on displaying the minimum number of objects necessary to convey an environment. If you were in a virtual environment and looking out of a window, all the objects behind and out of your line of sight would not be represented in the model, drastically reducing the processing power necessary for smooth navigation. Similarly, research into the rendering processes involved in navigating a virtual environment has found that a computer can get away with rendering items outside of the direct cone of vision of the user at a lower resolution than those objects being directly focused on. This seems reasonable when one considers that peripheral vision is much less developed and even lacks the capabilities to view colors. Since this is the case rendering extra detail in these areas is merely wasting computer processing time. (Goodfellow 1996)

Virtual realities can vary in the degree to which they pull the user in. One very effective way to immerse the user in the virtual environment is to surround his/her entire field of view with the images of the environment. This, however, is not an easy task for the average human has a field of view of 270 degrees. This is further complicated if one wishes to have this information presented in a stereographic manner. Humans perceive depth through the stereographic nature of their vision. Traditional computer monitor technology can however only offer a monographic view of an image. If a computer is to display stereographic information it is essentially doing twice the processing work in generating the scene from a slightly different angle. This processing problem is greater than the actual trivial nature of getting the image to the other display.

Virtual Reality is most appreciated for its capability in “adequately simulating the form of buildings and to analyze how people use and interact within those virtual environments.” (Neto 2001, p.671) Vassil claims that “The role of VR is not to imitate reality but to aid in communicating ideas” (Vassil 1997, p.3)

2.2.4 Multimedia and Internet (Web-based) Applications

Multimedia computing offers exciting new opportunities for urban design visualizations. Multimedia systems extend the range of computational data types beyond numbers and basic text to :

- still and animated computer graphics,
- still and animated images,
- audio,
- structured text (e.g. hypertext). (Worboys 1995, p.26)

Recently, multimedia has become a powerful format for visual communication of urban design concepts. It helps to increase the quality in project comprehension, by linking planners' analysis, architect's proposals, grids of aerial photographs, and project phasing studies. 'Point-and-click' navigation through a wealth of associated data quickly yields insights difficult to convey in conventional presentation drawings. Interactive nature of multimedia tools can greatly enhance communications for designers in the public participation process. (McCullough 1995, p.119)

However, multimedia applications can also cause several difficulties. A single graphic or image file is itself large in size; animated graphics, video and audio raise this level of data volume to new heights. Thus; storage, compression and transmission of such files bring new problems to solve. Standards are emerging (e.g. MPEG file format for video) and computer graphics systems are beginning to support these new types. Multimedia technology is a fast-changing field; and will definitely be utilized in many applications; in combination with GIS, CAD and Internet.

The Internet, and more specifically the graphically rich World Wide Web (WWW), has become a significant technology in the communication industry. The Internet is a world wide network of computers and the WWW is a graphical interface for retrieving information from those computers. By using this technology one can currently share ideas and images with millions of people, however a new technology known as VRML is allowing this same network to transmit and share virtual environments. VRML stands for Virtual Reality Modeling Language and was invented by Mark Pesco and Tony Parisi. VRML is not a particular product but rather a technical standard used to describe three dimensional computer models. Users of the Internet can then view these VRML worlds using applications known as VRML browsers. Development of VRML started in January 1, 1994, building on Silicon Graphic Incorporated's "Open Inventor's" format. The importance of developing a standard is paramount to the effective communication of information. Basic language is in fact merely a standard set of sounds that have been accepted to mean certain things. This is what has occurred with the development of VRML. A new language of communication has been established to allow browsing applications to understand the VRML file format. Standards such as VRML tend to undergo a number of mutations as users try to push the limits of the standard. The user who wishes to implement new features within the model that aren't currently supported may develop a variation on the original standard. This practice is however a dangerous one for it can lead to incompatibility issues, where one browser may not be able to read the files of another. Currently a number of companies are in fact attempting to create their own variations on the VRML standard in hopes that their features will set them apart from competing browsers and modelers. There is also a hope that if implemented well their variation may be adopted as the next standard version of VRML or VRML v.2. Currently some of the VRML variations are VRML+, WebFX, IVRML, and Moving Worlds. As of Feb. 12, 1996. Silicon Graphics and Netscape Communications Corporation announced that their new Moving Worlds, VRML variation has gained support by 56 leading software developers and is a likely candidate for the new VRML 2.0 standard. In fact Mark Pesce, the developer of VRML 1.0 stated, " The Moving Worlds proposal is - without any doubt - the leading candidate to become VRML 2.0." This quickly developing technology is leading to the development of a tool for Urban Designers to use in the communication of design and development issues. VRML 1.0 has some problems in that it does not deal with the efficient 3-D database handling necessary for viewing large models on modest computer equipment. This forces the computer to redraw all of the objects in the model whether they are in view or not. The recent announcement of Moving Worlds has not as of yet, made any public statements about this important issue. At least one current variation on the VRML 1.0 specification has implemented an efficient database management system. Virtus VRML has implemented such a database management system that allows browsers to efficiently navigate large models. The one advantage the Urban Designer has in this uncertain time of changing standards is the assurance that all of these various VRML implementations rely on the same three dimensional data and thus, once a standard is settled on, the developed three dimensional models can easily be ported to one or the other with a relatively small capital expenditure on small translation utilities. (Goodfellow 1996)

The product known as Virtus VRML is currently capable of supporting a virtual conference within a virtual three dimensional space. Participants in these virtual conferences can be represented to the other parties through a direct video signal that is mapped onto a surface within the environment. To communicate with other participants of the conference, users can use voice communication or they can pull in a virtual white board to draw visual information. This tool, although a useful one, still lacks the interactive model space modification capability found in the Sense8 Virtual House Design project. If one were to attempt to implement the Virtus VRML solution as a cooperative urban design workshop, one would be limited to navigating a completed virtual model and only be able to suggest changes via drawings on a white board within the space. This is not exactly using the three dimensional tools available to its full potential, however, it does provide for an example of the techniques available today, and the tools that may be available in the future. (Goodfellow 1996)

Chapter 3

URBAN ENVIRONMENTS IN A VIRTUAL WORLD

> *"There seems to be a public image of any given city which is the overlap of many individual images. Or perhaps there is a series of public images, each held by some significant member of citizens. Such group images are necessary if an individual is to operate successfully within his environment and to cooperate with his fellows. Each individual picture is unique, with some content that is rarely or never communicated, yet it approximates the public image, which, in different environments, is more or less compelling, more or less embracing."*
>
> (Lynch 1994, p.46)

3.1 Recent Developments in Visualization with Urban Appeal

Visualization of urban environments requires "a distinctly rich hybrid of geometric, geographic, and annotative information" (McGullough and Hoinkes 1995). These requirements suggest new techniques for collaboration, data integration, and rich datasets. For the computer to become more useful to the designer, it must be familiar and subordinated to the design concept. Studies focused on making the interaction between the designer and computer become less and less distracting. (Doubilet 1984, p.140)

Michael Batty, in his article 'The New Urban Geography of the Third Dimension', explains the outrageous 'technologically driven' developments in digital graphics and widespread utilization of these systems for urban applications in the last two decades:

> *“To date, our urban geography has also been a geography of two dimensions–a geography of the map–but with the emergence of data in the third dimension at the fine scale, there is every prospect for theories and models which treat the third dimension in much the same way that we have been treating lower order dimensions in modern urban theory since von Thünen. A generation ago, when computer graphics reached the point where large-scale 3D computer aided design (CAD) models of cities could first be built, the emphasis was simply on getting such visualizations going. The model of downtown Chicago promoted by SOM in 1982 was a wire-frame rendition of large-scale building structures through which the ‘user’ could fly to get some idea of the form and massing of the building blocks forming the financial district. The focus, of course, was on using such models to visualize changes to building forms. Ever since, the emphasis on such 3D modeling has been on rendering, faster fly-through, and greater realism."* (Batty 2000, p.483)

3.1.1 Developments in Computer Systems

The limits and success of digital visualization have always been dependent on the capabilities and power of computer systems. Thus, developments in computer systems, in terms of both hardware and software, have influenced the professionals in the field, to achieve larger models, with greater realism, and as more interactive environments. But naturally, the developments mentioned here will only be a snapshot of the technology in a particular period of time. Still, these explanations will definitely help to understand the fundamentals of computer systems, and the rapid growth trend in the industry.

The fundamental elements of any computer system are; computing machinery and associated devices, known as the *'hardware'*, the *'data'* to be operated upon, and the programs which are collectively referred to as the *'software'* (Mitchell 1977, p.3). Especially in the last decade, all of us have witnessed a tremendous progress in microcomputers and their applications. Technological advances have already revolutionized the . In today's world, it is not surprising to hear about a new version of operating system or a CAD software every year, or see a faster version of your processor in commercials.

3.1.1.1 Hardware

Late 1970s, is accepted to be the time of a computer revolution with the production of first microcomputer -called '*Apple*' by its inventors Steve Jobs and Steve Wozniak (Arbeit 1988, p.114). Microcomputers changed it all with their miniaturized components and high computing power. The microcomputer revolution is most markedly characterized by the accessibility of microcomputers to people other than computer professionals. This accessibility and widespread use have caused an important conceptual shift concerning the design, production and configuration of systems.

Technological advances in computer hardware have been devastating particularly in the last decade. Not that long, but just ten years ago, hardware requirements for a CAD system, written in a PC magazine of that time, summarizes the situation: "...AutoCAD's powerful features and hardware requirements can be daunting. You'll need a fast 386 or 486, a math coprocessor, and at least 4MB of memory and 9MB of disk space..." (Grabowski and Zottoli 1991, p.212). In today's world, disk space is mentioned in tens of giga-bytes(GB), 386 type of processors have already reserved their places in technology museums and most of the people have already forgot the term 'math co-processor'.

Despite the bewildering and rapid changes in computer technology, the basic set of elements and the logic still remains the same. In simple terms, the functionality of a computer can be divided into four tasks: 'processing, storage, data movement and control' (Worboys 1995, p.27) In terms of components, each piece of equipment in a computer system can be categorized as one of the following types: 'central processing unit(CPU), input, output, memory and storage'. (Mitchell 1977, p.3-5; Voisinet 1987, p.21; Worboys 1995, p.28)

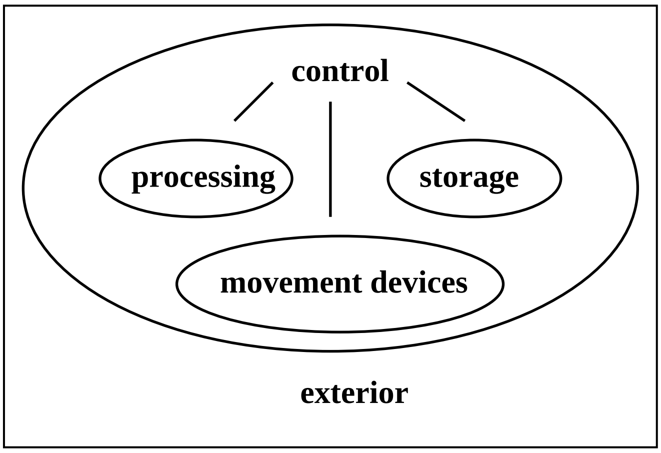


Figure 3.1 Overall computer architecture (Cassettari 1993, p.183)

The central processing unit (CPU) forms the computing portion of the system. Typical input equipment include 'alpha-numeric and functional keyboards, mouse/track ball, graphics tablet/digitizer, scanner, light pen, etc.' Most common output equipment are 'cathode-ray tube (CRT) and liquid-crystal display (LCD) screens, printers, plotters, computer-aided manufacturing (CAM)-robotics, CNC devices, etc.' Storage devices are produced using magnetic and optical technology; such as 'memory chips, magnetic hard-disks, floppy-disks, CDs, data tapes, memory cards, etc.'

Generally, CAD and GIS applications can work on a single computer workstation. On the other hand, when a VR system is considered, the input and output are different elements using distinct hardware and software. For example; a typical VR system includes ‘a computer-generated model, a stereoscopic display, a device to interact with the computer-generated world’, and the software which controls all the different components. (Bertol 1997, p.93) VR systems have become available by the development of special hardware. These include 'wired gloves, wands, treadmills and even biological signals' as control devices; and 'head-mounted displays, BOOMs(binocular omni-orientation monitors), projections, CAVE(Cave Automated Virtual Environment), 3D glasses and retinal devices' as output devices.

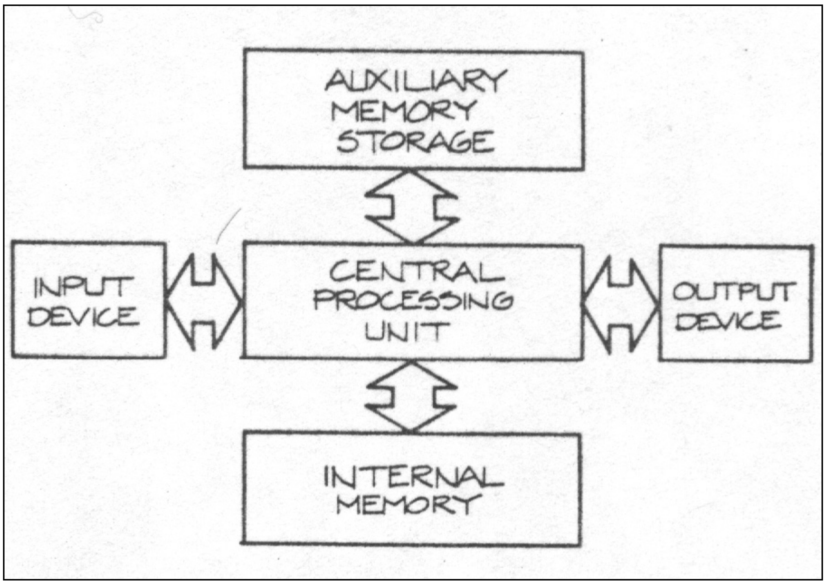


Figure 3.2 The main components of a computing system (Gionet 1988,p.130)

A number of computers can be linked together to form a *'network'* . Developing hardware increased networking capacity; thus expanding the communication capabilities between computers. By the use of 'Local Area Networks(LAN), cable and dial-up connections, it has been possible to connect different groups in a project, who have to be physically apart; like project consultants, co-developers, site managers and site engineers, clients, project design offices, etc. For instance, urban planning and architectural firm *Jerde Partnership Int. Inc*., has utilized Fast Ethernet and FDDI backbone type network to use in their new mixed-use development complexes; so that they could quickly move their designs through the pipeline. Now companies like this do not hesitate to spend as much as $250,000 just to purchase equipment (switching hubs, adapters, and servers) for their high-speed network infrastructure. Tom Jagger, CAD director of the Jerde Partnership, tells about the advantages of networking: "We have a virtual office station ... our office is really an extension of people. With a high-end laptop, a person has the entire office with them, they can connect via modem into our system, -including a limited access web-site and firewall protected ftp site- download what they need, send e-mail to their team and rework something" (Sullivan 1997, p.81-2)

The capacity of hardware limits the potentials of other components of a system; such as software and liveware. Many genius ideas had to remain in the minds of developers because of hardware limitations, before finding any chance of application. Especially knowledge-based systems required a completely new understanding in hardware infrastructure, leading to the concept of *'artificial intelligence'* (AI). Although AI is not in the scope of this thesis, it is worth mentioning the fact that; it will have great influence in the field of design as research and development studies suggest.

3.1.1.2 Software

The various types of programs utilized in a computer system are named collectively as 'software' (Mitchell 1977, p.7). Developments in hardware and software systems are mutually dependent. The need for better programs have forced the industry to increase the capacity of hardware components , and alternately powerful computers enabled the creation of better versions of all kinds of software. With more user-friendly and effective software applications, hardware performance could also be increased. (Dong and Gibson 1998, p.2)

All computer software can be classified in three groups according to their functions (Arbeit 1988, p.119) :

1. Systems Programs
2. Utility Programs
3. Application Programs

System programs organize the overall operation of a computer, such as operating systems, providing the essential control and instructions. Utility programs are configured to simplify tasks that computers must frequently perform. Application software include programs written to solve specific problems and perform specific tasks for the user. In our study, the emphasis is on application programs since CAD, GIS and multimedia systems are all of this kind. However, advances in system and utility software directly affects these systems. For instance; as an operating system, windows platform has very much influenced the development of application programs.

There are basically two trends in software development. First, these programs offer more and more graphic elements in terms of user-interfaces, secondly there is a transformation from general purpose programs to more problem-oriented packages (Zelissen 1988, p.253) Remarkably, problem-oriented software develop in two separate ways. On the one hand, programs (or modules) are produced in a way that they use output from another system as input. For example; the problem is formulated graphically with the aid of a drafting system, and the additional/separated module carries out the rest. The second way is in the form of an integrated software, which is configured for a specific problem by using the symbolism and algorithms of that type of problem. In this case, the program supports the designer interactively while formulating his problem and tries to protect him against contradictions.

In the years, software developers have worked on their packages to be able to meet demands such as; 'performance, interoperability, standards, data security, and multiple operating system support' (Miles 1992, p.66-8). In evaluating a software system, five important factors can be named as: 'scalability, collaboration, project life cycles, customization and productivity' (Jenkins 1998, p.27). Within this framework, software companies tried to develop their programs accordingly; so that they could create more user-friendly, convenient, specific and purpose-made packages. The criteria listed above have described the key points in increasing the efficiency, capacity, ability, productiveness, and competency of programs.

Scalability sets the ability of a CAD system to support increasingly complex projects. The most important component of scalability is the extent to which a CAD product line supports 3D modeling. Today, all kinds of digital graphics packages try to reach to a perfection in their 3D visualization features. Collaboration is another key criterion; that is, the support of collaboration both within a company and beyond is critical. A collaborative environment also suggests compatibility and standardization. Customization, which means design-automation of common tasks, addition of task-specific and user properties features, is a top issue in software development. A quality package is the one that can be customized to meet your standards and needs (Grabowski and Zottoli 1991, p.215-222).

In today's world, software systems have reached to a sophistication that they can be used effectively in an integrated environment.

3.1.2 Integration of Systems

Computer applications in urban design present ’a distinct identity, based on a blend of computer-aided design (CAD), urban-geographical information systems (Urban-GIS), World Wide Web (WWW) and interactive multimedia. The nature of urban design process requires a more comprehensive approach in digital technology. This is quite unusual in comparison to the works performed in a single environment by professionals in related fields, such as perspective renderings for architects or spreadsheet applications and informational maps for planners.

Sullivan expresses the need for systems integration in his statement: “If a virtual city is to be more than just a glitzy visual representation, it must be linked to intelligent data that contributed to its design and operation.” (Sullivan 1998, p.213)

In a typical process of urban design; one might begin with an area analysis, perhaps for the purpose of site selection, by means of a geographic information system. Here, a system of queries might gradually isolate a concise set of possibilities. Next, (or as an equally valid point of departure) one could conduct numerical simulations, e.g. density calculations or traffic flows, by means of a spreadsheet or a specialized analysis program. Visualizations of these models have normally been confined to charts and graphs. For a more pictorial visualization, one would then have to build a three-dimensional model in a CAD system, using plan data from the GIS, and vertical data from a variety of sources, possibly including field survey. Any relations inherent in the existing databases or simulations would normally be reduced to a simple layer classification and/or block hierarchy. At this point, however, better visualization of other sorts would become possible, as one could now prepare images of the three-dimensional model by means of a rendering program. These images could use color, texture, lighting, etc. to express schematic differentiation in a manner intelligible to a design-oriented audience. Finally, content from any of these many representations could be assembled in narrative structures, such as animated presentations, intelligible to a truly general audience. Some of these collections could be arranged to be navigable by browsing and made available for asynchronous review, either by delivering a multimedia stack on disk to a client, or by posting on the World-Wide Web.

> “While all of this situation represents a considerable advance over attempting such work in a purely CAD-based environment, it leaves many needs unanswered. Since so many tasks are separated by so many pieces of software, the design process becomes compartmentalized,

> overly serial, and inadequately able to evolve a design on the basis of complex relationships. The situation is limited by the static nature of the data. Moreover, since most actions are structured by intrinsic properties of the tools, rather than the data, many relationships directly evident in the data remain difficult to explore.” (McGullough and Hoinkes 1995)

3.1.2.1 GIS and CAD

The different capabilities of computer-aided design and geographical information systems force these technologies to become ‘a perfect combination’ for urban design applications. The ideal system is likely to include 'three-dimensional modeling and visualization tools of CAD' in combination with 'data storage-manipulation and analytical tools of GIS'. Each can do what the other can’t ; thus together they become ideal partners.

There is an ongoing debate about how this integration should be. The leading software companies in the market have made attempts to unite these systems in a single environment. Some have produced functional tools for database management as additions to their traditional CAD packages. On the other hand, GIS systems have improved their 3-D modeling and visualization capabilities to be able to offer outputs as satisfactory as CAD packages. (Mahoney 1998, p.48; Sullivan 1998, p.216)

Although CAD and GIS packages have started to show similarities in terms of modeling and visualization, there are enough reasons to hold these systems quite distinct. GIS may include a very important visual component, but more than that special emphasis is on non-visual components to geo-data. Correspondingly, when CAD is configured to support non-graphical properties of objects for simulations, the types of data and functional requirements differ from the ones in GIS. A wide range of data from natural and artificial sources have to be captured in GISs. In spite of the fact that these systems are of different character, both sides learn much from the researches of the other and benefit from studying the connections in-between (Worboys 1995, p.4).

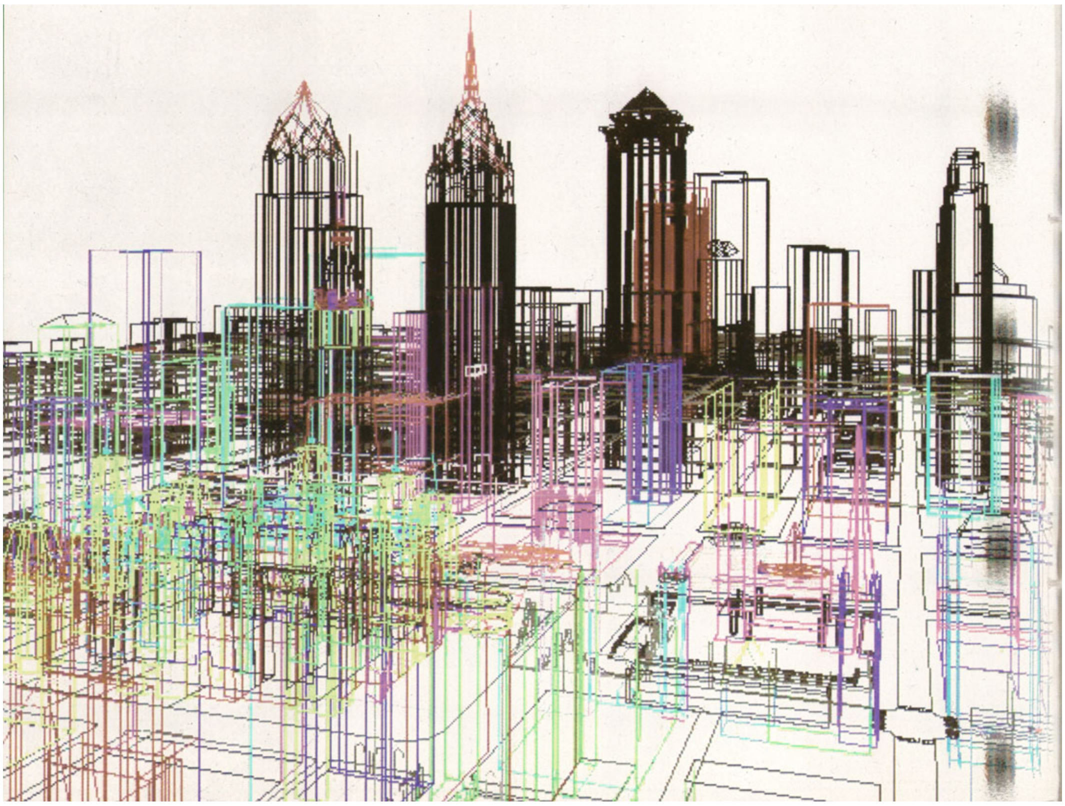


Figure 3.3 Hybrid CAD and GIS applications enable complex urban models. Wireframe model of the city of Philadelphia (Sullivan 1998, p.212)

GIS-side, mostly, believes that their system proves to be the best and most comprehensive platform for this integration. This idea is mostly supported by those who believes data and information should be The dominance of CAD technology for years in design-related fields mainly because lack of spatial properties in GIS :

> “CAD models by themselves no longer mark the cutting edge. GIS now appears to be the major in that this software looks both to spatial data technology and to visualization in three dimensions. As such it stands at the crossroads of software technologies necessary for such integrated modeling” (Batty 2000, p.484)

Mr. Asroth, from the leading software company *Autodesk*, claims that the integration of these systems in a single program does not make any sense and is not an accurate kind of approach to the problem :

> “People like the idea of doing everything in one environment. But we’ve learned from people like Bill Gates that the best way to do that is to have a bunch of applications on your desktop that work together. You don’t try to do your Excel spreadsheets in Word , you do them in Excel, then Word knows how to deal with them. We have to think about what’s the best tool for the job, then work on sharing the data.” (Mahoney 1998, p.50)

CAD/GIS integration has been best utilized in the creation of ‘Virtual Cities’, in the applications like 'Virtual LA'. These projects will be discussed further in this thesis under the heading ‘Samples of Urban Visualizations’.

3.1.2.2 VR and CAD

Virtual Reality seems to be ‘the next logical step’ in computer-aided design technology. These two systems have close relations. VR systems benefit from the modeling capabilities of CAD systems. And CAD models find themselves a true interactive environment to be presented. (Bertol 1997)

It is not surprising that VR has become popular for many applications; such as computer games since it makes the player an integral part of the game. For urban design applications, it could provide many opportunities when this technology is utilized with real spatial data and true 3D models. Then it would be possible to create virtual environments, which correspond to real world locations. This would make great contributions to public participation and decision-making process. But, today the limitations of computing power, required to handle such voluminous urban data, prevent the use of such systems.

The pioneering example of this type of a system was developed by General Electric, NY, and delivered to NASA in 1967. It was used for simulation of spacecraft maneuvers. Display capacity -limited to 240 polygon edges- was low and smooth shading of curved surfaces could not be possible. But, by using this technology, a film called *'Cityscape'* was produced by Peter Kamnitzer, at *UCLA*. It demonstrated for the first time how this type of technology could be employed for simulation. (Mitchell 1977, p.364)

Today, in a project called The Urban Simulator, *UCLA* has succeed to create A Virtual LA Model, covering an area of 10,000 square miles. The Urban Simulator combined three-dimensional CAD models to create a realistic model of an urban environment, that can be used for interactive fly, drive and walk-through simulations.

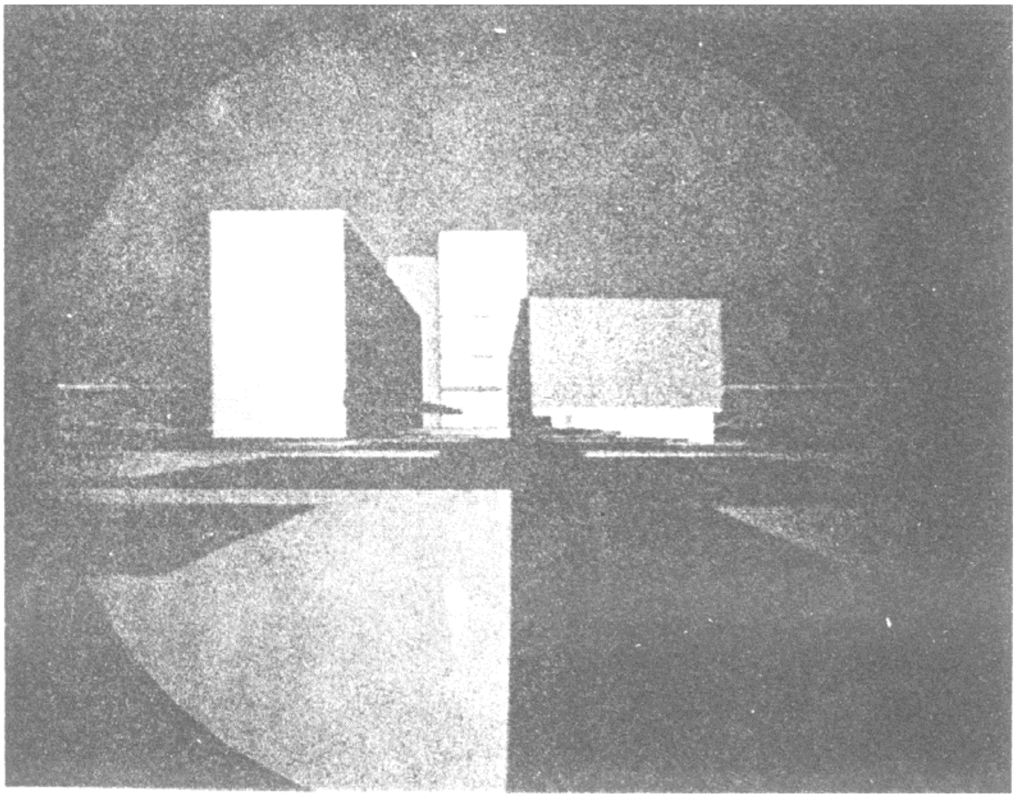


Figure 3.4 A frame from Peter Kamnitzer's 1968 film, 'Cityscape', produced using spacecraft landing simulator (Mitchell 1977,p.365)

However, VR should also be carefully considered in terms of the visualization of urban design concepts. Because, it is easy to perform ‘technical wizardry’ for affecting the user in favor of an idea (Cassettari 1995, p.192).

3.1.2.3 Multimedia-Internet and CAD

In recent years, developments indicate the increasing importance of Internet in communication technology. World Wide Web (WWW) have made significant contributions to the publication, presentation and sharing of data and information from a wide range of sources. Moreover, interactive multimedia has become a convenient platform for visual communication of urban design concepts.

Computers have gone further than becoming the medium to create digital imagery, eventually morphing into the medium for a world wide web of communication (Guerra 1996, p.12). As Batty noted: **"**The entire enterprise moved from minicomputers to workstations, thence to PCs, and now to the web where CAD is embedded in the latest VRML plug-ins which enable such visualization to be accessed and viewed within web browsers.” (Batty 2000, p.483)

CAD systems that include intranet/Web publishing features can significantly accelerate the phases of the process that cannot be controlled directly by the designers - purchasing, marketing, manufacturing and service (Jenkins 1998, p.28). Moreover, interactive multimedia can enhance communication, by adding ‘hypertext, sound, animation, rendering, and photographic sampling and processing’ to the models created in CAD environment. If these systems could be integrated effectively, they would certainly present a set of distinguished applications peculiar to urban design.

3.2 Samples of Urban Visualization

The developments in computer visualization modeling technology have enabled professionals to create better models and make valuable contributions to the field of research. The samples chosen are the most outstanding examples of these applications. These samples will be examined under three headings, according to the location of the model in the scale of time- from the past to the future.

3.2.1 Visualizing Lost Times

Time-travel has always been one of the significant aims of human civilization and one of the main themes in science-fiction stories. Five reasons dominate the desire for time-travel and these can be accepted as the goals to revisit the past : (a.) Explaining the past; (b.) Searching for a golden age; (c.) Enjoying the exotic; (d.) Reaping the rewards of temporal replacement; (e.)Refashioning life by changing the past. (Lowenthal 1999, p.22) To know how and why things happened and to be able to interpret the changes in time are imperious purposes for witnessing the past. Getting into the past and to recover valued past scenes by the use of a time-machine still remains as a dream. But the developing computer technology allowed the modeling of lost times, at least for visualization purposes.

Many important places and buildings no longer exist; some of them demolished; some designed but never had the chance to be built; or impossible to visit because they were buried under other structures. Reconstruction of archeological sites or inaccessible architectural sites, or modeling a demolished historical building or the past situation of a city are all valuable applications of digital graphics technology. The utilization and integration of different visualization modeling systems are required for these simulations; such as computer-aided design, virtual reality and multimedia systems.

Lessons from the past are important sources for urban design, by analyzing and understanding urban growth and change through visualization. In a study performed by the students of University of Waterloo(Ontario), under supervision of Prof. Seebohm, 3D CAD was used to model urban growth during various historic periods (Novitski 1993, p.48). *Virtual Heritage* conferences are also important organizations where significant applications of 'walking through the past' are presented. *Virtual Heritage '95*, which took place in the World Heritage City of Bath, was a successful experiment as a first event of its kind (Bertol 1997, p.131). It influenced future applications in the field. Some outstanding examples and details of how the various cities were digitally reconstructed are described below :

- **<u>18th Century Montreal :</u>**

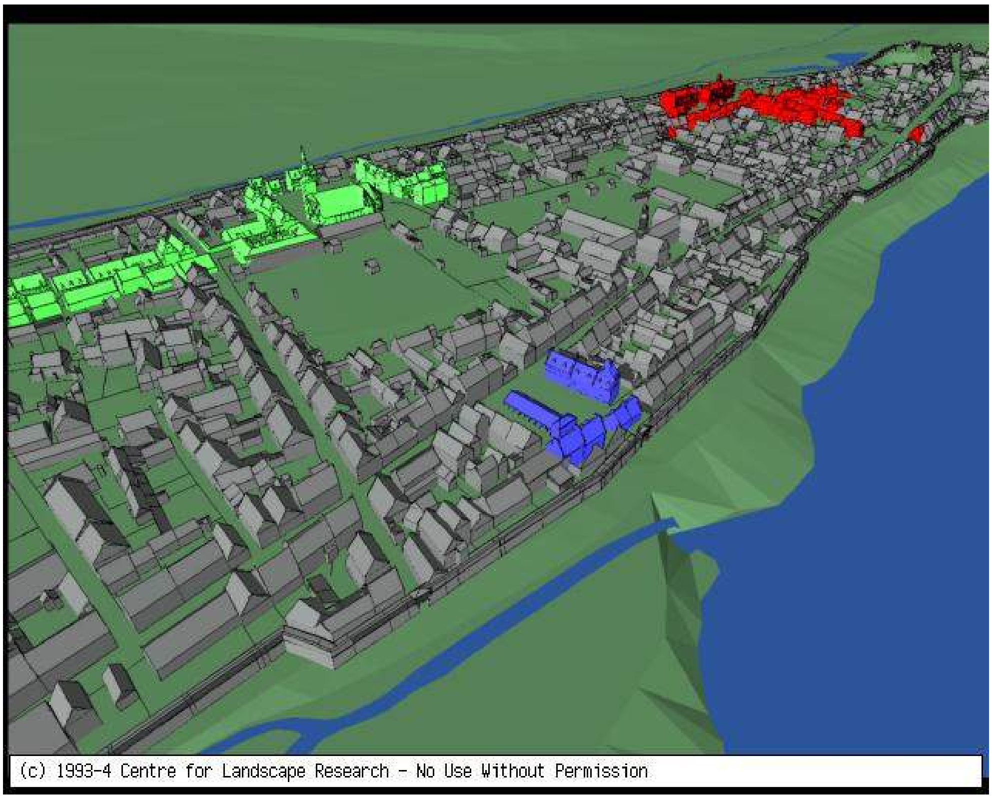


Figure 3.5 3-D Model of 18th Century Montreal
(http://www.clr.toronto.edu/COLLAB/CCA/Gates/maps1.html)

The Centre for Landscape Research (CLR) at the University of Toronto School of Architecture and Landscape Architecture has long been developing and integrating highly interactive multiple media design exploration tools into the curriculum of the school (Danahy 1990; 1992). In 1992, these tools were applied to a public multiple media exhibit "Opening the Gates of 18th Century Montreal", developed with the Canadian Centre for Architecture. Here, the historically reconstructed 3d models were integrating with historical paintings of the city and its social life along with thematic mapping of its ethnic and commercial changes over the century (Hoinkes and Mitchell 1994). These were presented in an interactive kiosk within the traditional exhibition setting. The exhibit proved to be highly successful (and was extended several months), with the kiosk allowing the public a more personal interaction with the historical information, actually touching digitized copies of the imagery to zoom in for more detail or strolling down the reconstructed main street - possibilities that have not existed in conventional settings. While the CLR, acting as experts running the system, had employed these technologies with the public many times in the past, the possibilities for allowing people direct access to the material to built their own experience and interpretations had made a powerful impact (Hoinkes, 1995).

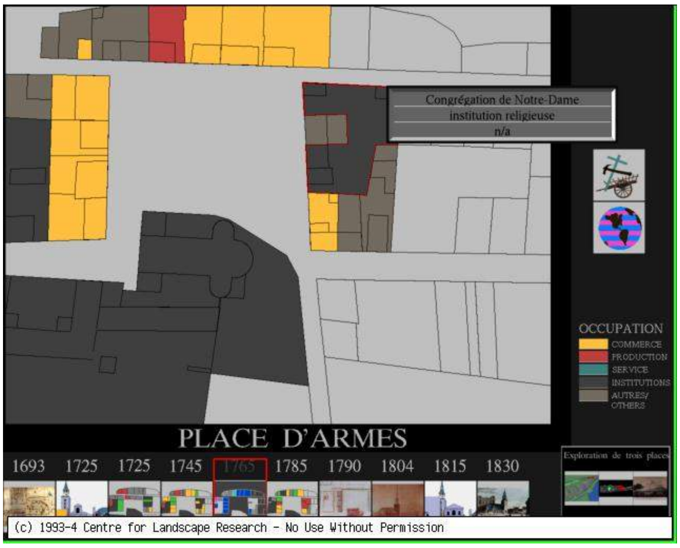
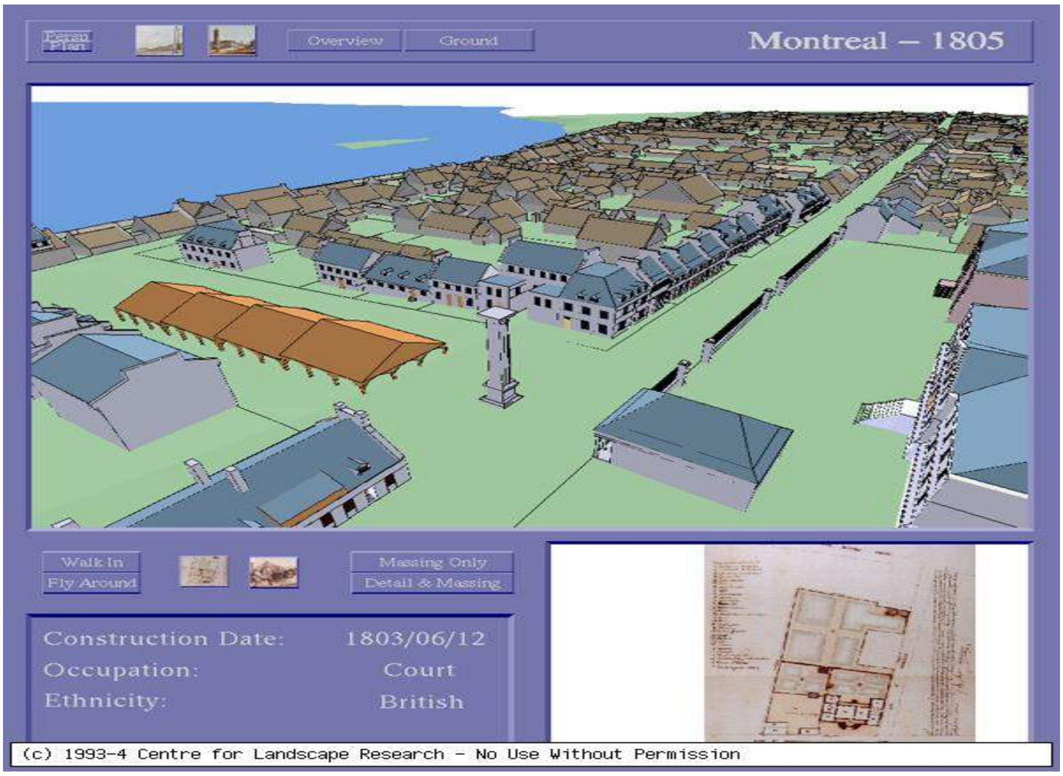


Figure 3.6 Plan of 18th Century Montreal
(http://www.clr.toronto.edu/COLLAB/CCA/Gates/maps1.html)

(c) 1993-4 Centre for Landscape Research - No Use Without Permission

Figure 3.7 Interface developed for Montreal model



Construction Date: 1803/06/12
Occupation: Court
Ethnicity: British

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Figure 3.8 Snapshot from the Montreal model
(http://www.clr.toronto.edu/COLLAB/CCA/Gates/maps1.html)

- Edinburgh Old Town - 16th Century :

A large-scale model of 16th century Edinburgh was reconstructed in digital environment by Prof. Tom Maver, at the University of Strathclyde. This project also included multimedia information displays, to provide highly informative and interactive walk-throughs of historic European sites.

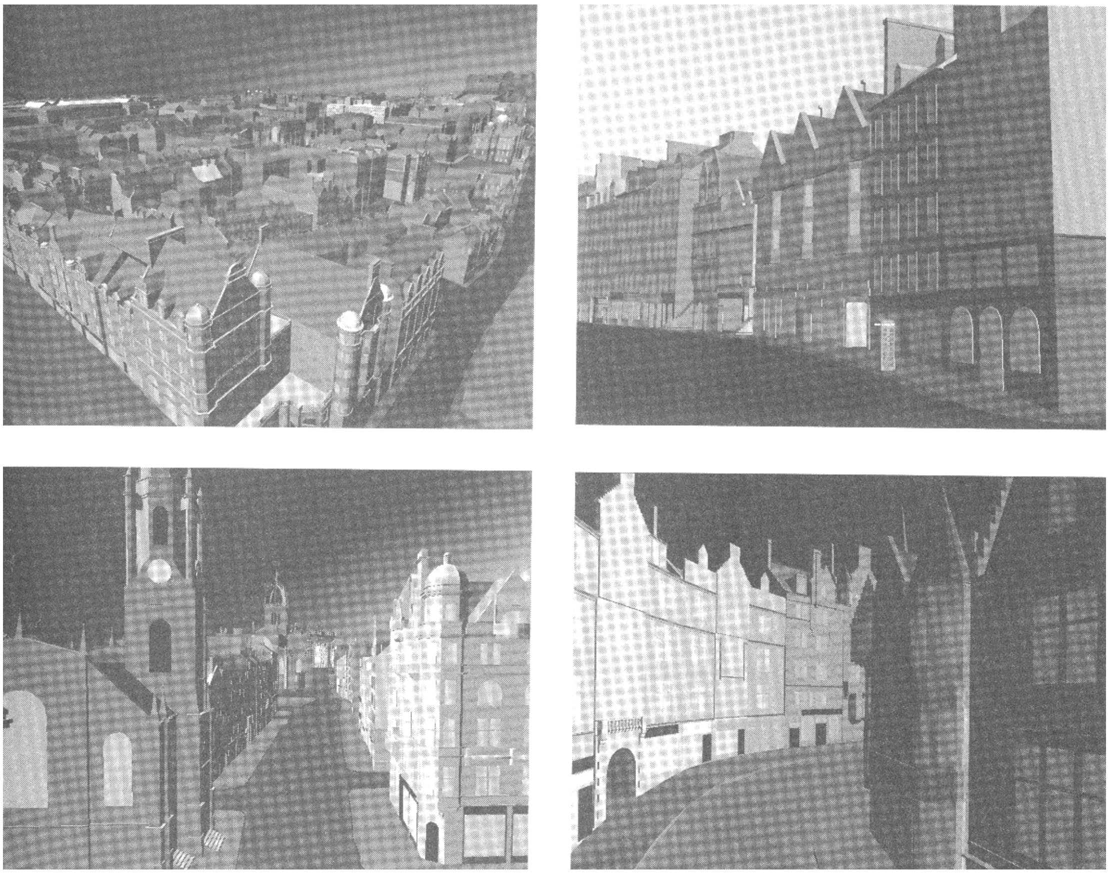


Figure 3.9 Views from Edinburgh 16th Century - Model (Bertol 1997, p.135)

- The City of Giotto :

This project was realized by the Italian company *Infobyte*, which develops VR projects focused on the rendition of monuments and sites. In the City of Giotto, the participant can walk through the Basilica of St. Francis in Assisi. The walls of the church is texture mapped with frescoes of Giotto. Each fresco can be selected, or actually entered, enabling a walk-through in imaginary medieval cities inspired by Giotto's pictorial visions. (Bertol 1997, p.135-6)

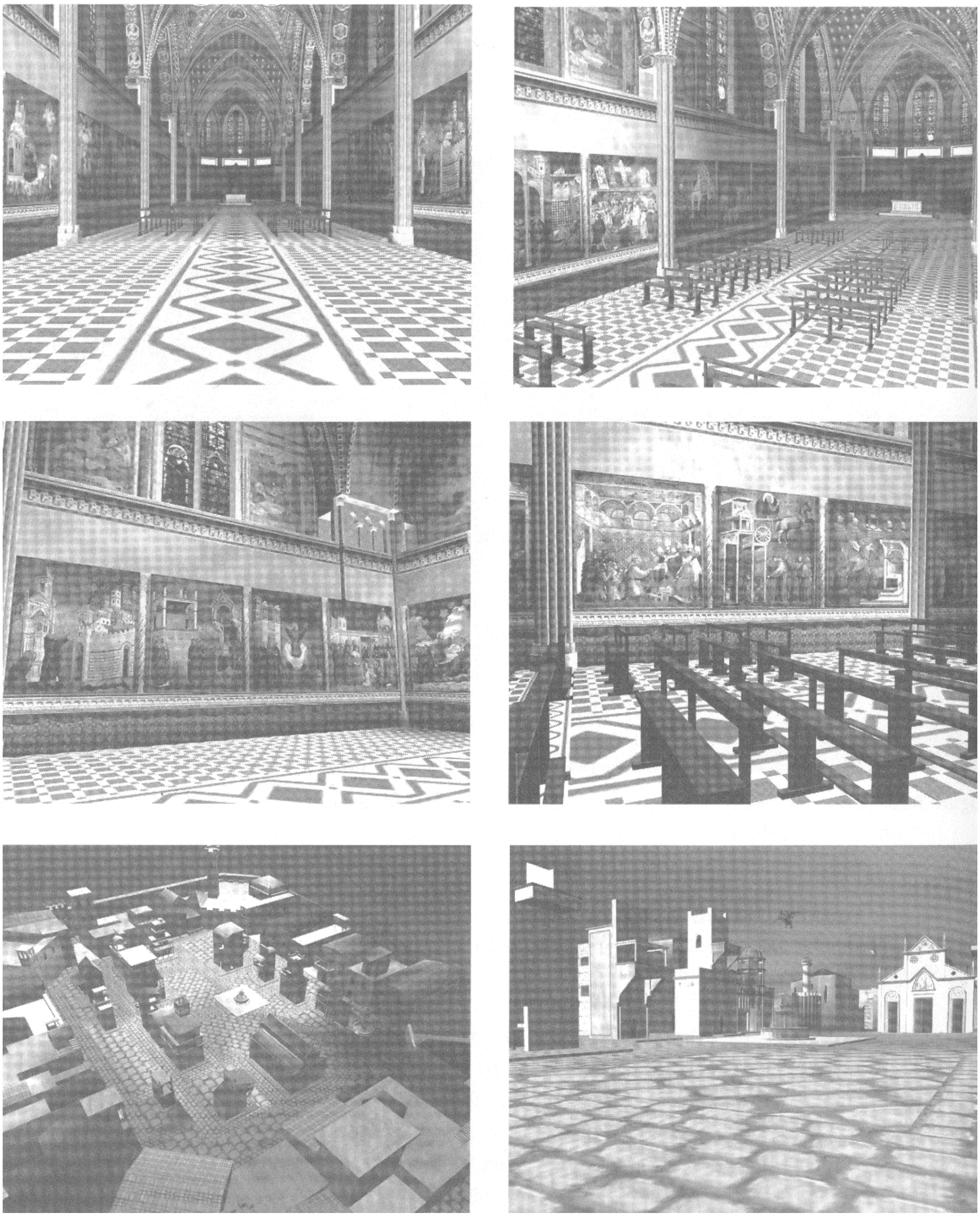


Figure 3.10 Visualization of the City of Giotto (Bertol 1997, p.136)

3.2.2 Today’s Urban Environments

- **Virtual LA :**

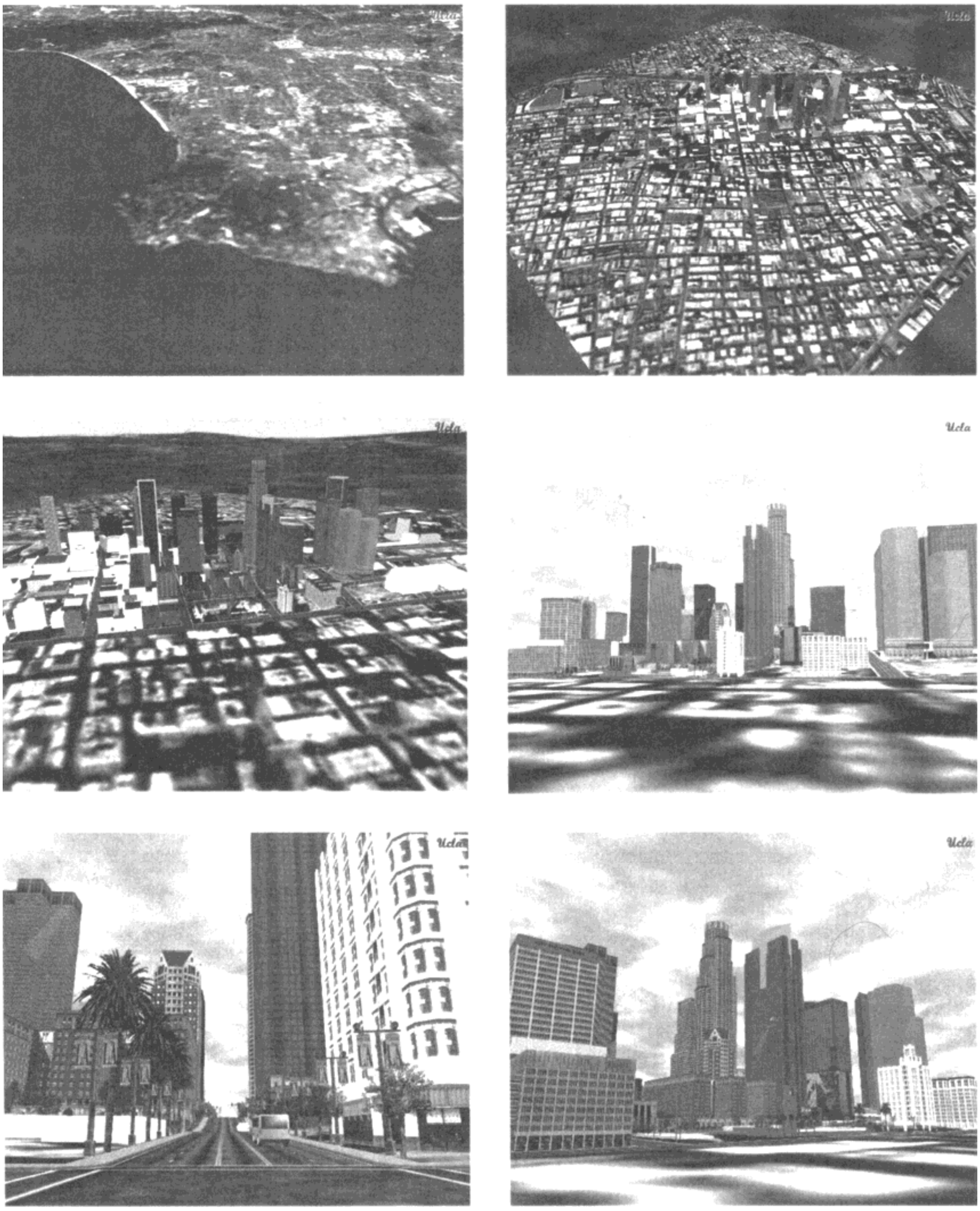


Figure 3.11 Views from the Los Angeles Model (http://www.gsaup.ucla.edu/bill/uSim.html)

- **CyberCity Berlin :**

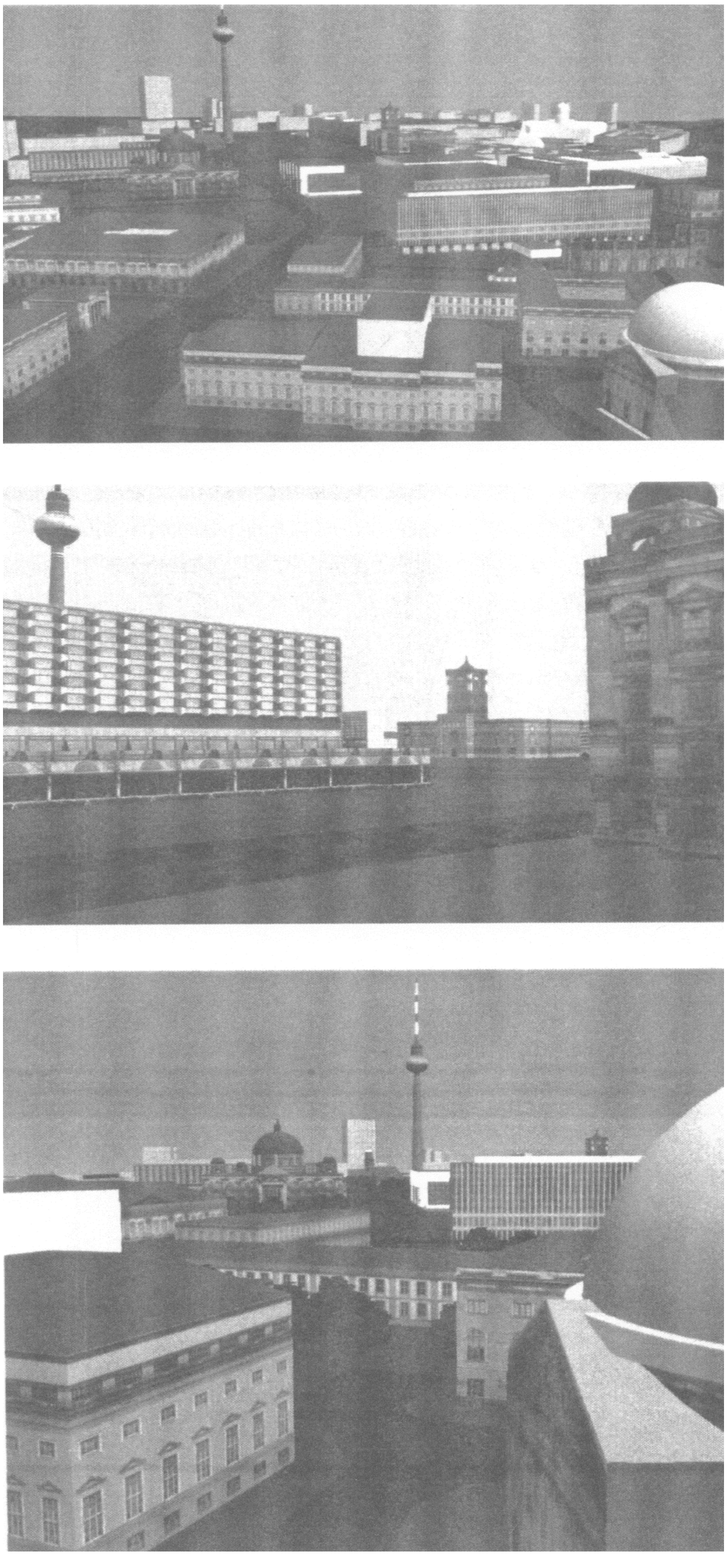


Figure 3.12 Views from the Berlin Model (http://www.cyberlin.de)

- **Virtual Venice :**

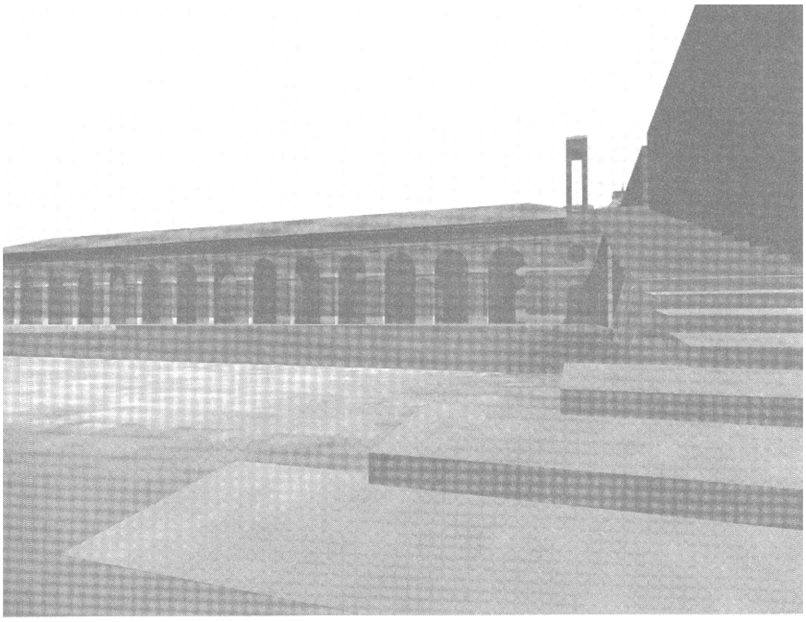


Figure 12.5 A view of the Venice's Arsenale, featuring the Squadratori.

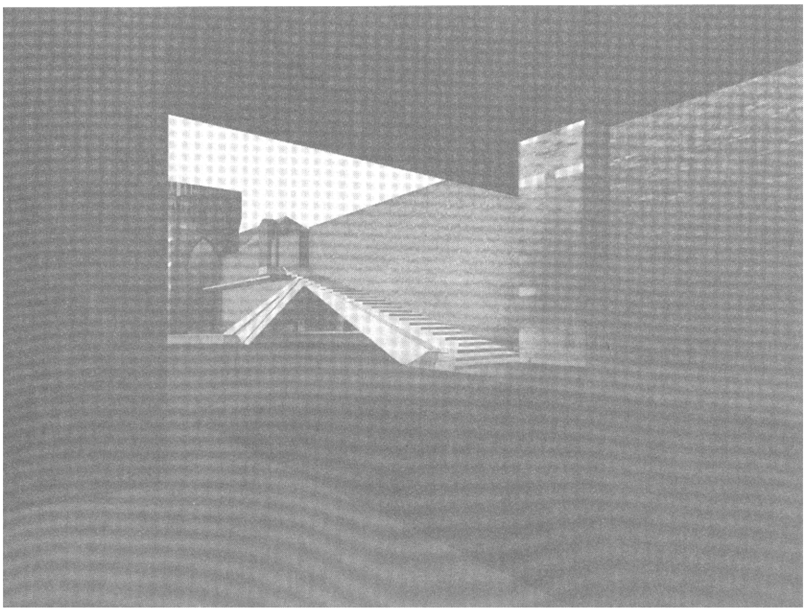


Figure 3.13 Views from the Venice Model (Bertol 1997, p.213)

- **The City of Toronto :**

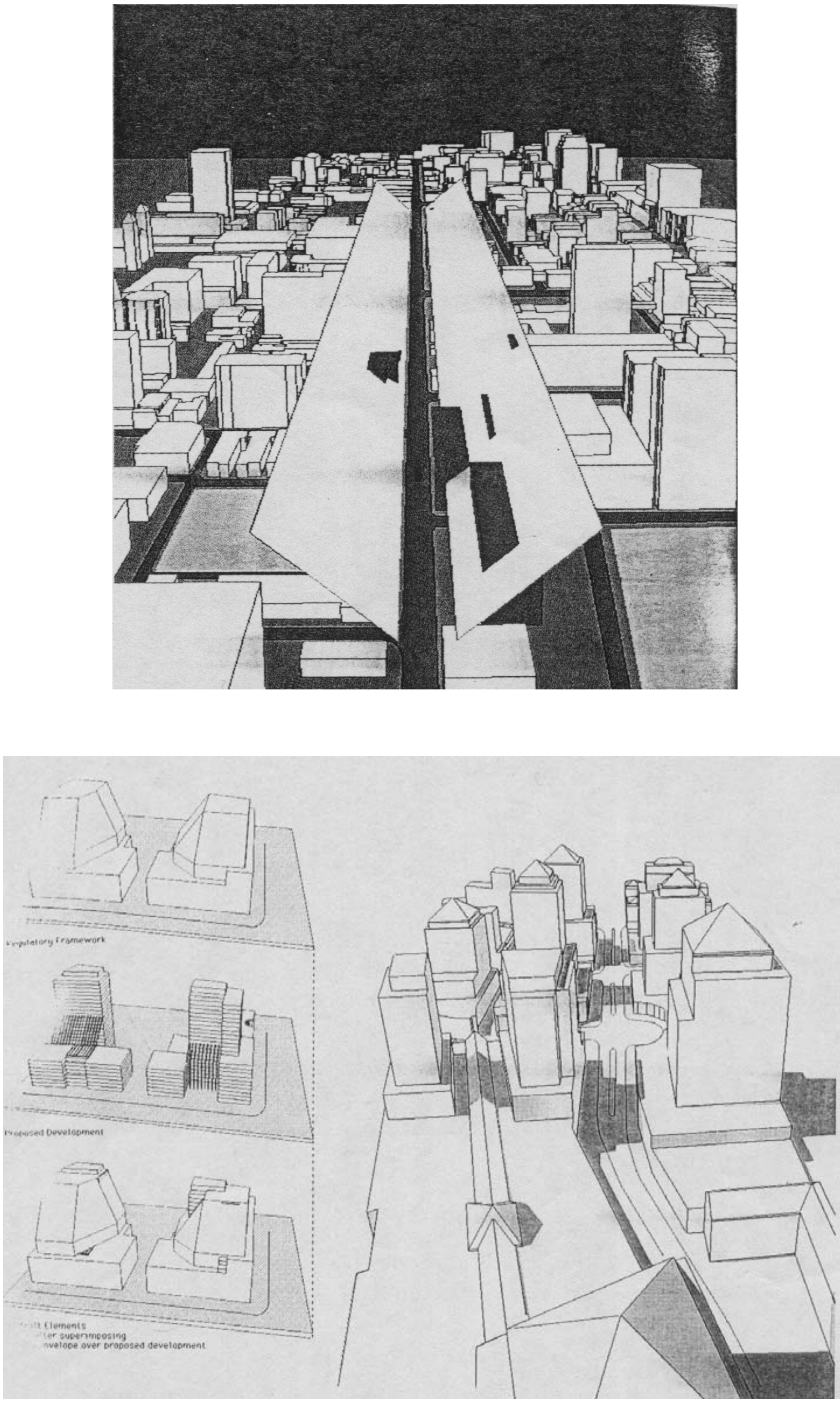


Figure 3.14 Views from the Toronto Model (Jacunski 1993, p.40-41)

- **Seattle Commons :**

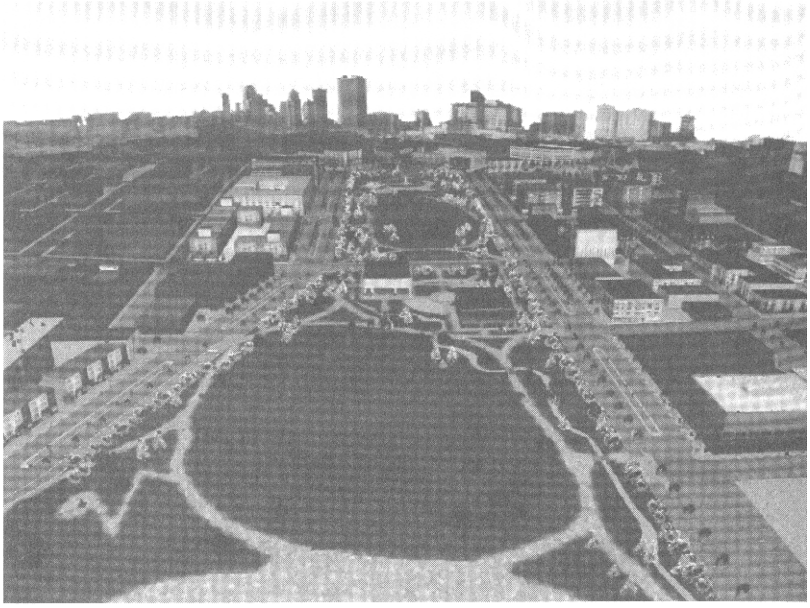


Figure 12.1 An aerial view of the Seattle Commons proposal, represented as a virtual environment.

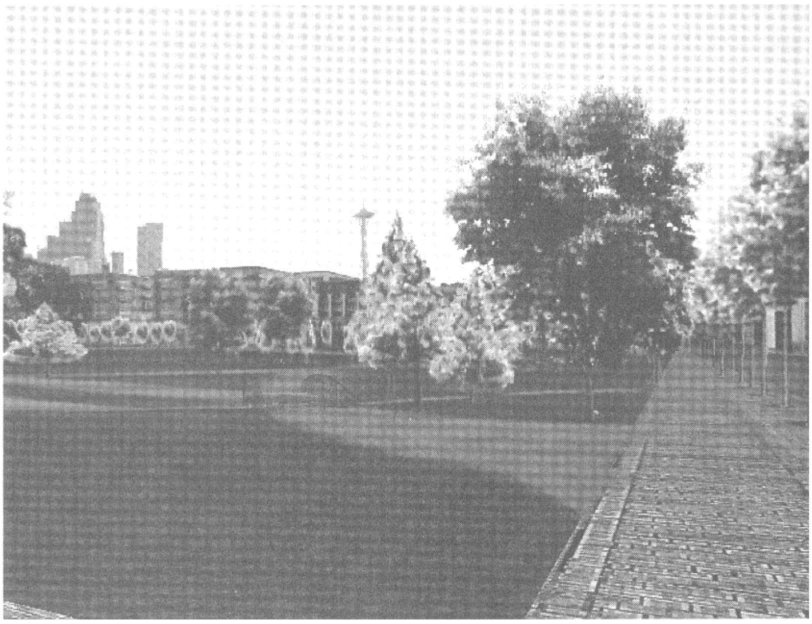


Figure 3.15 Views from the Seattle Model (Bertol 1997, p.210)

- **Master Plan Design –Nanyang Polytechnic :**

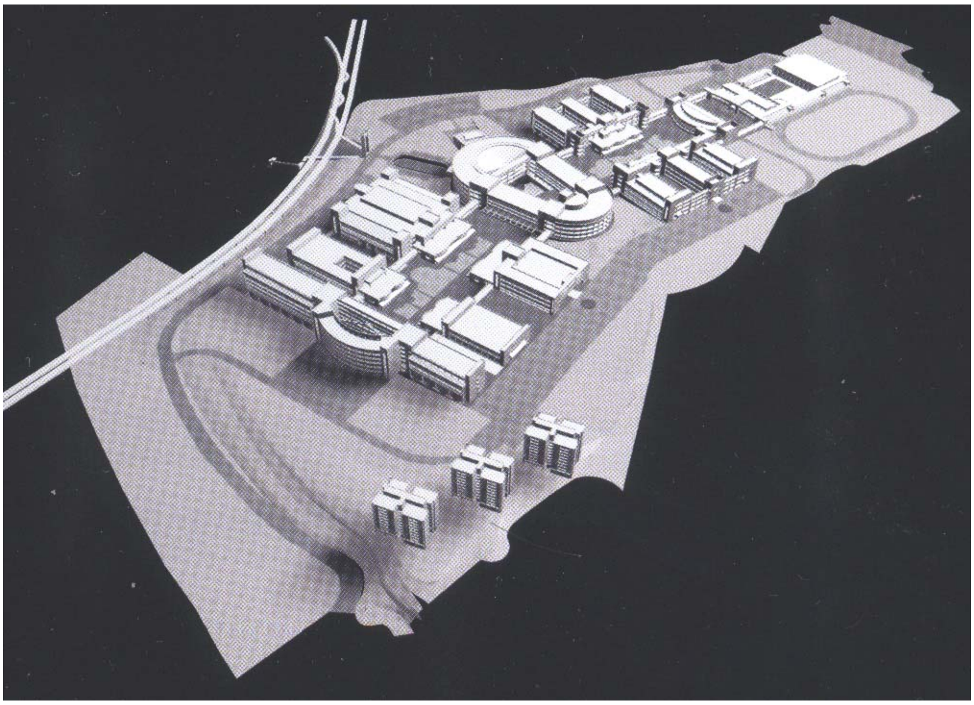


Figure 3.16 Nanyang Polytechnic – Bird’s eyeview (Ojeda and Guerra 1996,p.111)

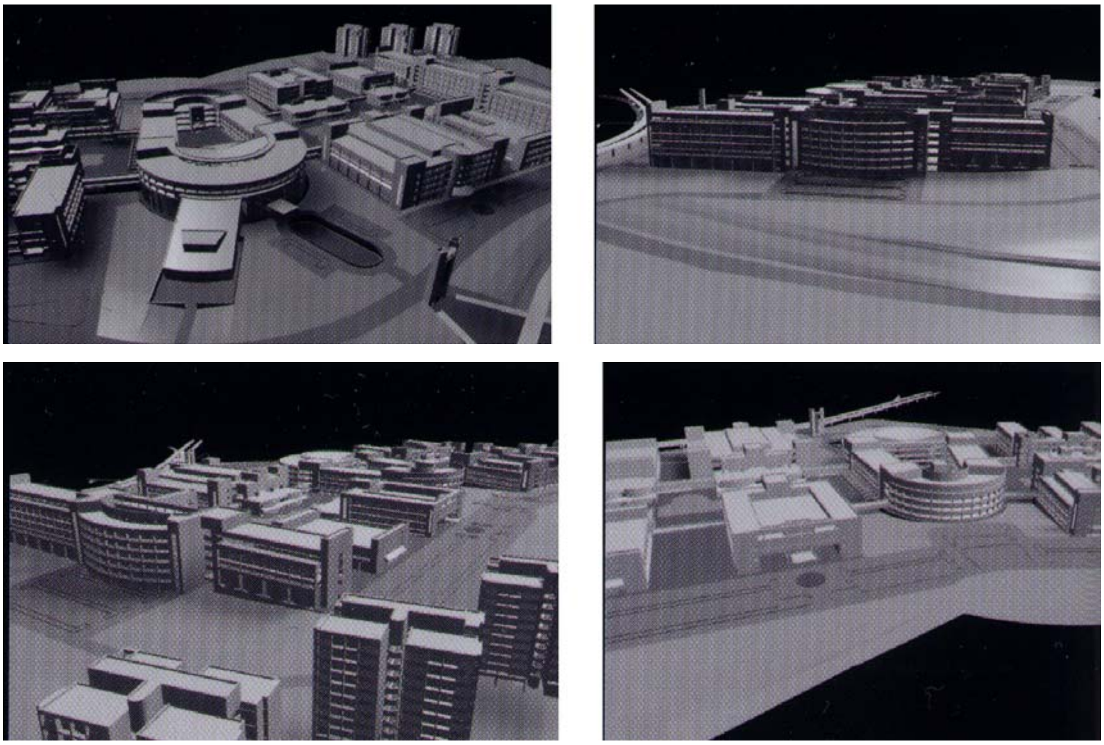


Figure 3.17 Nanyang Polytechnic – Perspectives (Ojeda and Guerra 1996, p.110)

- **Yerba Buena Gardens Development- San Francisco:**

Figure 3.18 Yerba Buena Gardens Development (Ojeda and Guerra 1996,p.160-161)

- **Virtual Design Studio – Melbourne/Toronto :**

Figure 3.19 Digital model created in the Melbourne/Toronto studio
(Dave and Danahy 2000, p.67)

Figure 3.20 Urban design project in the Melbourne/Toronto studio
(Dave and Danahy 2000, p.67)

3.2.2 Scenarios for the Future

- **CitySpace Project :**

The CitySpace project is an on going experiment allowing elementary and high school students from Canada and the United States to design and navigate three dimensional virtual cities collaboratively (http://cityspace.org 1996). These students are engaged in the act of Virtual Urban Design as it will be practiced in the not too distant future. In fact when these students reach the work force, their generation will put pressure on the planning and development community to utilize this technology and allow citizens to partake in the process.

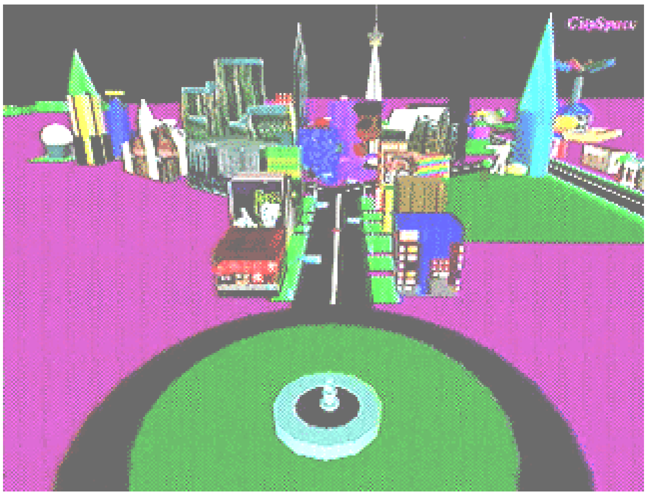


Figure 3.21 CitySpace Project - Approach (http://cityspace.org)

The project is currently still underway at the Ontario Science Centre in Toronto, the Exploratorium in San Francisco and the Boston Computer Museum. To develop the virtual world, students used the software package CLRmosaic, developed by the Centre for Landscape Research at the University of Toronto. The overall simulation is run on some of the most powerful computer graphic equipment available today. This system is also connected to a wall sized projection system which further facilitates the involvement of a number of participants(http://cityspace.org 1996).

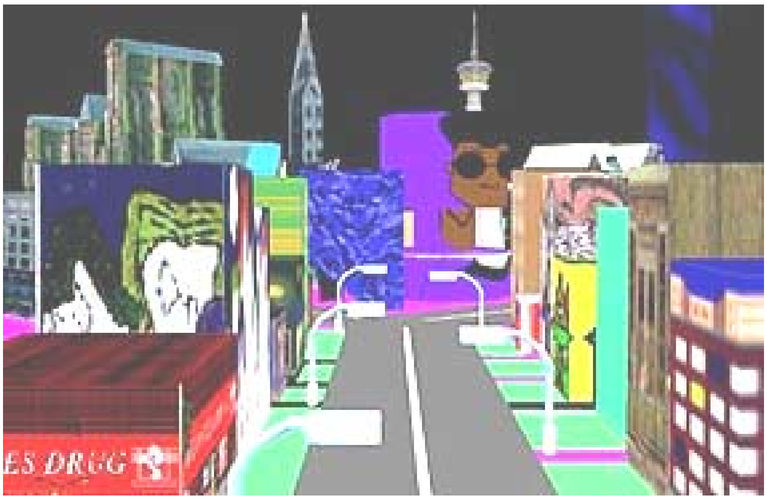


Figure 3.22 CitySpace Project - Street (http://cityspace.org)

To communicate between participants located in geographically remote areas, a video conferencing system was used parallel to the 3D simulation to allow verbal and visual communication between the students. This communication was made possible through high speed connections to the Internet at either end of the system. The specific video conferencing application used was a product known as CU-SeeMe. (White Pine Software,CU-SeeMe WWW Document at http://cu-seeme.cornell.edu/ 1996) CU-SeeMe is a very inexpensive, yet feature rich video conferencing system which is available for a number of computer platforms. (Goodfellow 1996)

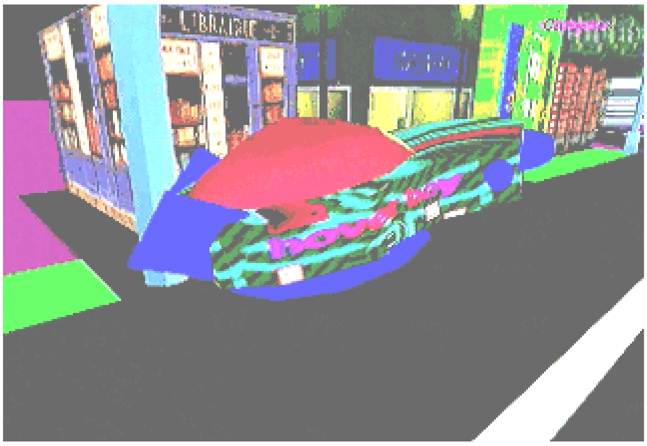


Figure 3.23 CitySpace Project -Toronto (http://cityspace.org)

- **The GreenSpace Project:**

The Greenspace project has served as venue developing distributed, networked virtual environments for collaboration by multiple participants. After a first phase of development, an historic demonstration of this technology took place in November 1994 in which a trans-Pacific virtual environment was inhabited by participants located in Seattle, Washington and Tokyo. The experimental demonstrations of the GreenSpace project have indicated several new directions for further study in the field digital technology.

Figure 3.24 The GreenSpace Project – A view of multiple participants greeting each other within the GreenSpace vestibule (Bertol 1997, p.216)

Figure 3.25 A view of the GreenSpace section-cutting tool (Bertol 1997, p.217)

Figure 3.26 A view within one of the hotel guest rooms used as GreenSpace content (Bertol 1997, p.217)

Chapter 4

THEORY OF PIECEMEAL (INCREMENTAL) GROWTH

> *“Cities develop over time because of the conscious and unconscious acts of people. Urban designers assume that in spite of the vast scale and complexity, cities can be designed and their growth shaped and directed.”*
>
> (Steger 2000, p.138)

Urban planning has to function generally under conditions of ‘imperfect knowledge, unclear objectives, and certain means’ for realizing its objectives. According to the clarity of ‘planning goals’ and ‘methods’, several different planning approaches have emerged. ‘Rationalism, incrementalism, utopianism, and methodism’ are among these planning approaches (Catanese&Snyder 1988, p.48).

	Clarity of ends	
	High	Low
Clarity of means		
High	Rationalism	Methodism
Low	Utopianism	Incrementalism

Table 4.1 Four types of planning situations and their associated types of theory (Catanese&Snyder 1988, p.48)

In the first half of the twentieth century, urban planning was accepted as ‘civic design’ in a tradition that remained for many years thereafter; which had a great effect on both planning education and the planners in practice (Adams 1994, p.3). In the 1940’s and 1950’s, a new approach originated in the USA; known as ‘rational-comprehensive planning’ (Adams 1994, p.5). Rational comprehensive planning tries to solve problems ‘from a systems (integrated) point of view, by using conceptual or mathematical models that relate ends (objectives) to means (resources and constraints) with heavy reliance on numbers and quantitative analysis’. The four typical elements of rational-comprehensive planning are: ‘goal setting, identification of policy alternatives, evaluation of means against ends, and implementation of decisions with feedback loops and repetition of steps’ (Macleod 1996).

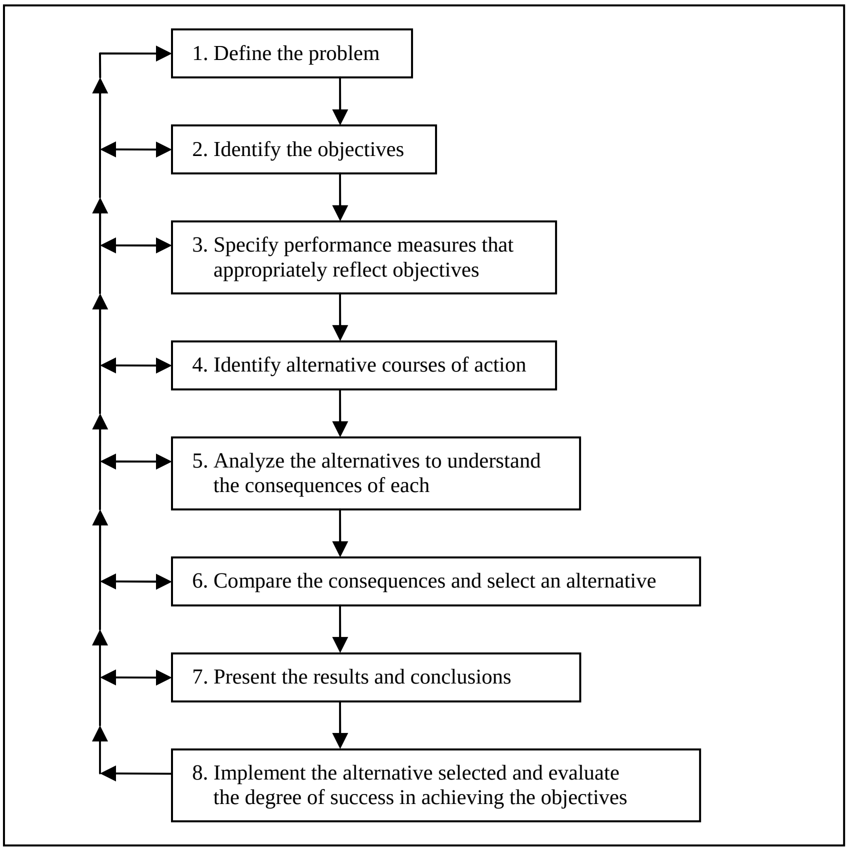


Figure 4.1 A rational decision model (Catanese&Snyder 1988, p.49)

Although rational comprehensive planning was dominant and had a significant influence on urban planning practice, research and education in the 1970's, several competing concepts of the planning process have also emerged.

In spite of its dominance, rational model has been subject to a great deal of criticism. As a result of these critics, several new approaches to planning , such as : 'Incremental, Advocacy, Strategic and Equity' planning (Campbell and Fainstein 1996, p.262). Levy asserts three basic approaches to the process of urban planning (Levy 2000, p.331):

(1) The rational model
(2) Disjointed incrementalism
(3) Middle-range models

Critics argues that rational comprehensive planning can only be applied to relatively simple problems as a methodology. Inherent limitations on resources, information and time make it impossible to use. Its demands are considerable and require more than decision-makers are capable of giving. It relies heavily on a particular model of a clear, unitary notion of the public interest which is impossible to achieve in the real world. Many comparisons have been made between the rational model and disjointed incrementalism, which represent almost opposite poles.

4.1 Incrementalism in Urban Planning

Incrementalism has been a powerful and lasting counter-argument to traditional master planning. It presents a fundamental transformation in planning thought. Incrementalism is an alternative theory that accepts most obvious shortcomings of rational planning. Although it was grounded in the comprehensiveness of architecture and urban design, now it is also oriented to the marginal analysis of economic policy and pragmatic politics. (Campbell and Fainstein 1996, p.262).

Favors Rational Model	**Favors Incremental Model**
Adequate theory available	Adequate theory lacking
New question	Modification of old question
Resources generous	Resources limited
Substantial time for study	Limited time for study
Numerous relations to other policy issues	Few relations to other policy issues
Wide range of policies might be politically acceptable	Policy options highly limited by political realities

Table 4.2 Which model to use (Levy 2000, p.336)

Incremental planning was firstly mentioned by Charles Lindblom in his article, *‘The Science of Muddling Through’* in 1959. Lindblom claimed that ‘rational planning is a hard model to realize’ and ‘the costs of being more comprehensive often exceeds the benefits’ (Macleod 1996). Lindblom described decision making as ‘a series of small incremental steps, edging into the future and toward the unknown’. He called this type of planning ‘disjointed incrementalism’ or ‘muddling through’:

> “It *(rational-comprehensive planning)* is greedy for facts; it can be constructed only through a great collection of observations ... In contrast, the comparative *(incremental)* method both economizes on the need for facts and directs the analyst’s attention to just those facts which are relevant to the fine choices faced by the decision-maker” (Lindblom 1996, p.301)

Comprehensive planning has been criticized, mainly for two reasons: The first of these reasons is that it “limits the range of individual choice by imposing centrally made decisions”. The second is that it “requires ‘vastly more knowledge…about a huge variety of factors' than can be obtained or grasped by any individual or closely related group". (Stein 1995, p.88)

Rational-Comprehensive (Root)	***Successive Limited Comparisons (Branch)***
1a. Clarification of values or objectives distinct from and usually prerequisite to empirical analysis of alternative policies.	*1b.* Selection of value goals and empirical analysis of the needed action are not distinct from one another but are closely intertwined.
2a. Policy formulation is therefore approached through means-end analysis: First the ends are isolated, then the means to achieve them are sought.	*2b.* Since means and ends are not distinct, means-end analysis is often inappropriate or limited.
3a. The test of a 'good' policy is that it can be shown to be the most appropriate means to desired ends.	*3b.* The test of a 'good' policy is typically that various analysts find themselves directly agreeing on a policy (without their agreeing that it is the most appropriate means to an agreed objective).
4a. Analysis is comprehensive: every important relevant factor is taken into account.	*4b.* Analysis is drastically limited: i) Important possible outcomes are neglected. ii) Important alternative potential policies are neglected. iii) Important affected values are neglected.
5a. Theory is often heavily relied upon.	*5b.* A succession of comparisons greatly reduces or eliminates reliance on theory.

Table 4.3 Comparison of comprehensive versus incremental approaches (Lindblom 1996, p.291)

The goal of comprehensiveness in decision-making should be considered suspiciously. Incrementalism challenges the viability of large-scale, complex decision making and offers the much more modest approach of comparisons of limited policy change. Piecemeal approach tries to pose a large number of policy questions. This can be accepted as a great advantage for planning. Piecemeal approach enables interest groups to deal with questions that their members care about (Stein 1995, p.91-2). Incremental planners claim that “the excessive complexity of the comprehensive public interest prevented the planner from directly serving it.” (Campbell and Fainstein 1996, p.10).

Incremental planning supports the idea of coming to a decision by ‘weighing the marginal advantages of a limited number of alternatives’. It implies to ‘move ahead through successive approximations’, rather than ‘working in terms of long-range objectives’ (Fainstein and Fainstein 1996, p.271). In this model, plans are not constructed by a strict process, but by a series of consultations largely based on peoples’ experiences. Incrementalism has lesser demands for information, concentrates on the consequences of limited change, can be modeled to yield determinate solutions, and is able to respond to the radically constrained situations faced by decision-makers. The model recognizes that policy is continually being made and re-made, and thereby avoiding errors that come with radical change in policy and stays within predictive capability. (Macleod 1996)

> “Critics cannot avoid the fact that some form of muddling-through *(disjointed incrementalism)* is often the only rational way to proceed when high uncertainty surrounds a problem. Grandious schemes and elaborate analyses and studies may be a waste of time if neither the planners not the public nor the policy-makers really understand what is being considered and what the alternatives may be. Under such circumstances, the most rational behaviour may be simply to take small steps and to keep examining their implications in terms of whether they improve or worsen the problem at hand ... then it is best not to commit oneself to arriving at an unknown destination any earlier than absolutely necessary.” (Catanese and Snyder 1988, p.50)

In terms of classical planning approach, incrementalism cannot be accepted as planning at all; since “policy outcomes are not arrived at through formal rationality, and there is no specifying of ends and means” (Campbell and Fainstein 1996, p.272). According to some critics, incrementalism can only be ‘a description of what happens without planning’; but it is definitely ‘not a form of planning’ (Catanese and Snyder 1988, p.50). Some critics argues that incremental approach can result in extreme dependence on precedent and past experience, so that it can prevent new ideas. Therefore, “heavy reliance on incrementalism can lead one into excessive caution and missed opportunities” (Levy 2000, p.336).

On the other hand; although incrementalism demonstrates the opposite of planning in its methods, it produces the ‘fruits of planning’ in its results. Lindblom believes that behind incrementalism, there is a concept of problem-solving as a strategy. According to this view, public problems are too complex to be well understood and mastered. Thus; “one develops a strategy to cope with problems, not to solve them” (Lindblom 1996).

4.2 Piecemeal Approach in Urban Design

Urban design is the discipline which comes closest to accepting responsibility for the city’s wholeness. Christopher Alexander and his colleagues, in their study *‘A New Theory of Urban Design’*, imagine “a process of urban growth, or urban design, that would create wholeness in the city, almost spontaneously, from the actions of the members of the community … provided that every decision, at every instant, was guided by the centering process” (Alexander et al. 1987, p.5). They consider the study as the beginning of a new theory for the three dimensional formation of cities (Alexander et al. 1987, p.6). Alexander and his collaborators present some general rules applicable to the universe (Broadbent 1990, p.323).

Christopher Alexander always believed that principles could best be expressed in terms of more abstract relations; not in pictures –as in Gordon Cullen’s method-, but in words -as Jane Jacobs proposed- or even in built examples (Broadbent 1990, p.143). Alexander and his colleagues tried to describe an entirely new approach to architecture, planning and urban design. Their theoretical contributions to urban design are many, including essays such as *'A City is not a Tree'* and a series of books, which explain their studies on the subjects, include: *'The Timeless Way of Building'* , *'A Pattern Language'* (1977), *'The Oregon Experiment'* (1975), *'The Production of Houses'*, *'The Linz Café/Das Linz Café'*, and followed by *'A New Theory of Urban Design'* (1987).

The piecemeal approach, in their study *'A New Theory of Urban Design'*, deserves to be studied because it brings into discussion the distinction between a merely piecemeal approach, consisted of unrelated acts and ends up in a chaos, and one which is capable of producing 'growing wholes' in an incremental way (Akozer and Mennan 1995, p.23) As in the main argument of disjointed incrementalism, the reduction of the scope and the range of alternatives and the adoption of falsificationism carry the intention of making the problem more manageable by reducing its size and retaining the status quo, that is by managing the objectives as they coincide with the means available at hand: "…the piecemeal method permits repeated experiments and continuous readjustments…This – and not Utopian planning or historical – would mean the introduction of scientific method into politics, since the whole secret of scientific method is a readiness to learn from mistakes" (Popper 1971, p.163) :

> "Incremental, piecemeal design represents a socially and politically relevant approach to the pluralist democratic city where the urban design policy should adapt to a wide range of interests. In order to prevent its instrumentalization in favor of the dominating groups, such a policy relies on falsificationism, i.e., it never claims to be the final solution of a problem, expects to achieve goals only partially, continually readjusting itself and allowing for a change in the initial prospect, avoiding thus serious lasting mistakes and repeating the sequence as conditions, parameters, aspirations change and as prediction becomes more accurate" (Akozer and Mennan 1995, p.22)

4.2.1 The Idea of a Growing Whole

Incrementalism can help to achieve integration in design. Trancik claims that: “In many cases small-scale steps toward the renewal of an urban landscape are most effective than total redevelopment, which, as we have seen, often segregates the patterns of urban space. Through gradual selective infill, new pieces can be effectively brought into harmony with existing spaces and architectural forms” (Trancik 1986, p.219)

According to Alexander modern practice of urban design leads to ‘an artificial, contrived kind of wholeness’, ‘a superficial and skin deep order’; thus the theory presents ‘The idea of a growing whole’. Alexander suggests that wholeness can only be attained through a suitable process, and he lists certain fundamentals and essential features of ‘growing wholes’ as follows :

“First; the whole grows piecemeal, bit by bit.

Second; the whole is unpredictable. When it starts coming into being, it is not clear yet how it will continue, or where it will end, because only the interaction of the growth, with the whole’s own laws, can suggest its continuation and its end.

Third; the whole is coherent. It is truly whole, not fragmented, and its parts are also whole, related like the parts of a dream to one another, in surprising and complex ways.

Fourth; the whole is full of feeling, always. This happens because the wholeness itself touches us, reaches the deepest levels in us, has the power to move us, to bring us to tears, to make us happy.“ (Alexander et al. 1987, p.14)

According to Alexander, all traditional towns have these features in their growth. However, this kind of growing wholeness is not only found in old towns. It exists in all growing organisms and this explains the feeling of organic character of old towns. It also exists “in a good painting, during the time of its creation and in a poem” (Alexander et al. 1987, p.13). But, he claims that modern practice of urban design does not have these features. And it does not deal with growing wholes at all. (Alexander et al. 1987, p.14)

Alexander and his colleagues also presents a series of key results on the nature of wholeness. These results establish the following facts (Alexander et al. 1987, p.23):

1. Wholeness, or coherence, is an objective condition of spatial configurations, which occurs to a greater or lesser degree in any given part of space, and can be measured.

2. The structure which produces wholeness, is always specific to its circumstances, and therefore never has exactly the same form twice.

3. The condition of wholeness is always produced by the same, well-defined process. This process works incrementally, by gradually producing a structure defined as ‘the field of centers’, in space.

4. The field of centers is produced by the incremental creation of centers, one by one, under a very special condition.

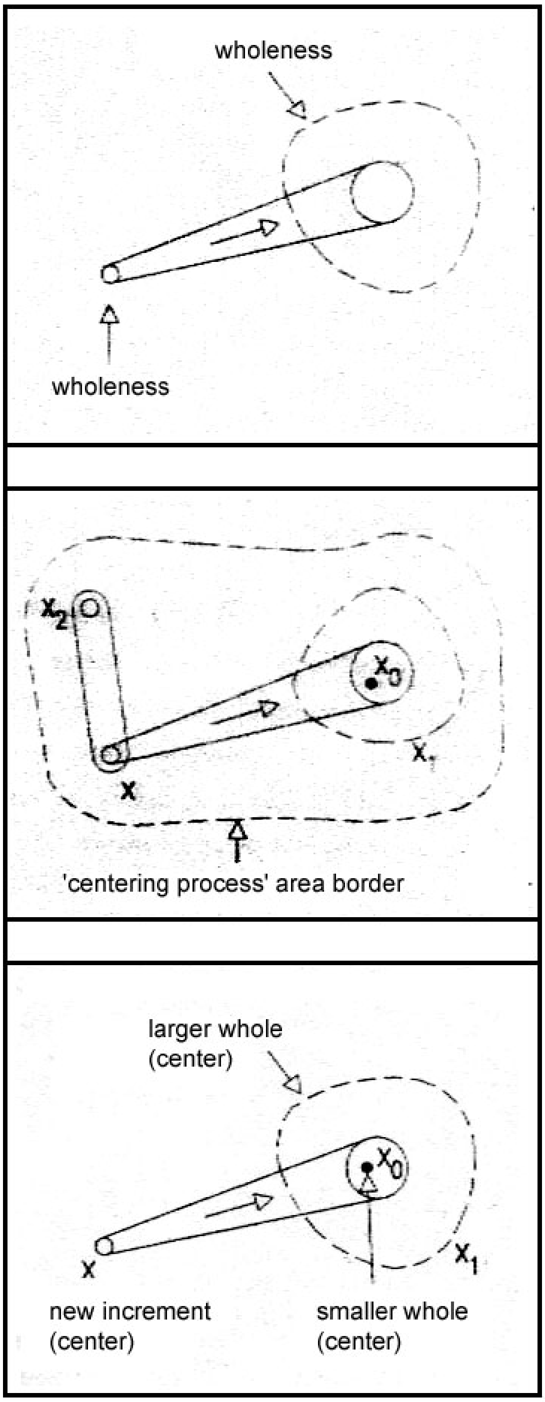


Figure 4.2 The idea of a growing whole
(Aran 1996, p. 58-9)

4.2.2 Rules of Growth

Christopher Alexander believes that it is a must to understand the laws which produce the wholeness in the city (Alexander et al. 1987, p.19). Wholeness in the city can only be created to the extent that these laws are made clear. Therefore, *'A New Theory of Urban Design'* describes 'seven detailed rules of growth', "to embody the process of centering at a practice level, consistent with the real demands of urban development (Alexander et al. 1987, p.5). According to Alexander, it is possible to see a new part of the city growing under the influence of these seven rules (Alexander et al. 1987, p.6). The 'seven detailed rules of growth' can be briefly explained as in the following (Broadbent 1990, p.321) :

1. ***Piecemeal growth :*** to 'guarantee a mixed flow of small, medium and large projects' – preferably in equal quantities by cost
2. ***The growth of larger wholes :*** 'Every building increment must help to form at least one larger whole…'
3. ***Visions :*** 'Every project must first be experienced, and then expressed, as a vision which can be seen in the inner eye (literally)'
4. ***Positive urban space :*** 'Every building must create coherent and well-shaped public space next to it'
5. ***Layout of large buildings :*** 'The entrances…main circulation, main division…into parts…interior spaces…daylight, and…movement within the building, are all coherent and consistent with the position of the building in the street and in the neighborhood'
6. ***Construction :*** 'The structure of every building must generate smaller wholes in the physical fabric…in its structural bays, columns, walls, windows, building base, etc. … in its entire physical construction and appearance'
7. ***Formation of centers :*** 'Every whole must be a center in itself, and must also produce a system of centers around it.'

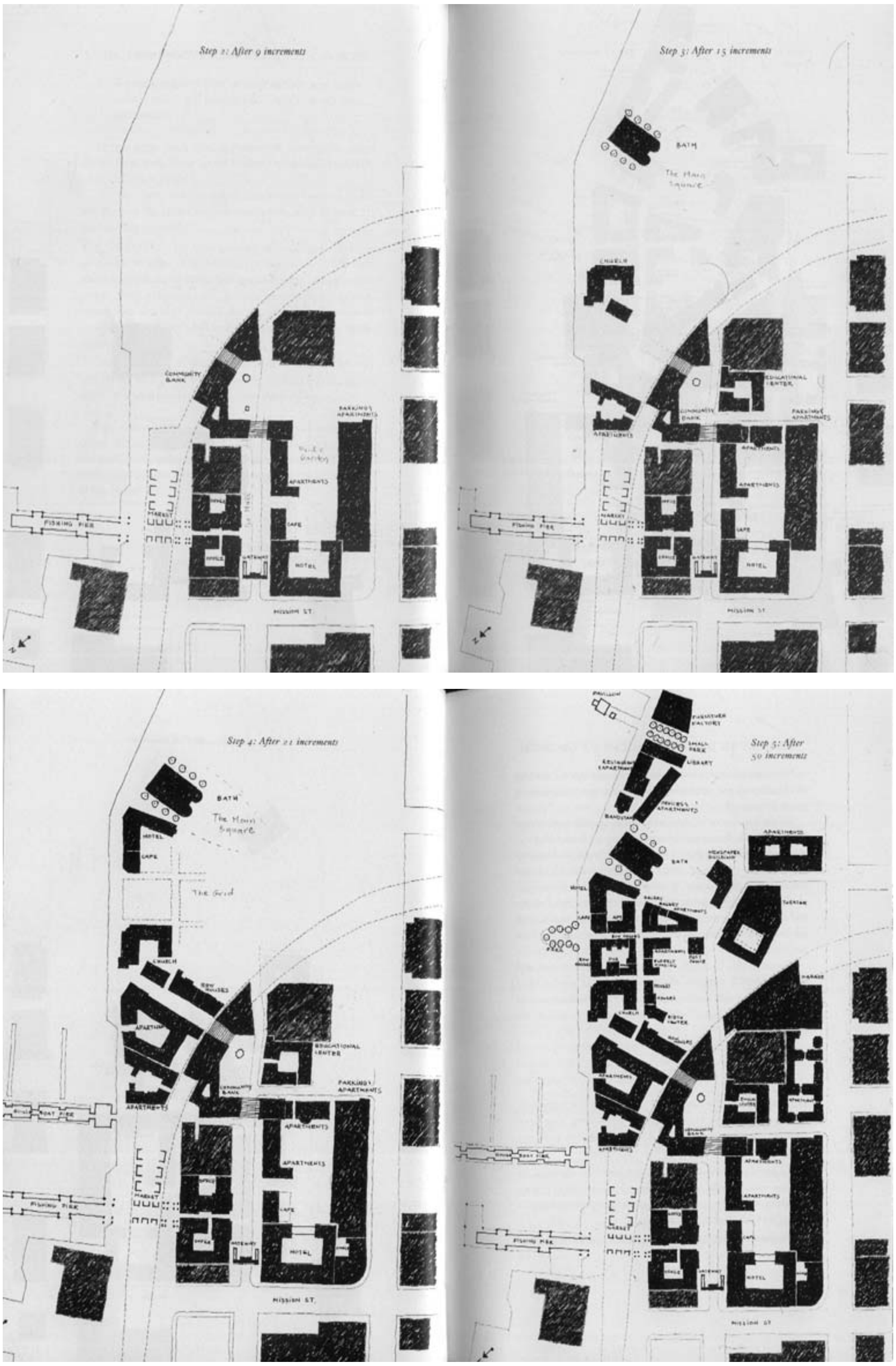


Figure 4.3 Four steps of incremental growth in the experiment (Alexander et al. 1987)

Alexander believes that these seven rules are imperfectly formulated, as they leave much to be considered both in their forms and detailed contents. In a real process of urban design, these seven rules would probably have to be improved and adjusted according to local context. Still, “some version of these rules will always be needed, to embody the overriding rule correctly in a city (Alexander et al. 1987, p.30).

4.2.3 Piecemeal Growth

Piecemeal character of growth is presented as a necessary precondition of wholeness. To guarantee the piecemeal nature of the growth, three subrules are described (Alexander et al. 1987, p.32-33):

- no building increment may be too large;
- there must be a reasonable mixture of sizes;
- a reasonable distribution of functions; in the piecemeal growth.

However, piecemeal growth would not create large wholes by itself. In fact, according to the theory, none of the seven rules can be relied on to produce wholeness, since they are all versions of the one rule; ‘The Overriding Rule’. They believe that: “Every new act of construction has just one basic obligation : it must create a continuous structure of wholes around itself”. (Alexander et al. 1987, p.22) Then, they formulate a single overriding rule as follows : “Every increment of construction must be made in such a way as to heal the city.” (Alexander et al. 1987, p.22)

In this statement, ‘to heal’ means in its old sense ‘to make whole. It does not only include repairing of existing wholes, but also the creation of new wholes. In general, each new increment ‘X’ does all three things(Alexander et al. 1987, p.43):

1. X always helps to complete at least one major center which already clearly defined.
2. X usually plays a role in pinning down some other, less clearly defined center, which has so far only been hinted at by earlier increments of construction.
3. X usually creates a hint, of some entirely new larger center, which will emerge fully, only in much later increments.

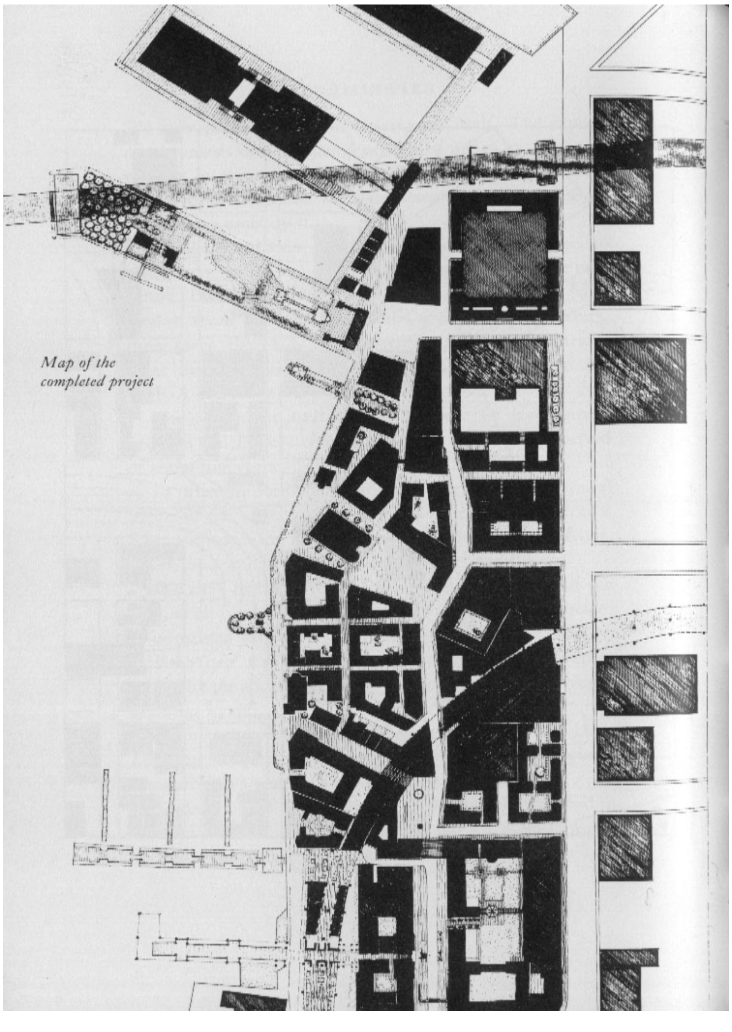


Figure 4.4 Map of the completed project
(Alexander et al. 1987, p.106)

4.3 The Experiment

The theory was tested by performing an experiment, in other words, a simulation. A part of the San Francisco waterfront, just north of the Bay Bridge, was taken and an imaginary process was simulated that makes use of the seven rules of growth, to govern all development over a five-year period. The total area of the site was about thirty acres intended for development in the near future. It includes several existing streets, three piers, a coffee factory, a nightclub, an old YMCA, and other warehouses and factories.

The simulation includes 90 development projects to be completed in the area in a period of five years. In order to do simulation, a physical and three dimensional model of the whole project area was made. Each increment was always represented by the addition of a physical piece, to the overall model; just like constructing a real town.

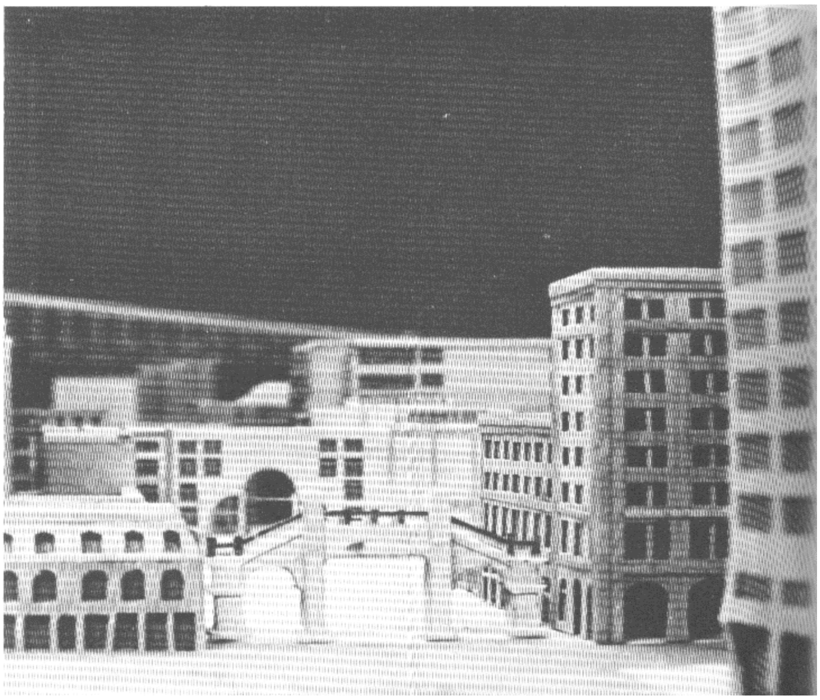


Figure 4.5 Detail from the model (Alexander et al. 1987, p. 116)

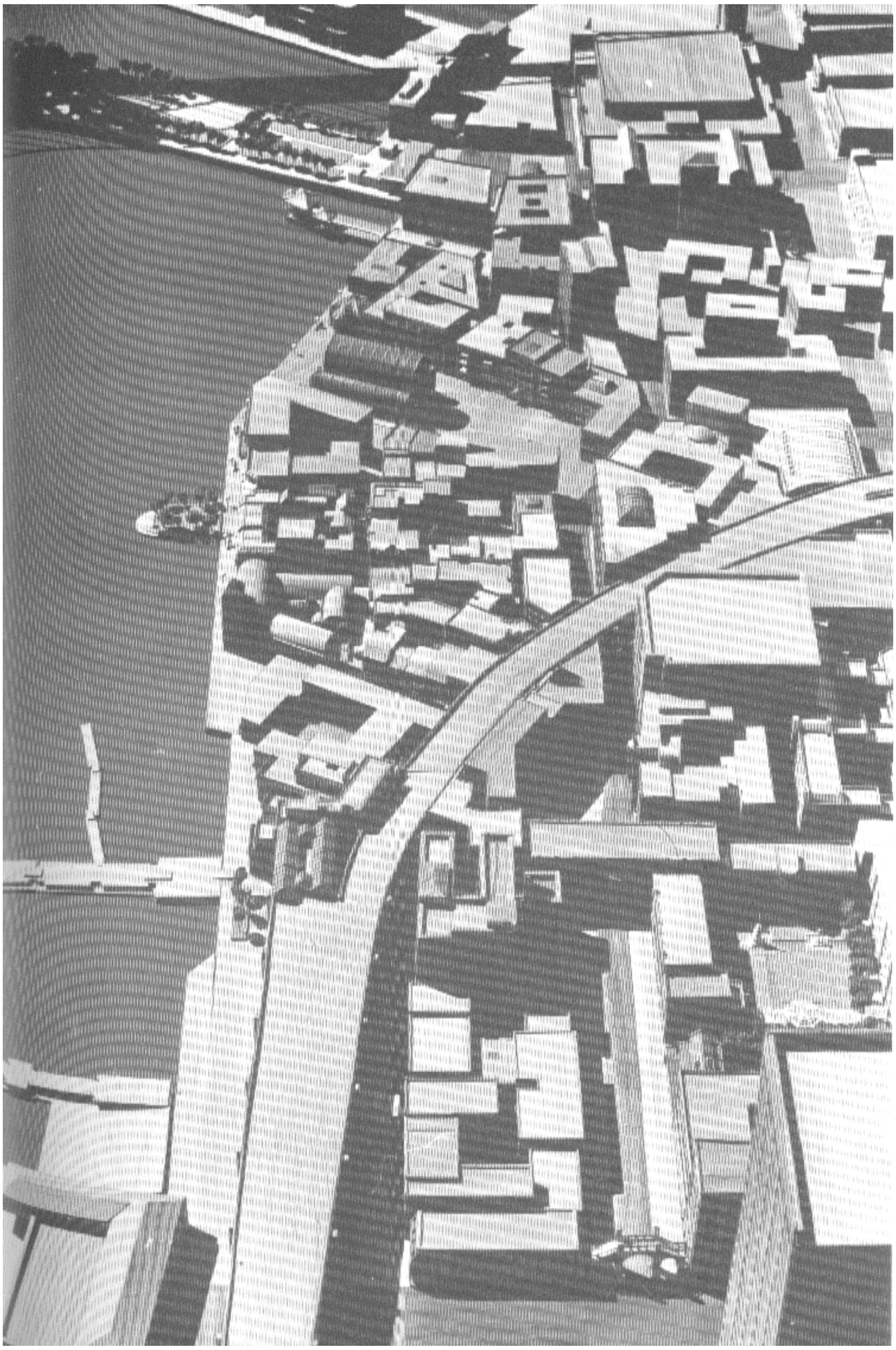


Figure 4.6 The physical model of the completed project
(Alexander et al. 1987, p. 107)

Chapter 5

A DYNAMIC DIGITAL VISUALIZATION MODEL FOR PIECEMEAL (INCREMENTAL) GROWTH

“... a process which is motivated and guided entirely by the search for wholeness, produces an entirely different effect from current practice in urban design, and goes far to remedy the defects which cities have today … an urban design process can only generate wholeness, when the structure of the city comes from the individual building projects and the life they contain, rather than being imposed from above. Wholeness only occurs when the larger urban structure, and its communal spaces, spring from these individual projects … the detailed rules necessary to generate this wholeness in an urban development process, can be formulated in a precise and operational fashion that can be easily understood and used. ”

(Alexander et al. 1987, p.248-9)

Visualization of urban environments in piecemeal growth needs a dynamic type of modeling that includes additional information about increments. Typical CAD systems allow modeling a static state – a snapshot - of an environment that does not have the possibility to display the processes of change, growth, transformation or evolution. However, urban design is a dynamic process that articulates relationships in ‘time and space-specific statements’ using differentiated parts of community to focus on the detail that is also connected to a larger context.

Spatial data should be considered as dynamic, or changing identities rather than as simple, static features. Time is an example of a dynamic component of a spatial data set. Recent technological developments are increasing computer hardware and software capabilities so that this dynamic aspect of data can be accounted for by today's systems. Viewing and analyzing change requires additional information, which depends on greater value of data. Dynamic data have not been a great concern in digital technologies for many years, but today changing patterns and dimensions are becoming more important. (Davis 1996, p.69)

Dynamic computer models can present an ideal environment to visualize the change in respect to time. Digital tools are much more efficient than conventional methods in explaining the growth and change of urban environments. Especially, incremental growth requires features not found in ' **static/analog** ' media. Christopher Alexander and his colleagues, in their book *'A New Theory of Urban Design'*, tried to justify their ideas about piecemeal growth by an experiment. The analog methods, such as physical models, two-dimensional diagrams, have been used to conduct the experiment and to convey their ideas about the design process. This thesis will try to produce a ' **dynamic/digital** ' tool that could be utilized in their experiment instead of static/analog methods:

> "Today's digital information systems – both spatial and aspatial – tend not to trace data lineage, retain prior versions of information, or track past and future production milestones or activities means that users of digital information systems must go without what analog information systems provide in rudimentary form. The analog systems that are being replaced by digital systems do tend to provide a historical view of the data: when an entity changes, a new card is stapled to an old one, a new line is added to an existing card to describe the change, or the old version of information is crossed out, yet still legible. Analog systems also tend to describe lineage: new entries are initialed or, at minimum, an individual's penmanship or graphic style provides a clue." (Langran 1993, p. vii).

5.1 Temporal Systems

When time is added, temporal (relating to time) trends can be considered. Research suggests that time is one of the four fundamental concepts to be modeled. A temporal system models the dynamically changing world; events are traced and no data are ever forgotten. Today's digital systems can only produce models which are static snapshots of the latest available data. However, the most interesting systems are dynamic in nature.

Information systems can model temporality in two ways: 'process modeling' and 'time modeling'. Process modeling allows a system to respond to temporal or trend-analysis queries. Time modeling is also calld as 'cause and effect', 'scheduling' or 'triggering'. Management information systems use triggers to deduce an appropriate action given a situation. In the scope of this thesis, process modeling will be accepted for temporal modeling.

5.1.1 Models of time

Various approaches exist for modeling time. However, time is most often discussed with respect to two key structural models:

- linear and
- branching, models of time.

In the linear model, an axiom imposes total order on time, resulting in the linear advancement of time from the past, through the present, to the future. The linear model of time incorporates the idea of a time-line. The branching model, also known as the 'possible futures' model, describes the time as being linear from the past to the present, where it then divides into several time-lines, each representing a potential sequence of events. (Hornsby 1999, p.23-5)

These models are typically based on the primitive elements of either time points or time intervals. For instance, a linear model based on time points assumes a set of time points that are totally ordered. When precise information on time is unavailable, time intervals become useful constructs. Reasoning about temporal intervals addresses the problem that much of our temporal knowledge is relative and methods are needed that allow for significant imprecision in reasoning. This view does not require that all events occur in a known fixed order and it allows for disjunctive knowledge. The representation also allows for uncertainty of information that is commonly found in tasks involving time.

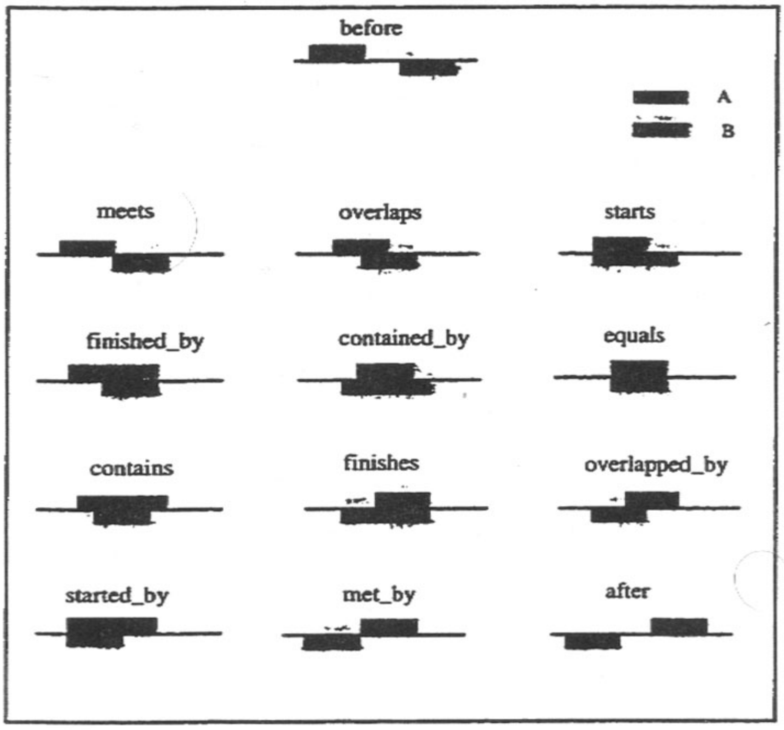


Figure 5.1 Possible temporal-interval relationships (Hornsby 1999,p.25)

5.1.2 Spatio-temporal (Space-time) Change

Change refers to the fact that an entity or phenomenon is transformed into something different through the result of some action or process or through an exchange or substitution. Change can involve the creation or destruction of an entire entity, or possibly only a characteristic of the entity is affected and altered. Change happens over both space and time and yet modeling has often focused on either one or other of these domains. (Hornsby 1999, p.5-6)

A spatio-temporal system is merely a system whose phase space includes spatial and temporal axes (Langran 1993, p. 73). Data can be configured and queries to the stored data can be made in a space-dominant, time-dominant, or spatiotemporal pattern. These sub-groupings are useful in identifying the precise nature of an application with respect to its data-processing requirements.

The term spatial data refers to data where each entity represented has associated with it a location or series of locations on, in or above the surface of the earth. Space-time data naturally includes a temporal coordinate. The representation of time and of space are tightly interrelated, both historically and theoretically. However, the representation of both space and time in digital systems are still problematic and functional space-time systems have not gone beyond the limited prototype stages. Representing time and space in a digital context have been problematic throughout the years of research and development (Peuquet 2001, p. 11-12).

The addition of temporal capabilities in database management systems started in the 80’s. The representation of past, as well as present, information became possible through rapidly declining storage costs and increasing capacity, and developments in database management systems technology. (Peuquet 2001, p. 11-12) “The consideration of time as a component in GIS has increased significantly with the awareness that temporal change is an important aspect of spatial modeling” (Cassettari 1993, p.190). One of the major functions of a temporal GIS is that of display with the ability to generate static or dynamic maps of temporal processes at work in a region.

Today’s geographical information systems are typically space-based. Although extensions to treat time have been discussed in the literature for about twenty years, no commercial temporal systems currently exist. Representing spatio-temporal change beyond a snapshot approach also exceeds the capabilities of current systems and is a challenging area. However, temporal systems are mostly mentioned by GIS researchers and Langran suggests that “the ability to work with time could herald a new stage of GIS” (Langran 1993, p.5). The fundamental functions of a temporal GIS are inventory, analysis, updates, quality control, scheduling and display.

Stage	Input	Analysis	Output
First	ad hoc, in-house digitization	none; stores and retrieves digitized maps	hardcopy; goal is to replicate exiting products
Second	centralized data capture, data exchange	single-state analysis, static modeling	interactive softcopy graphics; successful replication of existing products
Third	incremental updates, dissemination of change data	multi-state analysis, dynamic or predictive modeling	animated graphics, multi-temporal maps, new product designs

Table 5.1 Three stages of temporal GIS capabilities (Langran 1996, p.5)

5.2 Modeling Growth with respect to Time

The techniques that are available to describe the spatio-temporal changes are as follows:

-Time sequences, e.g. multiple editions or time series

-Change data, e.g text, graphic, or digital alterations to a base representation

-Static maps with thematic symbols of a temporal theme, e.g. symbols depicting dates, rates, paths, or order of occurrence.

-Animations, where both space and time are scaled to depict the metamorphosis of a study area.

5.2.1 Time-series models

Models represent what is happening generally. When applied to time, models can help to understand what is happening over a period of years. They can estimate what probably happened or will happen based on data provided for other times. These can be called time-series models. (Davis 1996, p.321)

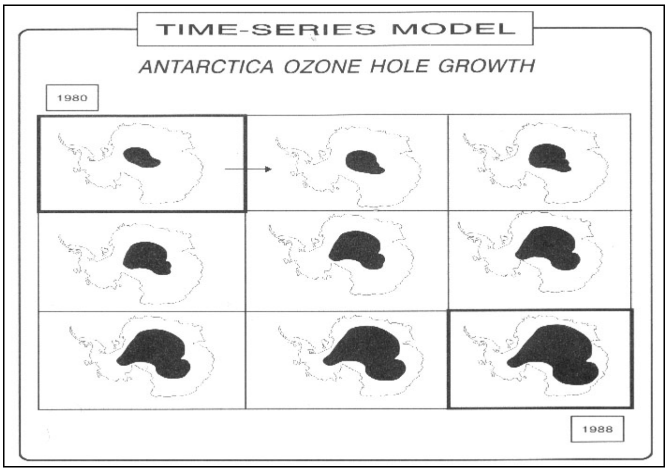


Figure 5.2 Time-series model (Davis 1996, p.320)

When conditions for two-times are given, a model may project backward, forward, or in between to extrapolate conditions. The illustration above presents a hypothetical case in which the 1980 and 1988 Antarctica ozone hole configurations have been provided and the time-series model estimates changes during the intervening years. (1981 to 1987)

Time series data can be recorded as attributes of spatial entities. Statistical summaries showing temporal change can be associated with areas; such as unemployment records or poll results. These types of data are simply displayed and interpreted using existing cartographic forms as the thematic maps (Cassettari 1993, p.191). However, the ability to visualize changes that occur in spatial objects through time are more important. The visualization of such ‘temporal maps’ is not well understood and requires considerably more research to identify successful methodologies for successfully communicating temporal information.

5.2.2 Time-patterning

Time-patterning can be defined as ‘”a process of connecting or linking periods to add dimension to place as a changing chameleon, relatively the same in size and dimension but changing according to the dictates of context” (Kasprisin and Pettinari 1990, p.112). Urban design communication is a highly patterned process that evolves through a specific sequence of formative stages (or parts) of a larger whole. Visualizing pattern through modeling at specific stages is a way of constructing the story as it is drawn, building a larger design as process, not pre-determined outcome.

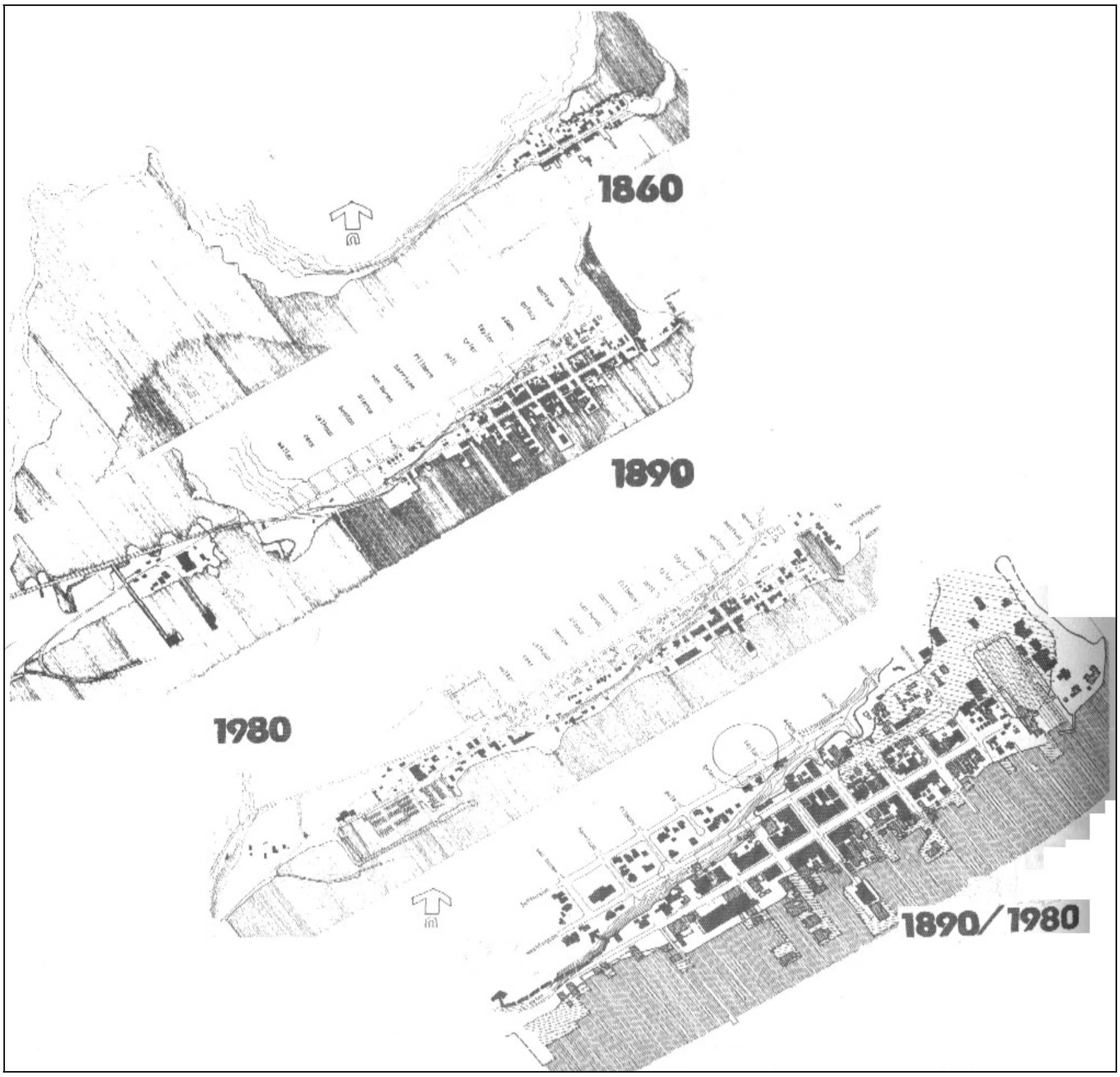


Figure 5.3 Time-patterning (Kasprisin and Pettinari 1995, p.114)

Some basic principles of time-patterning can be summarized as follows:

- as in conventional approaches , artifacts and historical values have local value, intrinsic to the artifact and the locale and characterized by its basic elements (dimension, color, style, material, historical function, etc.);
- the value of a historic pattern is dependent on the relationship of one time period to another period, preferably in a three time-period set –

value is defined as the precise worth or quality of information represented in the pattern and useable by the designer;

- historic and/or architecturally significant buildings, groups of buildings, or event locales are frozen images of past realities now a part of a present reality and possessing a new definition based on their passage from the past to the present; their role in future realities is further altered by the changing definition affected by time by relating the present to its path through time;
- time patterning can assist in determining the ‘formative dynamic present in a system’ at a given point in time by relating the present to its path through time; and
- time patterns have cultural rhythms within their boundaries, sources of design opportunity and context definition.

5.2.3 Incremental Update Methods

The effect of an update is to substitute current for outdated information. Incremental updates in a digital model measure time, location and other attributes, which makes these data appropriate for the contents of a temporal system. Incremental update methods now exist for atemporal spatial information systems that can also be suited to temporal systems. The difference between a temporal and atemporal update is that the former supersedes the outdated information while the latter deletes or overwrites it. (Langran 1993, p.19)

As digital modeling systems mature, update procedures become more critical. Entities in the real world can change in shape, location or attribute. Change can involve one or more attributes. Some attributes never change, some attributes change over time, and yet others are measured in the time domain. An object may have only one attribute set per time slice; a set of objects may be defined always to share an attribute set, even when the attributes change; or an object and its attributes may be clocked by several measures (Langran 1993, p.35). These systems are quite expensive, since maintaining current data can approach the cost and time involved in obtaining the original data.

5.3 A Dynamic CAD Model for Incremental Growth

Despite its many capabilities, a standalone GIS is insufficient to meet the demands of urban design applications. While it would clearly meet the informational needs of such applications, it lacks the graphical design functionality of CAD. The most obvious solution would be to implement a joint CAD/GIS system.

However, CAD/GIS integration is not an easy task. According to Levy, “CAD and GIS come from two different traditions” and their language and structure are different as well (Mahoney 1998, p.48). Then, integration can only mean ‘utilizing CAD tools to create, edit and maintain graphical information’ and ‘using GIS tools to model and analyze the relative data’. Autodesk has taken a different approach with its *AutoCAD Map* product: “We spent a lot of engineering resources developing object technology to let us read and write our competitors’ files in their original formats”. But now, it is possible to use a GIS database file in its original format in conjunction with a ‘.dwg’-based file (AutoCAD drawing file format) without translation (Mahoney 1998, p.50).

In a typical GIS, information is stored in thematic layers, and the layers are linked by geography. CAD systems also have layering features; each object belongs to layer. Layering is analogous to the use of transparent overlays in traditional drafting (Voisinet 1987, p.203).

In a CAD system, every increment would normally belong to a thematic layer. In order to develop a dynamic system, a temporal layering system is added; so that each increment belongs to a time-layer and has a temporal attribute. According to the theory, each increment should help to form at least one center (whole):

> “Every building increment must be chosen, placed, planned, formed, and given its details in such a way as to increase the number of wholes which exist in space.” (Alexander et al. 1987, p.248)

Thus, in a dynamic system for piecemeal growth, any increment should contain the following data: thematic CAD layering information(e.g. functional), time-layering information, properties and special data of the increment kept in incremental database, and finally all of these should be linked to a database for the concept of wholeness. This system can be explained as a diagram in Figure 5.4.

Such an input system for the increments will allow us to visualize different steps of piecemeal growth according to the time layering system. Time-layer information of each increment will help to decide whether that increment can take place in the digital image created from the model in that particular period of time or not. Animations showing the piecemeal growth can also be produced as a series of frames (images) by the addition of each increment in order of growth.

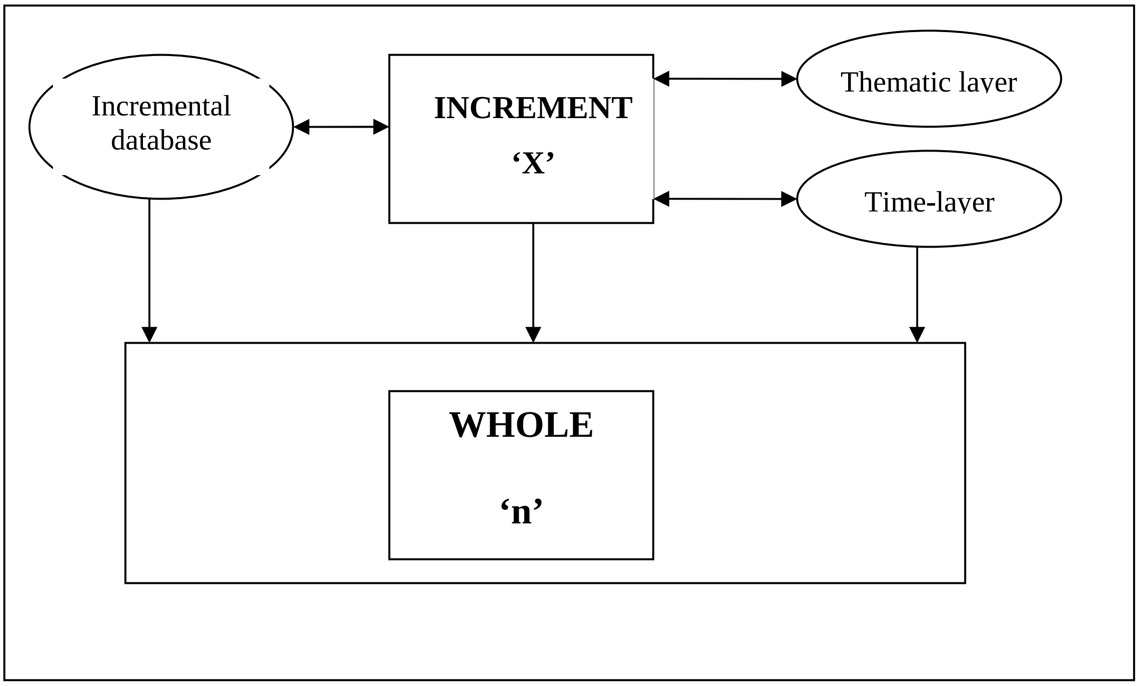


Figure 5.4 Dynamic Incremental database system for CAD

For visualization purposes, an interface has been created in the scope of this thesis. The interface basically operates on two menu bars: Top menu bar includes the time-layers, and side menu bar includes the view angles. The user chooses the time interval of piecemeal growth from time-layering menu bar and the viewing angle from views menu bar to visualize, then the computer generates the image of the urban environment for that particular period of time from the camera chosen. The number of time-layers depend on the input system of the increments in CAD software. The number of views can be infinite; but this beta version of the interface only includes some sample cameras for visualization purposes. The initial and sample screens of the interface are shown in Figures 5.7 and 5.8.

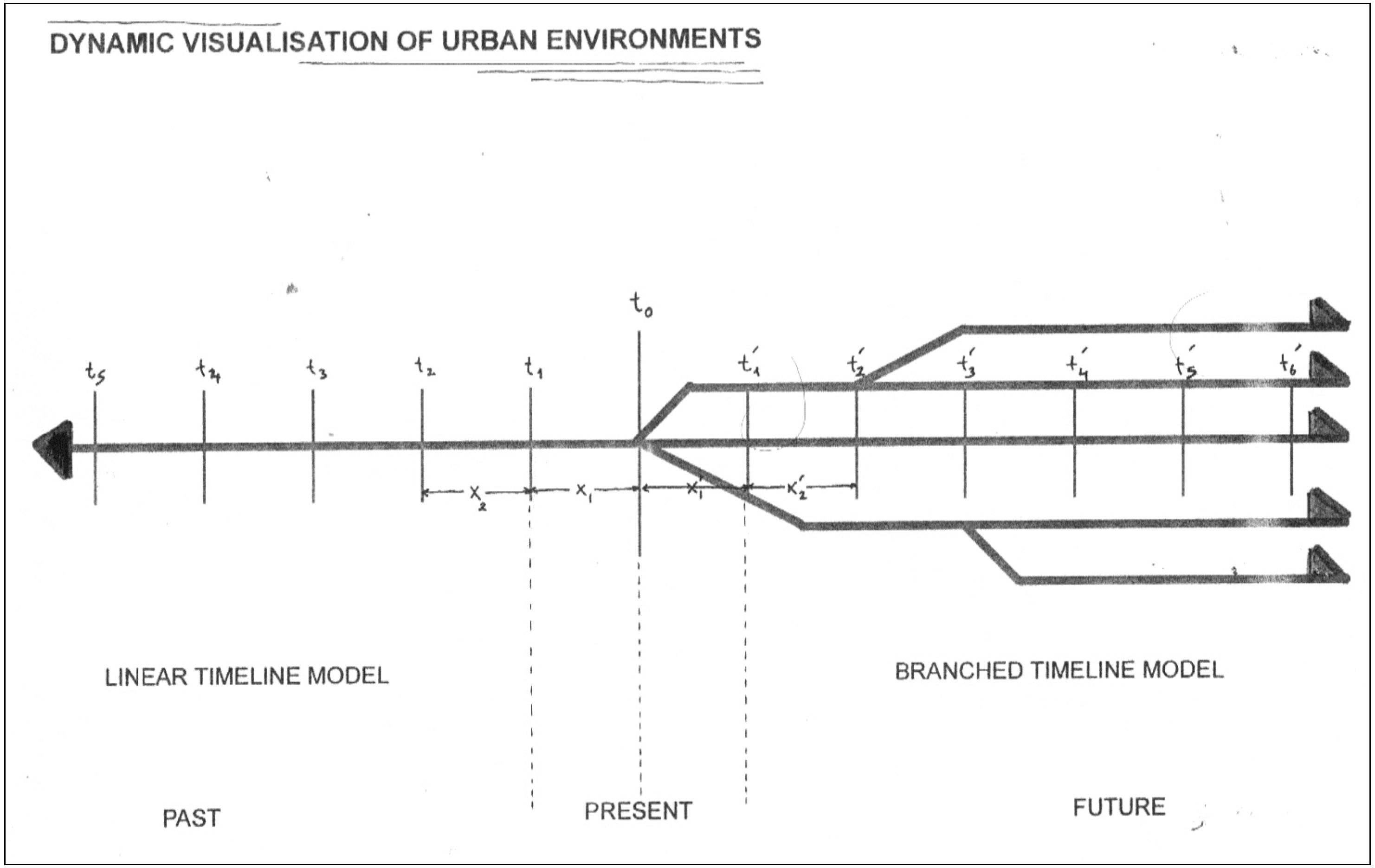


Figure 5.5 Time-line Model for Dynamic Visualization of Urban Environments

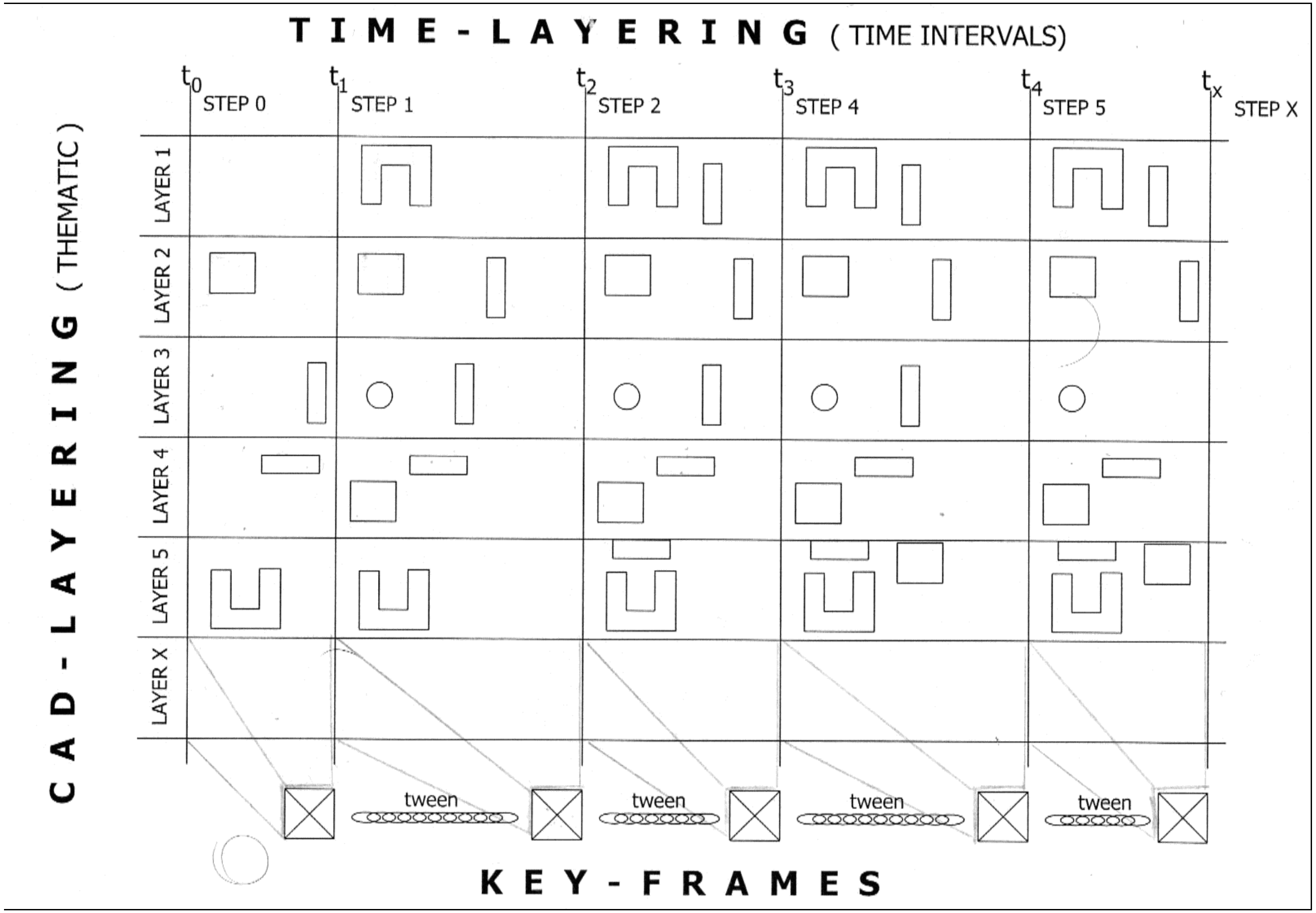
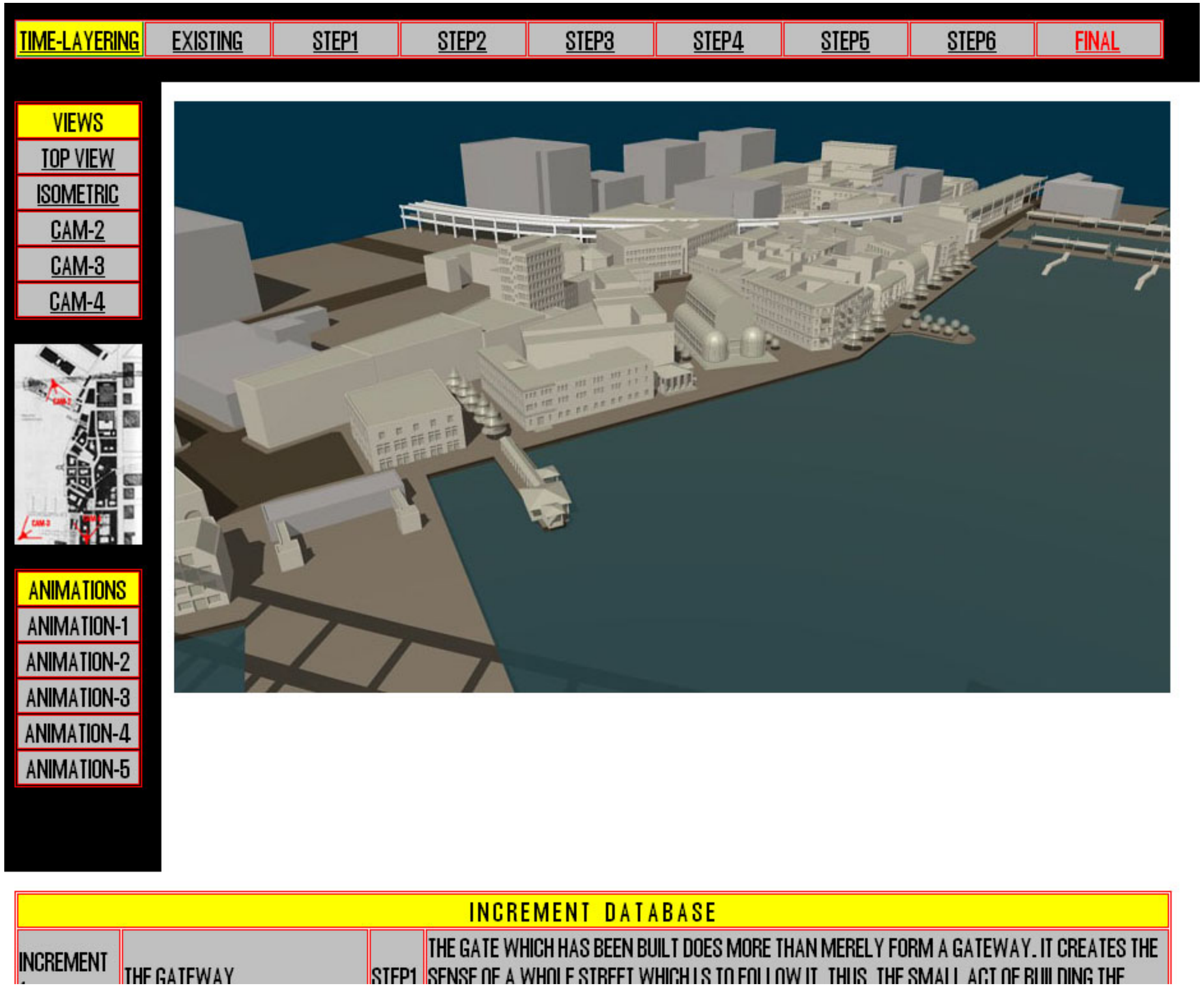


Figure 5.6 Time-layering in CAD

INCREMENT DATABASE			
INCREMENT	THE GATEWAY	STEP1	THE GATE WHICH HAS BEEN BUILT DOES MORE THAN MERELY FORM A GATEWAY. IT CREATES THE SENSE OF A WHOLE STREET WHICH IS TO FOLLOW IT. THUS, THE SMALL ACT OF BUILDING THE

Figure 5.7 Initial screen of the interface



INCREMENT DATABASE			
INCREMENT	THE GATEWAY	STEP1	THE GATE WHICH HAS BEEN BUILT DOES MORE THAN MERELY FORM A GATEWAY. IT CREATES THE SENSE OF A WHOLE STREET WHICH IS TO FOLLOW IT. THUS, THE SMALL ACT OF BUILDING THE

Figure 5.8 Sample screen from the interface (Time layer: Final – View: Cam 3)

Chapter 6

CONCLUSION

> *“Evolution is most plainly, swiftly in progress, most manifest, yet most mysterious. ... The patterns here seem simple, there intricate, often mazy beyond our unravelling, and all well-nigh are changing, even day by day, as we watch. ”*
>
> Patrick Geddes, Cities in Evolution, 1915
>
> (from Wegener et al. 1986, p.175)

In today’s digital design world, most CAD systems are configured to model only a static snapshot of the environment. Yet, it is not possible to experience urban environments as a single snapshot. Instead, phenomena change dynamically over space and time. In urban design, final design recommendations are dynamic, not static, and assured of changing even after final construction drawings are completed. Assuming that change is constant, and that the complexities of human agendas can alter the best intentions, it is worth experimenting with future time-place as a means of questioning decisions and anticipating previously unforeseen influences on implementation.

Within this framework, spatial data should be considered as dynamic, or changing identities rather than as simple, static features. Time is an example of a dynamic component of a spatial data set. Recent technological developments are increasing computer hardware and software capabilities so that this dynamic aspect of data can be accounted for by today’s systems. Viewing and analyzing change requires additional information, which depends on greater value of data. Dynamic data have not been a great concern in digital technologies for many years, but today changing patterns and dimensions are becoming more important.

It is observed that, dynamic computer models can present an ideal environment to visualize the change in respect to time. Digital tools are much more efficient than conventional methods in explaining the growth and change of urban environments. Especially, incremental growth requires features not found in ‘ **static/analog** ’ media. Christopher Alexander and his colleagues, in their book *‘A New Theory of Urban Design’*, tried to justify their ideas about piecemeal growth by an experiment. The analog methods, such as physical models, two-dimensional diagrams, were used to conduct the experiment and to convey their ideas about the design process. This thesis has tried to produce a ‘ **dynamic/digital** ‘ tool that could be utilized in their experiment instead of static/analog methods.

Furthermore, this thesis has tried to present a way of dynamic modeling urban environments with the goal of developing a digital visualization model suitable for piecemeal (incremental) growth. The model is based on an experimental study, but can also be utilized for professional practice. The present and future states of the urban environment were modeled in a linear timeline model; but for further studies a branched timeline model can also be considered.

However, it is not always the present and future states that is to be modeled. Design opportunities arise out of historic research and provide the basis for a pro-active use of historic applications. Visualizations through historic patterning can offer design opportunities. The models can help to trace the development of a historical site at critical times in history. Any one increment of time takes on more meaning when seen with other increments.

Visualization is inherent to the conduct of urban design as a direct connection between the designer three dimensional reality of urban settlements. Visualization assists the designer in the interpretation of complex urban patterns. The use of visualization as a cognitive process can be generative, since spatial relationships are formed and evolved as a result of the process. However, visualization of urban environments requires a distinctly rich hybrid of geometric, geographic, and annotative information. These requirements suggest new techniques for collaboration, data integration, and rich datasets. Digital systems can offer useful and practical visualization tools for urban designers.

In the field urban design, integration of systems such as GIS, CAD, VR, multimedia and internet can bring opportunities for designers and other interest groups. Each of these systems are widely used in today's urban design education, studies and practices. But their actual power in design process can be presented upon integration.

The addition of temporal capabilities to CAD systems can bring new opportunities for professionals in the field of research. Temporal systems are mostly studied in the scope of geographical information systems. However, computer-aided design can easily benefit from these temporal features.

As a final point, the digital visualization model created within the scope of this thesis was produced by using CAD systems that are widely available in the commercial market today. The hardware and software used during the production of the digital model were not configured for experimental studies, but mostly for conventional drafting purposes. However, this study could have been undertaken in a much different manner by using different systems with higher capacities and by the help of software experts. Especially studies in systems integration could be taken a step further. Still, the produced model, images and interface are quite satisfactory for the aim of this thesis.

In conclusion, this thesis has contributed new insights into dynamic CAD modeling. Additional key areas can be identified for further studies. Some of the interesting research areas that follow this work include: Temporal CAD systems; Integration of spatial information systems for urban design; Visualization tools for urban environments; Criteria for digital visualization modeling in urban design.

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APPENDIX A

GLOSSARY OF DIGITAL WORLD

Algorithm	A set of procedures which will produce a solution to a given problem
ASCII	American Standard Code for Information Interchange. A code for the representation of alphanumeric characters and symbols as bits.
Assembler	Computer language which is particular to a certain machine and its architecture or microprocessor
Automation	Equipment that increases productivity without additional expenditure of human energy
Basic	Simple and commonly used programming language
Bit	The smallest unit of computerized data, having value of either 1 or 0
Byte	A group of bits representing a number or other data item
CAD	Computer-aided drafting or computer-aided design and drafting
CADD	Computer-aided design drafting or computer-aided design and drafting
CAM	Computer-aided manufacturing
Character	A coded symbol for a digit or letter. Actually the same as a byte
Chip	A small slice of material containing electronic devices which perform functions with a computer
Command menu	Part of the graphics tablet overlay which lists all menu tasks

Compiler	A computer program which takes programs written in a higher level language and translates them into the machine language particular to the computer.
CPU	Central processing unit.
CRT	Cathode-ray tube. Similar to a screen, this screen allows the production of a drawing without the use of vellum or alphanumeric data
Cursor	A symbol used to indicate a particular location on a screen.
Data base	A file of information concerning graphic object and drawing properties
Data tablet	A graphic input device which reports the coordinate location of a stylus as the stylus is traced across its surface.
Digital	Refers to which performs operations with quantities , represented electronically as digits, usually in the binary system
Digitizer	Any one of many available types of hardware for encoding 2-D or 3-D data into a format usable by computers.
Disk	A type of data storage medium
Display	Visual output as seen on the screen of a CRT
DTM	Digital Terrain Model. The representation of topography as a matrix of elevation values.
DVST	Direct View Storage Tube. A vector graphics display unit with the ability to maintain an image for a lengthy period of time without redrawing it.
EPROM	Erasable programmable read-only memory
Firmware	Programs encoded on EPROMs, PROMs, or ROMs
Floppy disk	A flexible , transportable disk used for data storage
Fortran	Formula translator

GIS	Geographical Information System
Graphic display	The display of the lines, arcs, text, and the groups which the drawing includes
Graphic object	Areas, circles, ellipses, groups , lines, points or text strings which may be displayed on the CRT
Hard copy	Copies of computer-generated images which can be separated from the machine
Hard disk	A hard, usually nontransportable medium used to store data
Hardware	The computer itself or any of its related peripheral input or output devices
Interactive	Refers to the need for a human to initiate communication between different parts of a computer system
Interpreter	A program which interprets a program written in a higher-level language into machine language
Isometric	A drawing in which the horizontal lines of an object are drawn at an angle and vertical lines are drawn vertical. Isometrics can be generated automatically by a CAD system, including 3-D solid models, surface models, or other landform representation.
Machine language	The language employed by the microprocessor of a given computer to perform an operation
Master menu	All available graphics tasks are shown on the master menu
Menu	The master menu lists available tasks; an auxiliary menu lists the options offered by a given task
Microprocessor	A computer chip which contains the circuitry of necessary to manipulate data
Model, geometric	A complete, geometrically accurate 2-D or 3-D representation of a shape, a part, a geographic area, a plant or any part of it, designed on a CAD system and stored in the data base

Modeling, geometric	Constructing a mathematical or analytic model of a physical object or system. The designer describes the shape using geometric construction. The computer then converts this pictorial representation on the screen into the model.
Modeling, solid	A type of 3-D modeling in which the solid characteristics of an object under design are built into the data base so that complex internal structures and external shapes can be realistically represented.
Modem	Modular-demodulator. A device used to translate computerized data into a form which can be transmitted across telephone lines and to decode data at the receiving end
Mouse	A graphic input device which is moved across a surface to generate coordinate data
Operator	A general term for CAD users . Not all users are designers and drafters. A designer or drafter, however, may be an operator
Orthographic	A type of drawing in which the projecting lines are perpendicular to the plane of the drawing. In CAD, it is the commonly accepted way of showing mechanical objects. In computer-aided layouts, pictorial drawings are automatically generated on the system from orthographic projections.
PC	Printed Circuit. An electronic assembly composed of a nonconductive board, a conductive pattern, and electronic components.
Pixel	Picture element. The smallest addressable display element on a raster display.
Plotter	An output device which produces an image on paper or film
Program	A detailed set of coded instructions that are logically ordered
PROM	Programmable read-only memory
Prompt	Instructions informing the user how to implement the next operation

RAM	Random-access memory. Internal memory used during the processing of data
Raster	Used to describe TV-like units which produce images from a rectangular matrix of pixels
ROM	Read-only memory. A chip onto which data have been encoded permanently.
Scanning Digitizer	A digitizer which employs optical laser technology to encode a or other document as a raster image
SIS	Spatial Information System
Software	Computer programs
Solid graphics	Solid modeling enabling users to define complex, three-dimensional parts interactively from solid building blocks or planar figures.
State of the art	Referring to the latest technical advancement
Track ball	A half-exposed ball which is rotated to move a cursor on screen
TRAD	Traditional drafting
Turnkey	The name given to a complete CAD system
User-friendly	A CAD system that instructs, or prompts you step by step.
VDT	Video display terminal. Any terminal used to display imagery.
Video digitizer	A digitizer based on a video camera.
Wire-frame graphics	A computer-aided design technique for displaying a three dimensional object on the screen as a series of object lines outlining its surface.
Workstation	A computer that includes a monitor for display and manipulation of graphics data

APPENDIX B

LIST OF VIRTUAL CITIES ON THE WWW

BATH (UK)
http://www.ac.uk/centres/casa/bath/bath_low.html

BILBAO (SPAIN)
http://www.bm30.es/vrml/intro_uk.html

HELSINKI (FINLAND)
http://www.helsinkiarena2000.fi/demos.html
http://www.arena.net.fi/english.index.html
http://www.hel.fi/infocities/
http://www.enable.evitech.fi/enable97/submissions/linturi/paper.html
http://www.flexiton.hu/angol/index.html

JERUSALEM (ISRAEL)
http://www.jerusalem.muni.il/model/

LOUTH (UK)
http://www.realtimelouth.co.uk/home.html

VENICE (ITALY)
http://iris.abacus.strath.ac.uk/new/gintro.htm

WORCESTER (UK)
http://www.udg.org.uk/cs/worcester/worces.htm
http://www.udg.org.uk/ukgi/qitc/ude/wor/wor.html

TOKYO (JAPAN)
http://csis.u-tokyo.ac.jp/links-e.html
http://www.planet9.com/sfcitymenu.htm
http://www.ajiko.co.jp/info.com/index.html
http://webspace.com/worlds/tokyo.html
http://www.zenrin.co.jp/products/digital/l/zi2hp/2/2.html
http://www.oyo.co.jp/service/sentan/3d/index.html
http://www.seikabunka.metro.tokyo.jp/English/englishindex.html
http://www.cadcenter.co.jp/01-cg-frame.html
http://www.planet9.com/earth/tokyo/index.htm

NEW YORK (USA)
http://www.simcenter.org
http://www.u-data.com
http://www.planet9.com/earth/newyork/index.htm
http://www.esri.com/news/arcnews/summer98articles/03-av3danalyst.html
http://www.3dmetric.com/cities/new%20_york_city.jpg
http://www.3dmetric.com/cities/manhatten.jpg

MEXİCO CITY (MEXİCO)
http://www.mexico-city-3d-map.com.mx/etenoc.htm

LONDON (UK)
http://www.cs.ucl.ac.uk/staff/a.steed/london-demo/vrst99/index.htm
http://www.bath.ac.uk/centres/casa/London
http://www.millerhare.com/page0104.htm
http://www.architecturefoundation.org.uk/project2.htm
http://www.dome2000.co.uk/static/html/3d_dome/model/index.htm
http://www.aerobel.co.uk/urbanism.html
http://www.planet9.com/earth/london/index.htm

PARIS (FRANCE)
http://www.paris-france.org/vr/anglais/
http://www.paris-france.org/asp/carto2.asp
http://webscape.com/worlds/paris.html

LOS ANGELES (USA)
http://www.planet9.com/lacitymenu.htm
http://www.3dmetric.com/cities/losangeles.html
http://www.gsaup.ucla.edu/bill/la.html
http://www.aud.ucla.edu/ ~robin/esri/p308.html
http://www.ust.ucla.edu/ustweb/projects/downtown.html
http://www.multigen-paradigm.com/urbismhm.htm
http://www-ims.oit.umass.edu/ ~umassmp/intergraph/losangeles/html

CHICAGO (USA)
http://www.3dmetric.com/cities/chicago_downtown.jpg
http://www.home.digitalcity.com/chicago
http://www.planet9.com/earth/chicago/index.htm
http://www.uic.edu/cuppa/udv/

DELHI (INDIA)
http://www.thecpmall.com/virtualvision/vrml/cpvrml_aerial.htm

SAINT PETERSBURG (RUSSIA)
http://www.mapserv.com/new/e/index.htm

HONK KONG
http://www.hkugis.hku.hk./campus/
http://www.centamap.com

PHILADELHIA (USA)
http://saturn.Bentley.com/news/97q2/modelcity.htm
http://www.bentley.com/modelcity/index.html

BERLIN (GERMANY)
http://www.cyberlin.de
http://www.artcom.de/contacts/city-and-architecture/berlin.de.html
http://www.echtzeit.de/virtualcompany.html
http://www.mulingen-paradigm.com/echzeit/echzeit_story.htm
http://www.echzeit.de/e-berlin/index_e.html

DETROIT (USA)
http://www.3dmetric.com/cities/detroit_downtown.jpg

SANTIAGO (CHILE)
http://www.uchile.cl/faculdades/arquitectura/urbanismo/articulo/urban.htm

SAN FRANCISCO (USA)
http://www.abag.ca.gov/bayarea/eqmaps.html
http://www.planet9.com/sfnasa.htm
http://www.planet9.com/sfcitymenu.htm
http://www-laep.ced.berkeley.edu/research/simlab
http://webscape.com/worlds/sanfrancisco.html

BOSTON (USA)
http://www-ims.oit.umass.edu/~umassmp/intergraph/boston.html
http://www.planet9.com/earth/boston/index.htm

TORONTO (CANADA)
http://www.clr.toronto.edu
http://www.clr.utoronto.ca

SYDNEY (AUSTRALIA)
http://www.cityofsydney.nsw.gov.au/vg_panoramas.asp
http://www.culture.com.au/virtual
http://www.planet9.com/earth/sydney/index.htm
http://www.bentley.com/biuc/awards/psnurban.htm

WASHINGTON D.C. (USA)
http://www.3dmetric.com/cities/washington_nw.jpg
http://www.geocities.com/pentagon/8215/digital.html

SINGAPORE
http://www.singapore.vrt.com.sg/sing-1/merlion_frame.htm
http://www.bizarts.com
http://www.ura.gov.sg/corporate/gallery_main.html

YOKOHAMA (JAPAN)
http://www.ymm21.co.jp/annai/

HOUSTON(USA)
http://www.transamerica.com/business_services/real_estate/terrapoint/technology/demo/asp

WARSAW (POLAND)
http://www.andante.iss.uw.edu.pl/cgi-bin/modzel

LİSBON (PORTUGAL)
http://ortos.cnig.pt/igeoe/ingles
http://www.marconi-is.com/products/

CLEVELAND (USA)
http://www.3dmetric.com/cities/cleveland.jpg
http://www-ims.oit.umass.edu/~umassp/intergraph/cleveland.html

SAN DIEGO (USA)
http://www.sci.sdsu.edu/people/jeff/newhome/phase4.html
http://www.planet9.com/earth/sandiego/index.htm

SEATTLE (USA)
http://www.wizards.com/rpga/vs/welcome.asp
http://www.download32.com/proghtml/18/1859.htm

ATLANTA (USA)
http://www.planet9.com/earth/atlanta/index.htm
http://websape.com/worlds/atlanta.html
http://www.3dmetric.com/cities/cleveland.jpg
http://www-ims.oit.umass.edu/~umassp/intergraph/atlanta.html

BALTIMORE (USA)
http://www.planet9.com/earth/baltimore/index.htm

GLASGOW (UK)
http://iris.abacus.strath.ac.uk/glasgow
http://www.glasgow1999.co.uk/
http://www.glasgowdevelopment.co.uk/
http://www.glasgow.gov.uk/

KYOTO (JAPAN)
http://www.digitalcity.gr.jp/

DENVER (USA)
http://www.planet9.com/earth/denver/index.htm

VANCOUVER (CANADA)
http://www.planet9.com/earth/vancouver/index.htm

PORTLAND (USA)
http://www.planet9.com/earth/portland/index.htm
http://www.pdx3d.com/default.htm
http://www.pdx3d.com/links.htm
http://www.nc3d.com/links.htm
http://www.nc3d.com/services.htm#3dmodeling

NEW ORLEANS (USA)
http://www.virtualneworleans.com/main.html
http://www.planet9.com/earth/neworleans/index1.htm
http://www.pb4d.com

APPENDIX C

SNAPSHOTS FROM THE MODEL

Figure C.1 Dynamic visualization of urban environments

Figure C.2 Top view of the completed project

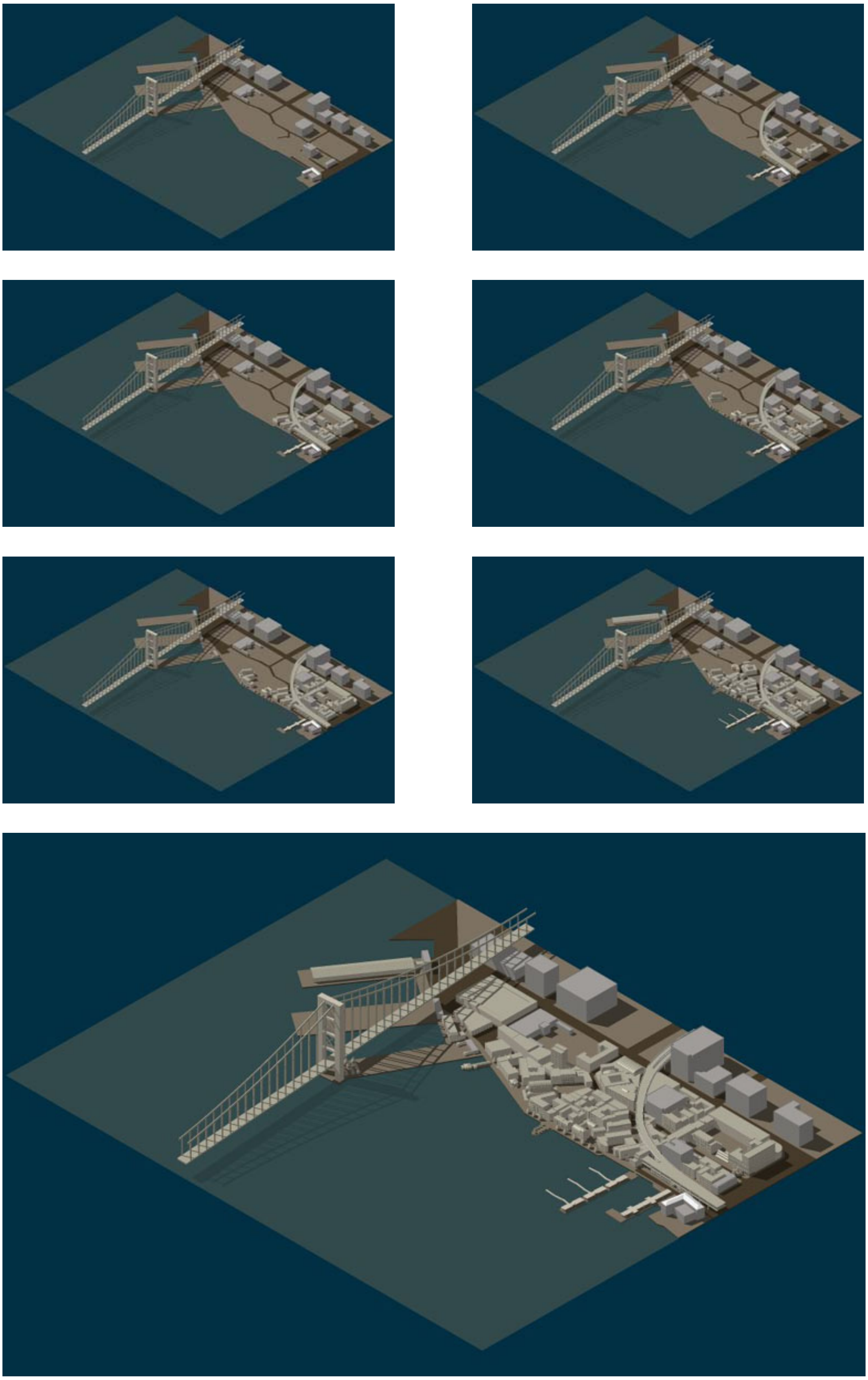

Figure C.3 Isometric views

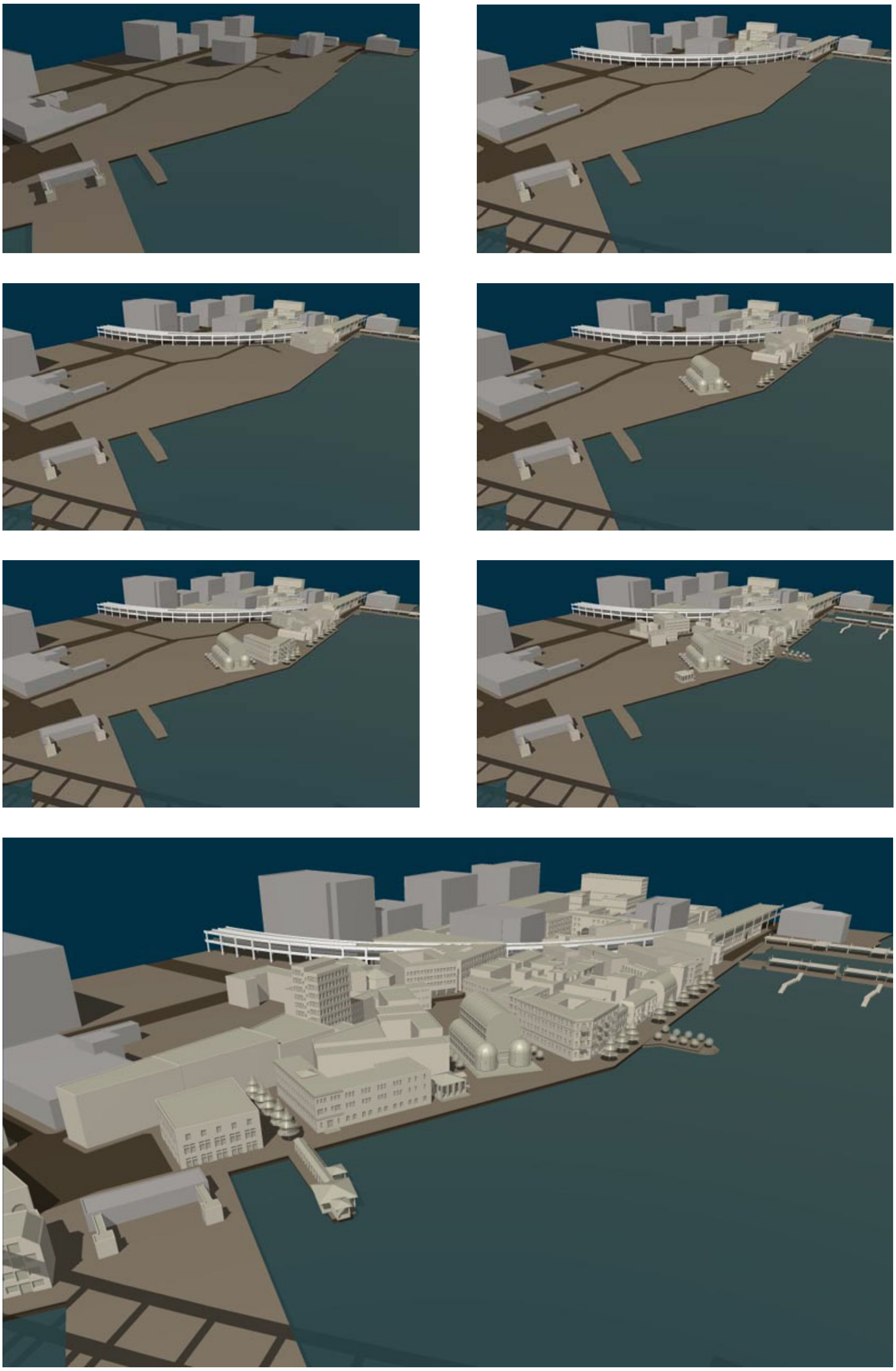

Figure C.4 Perspective views - camera 1

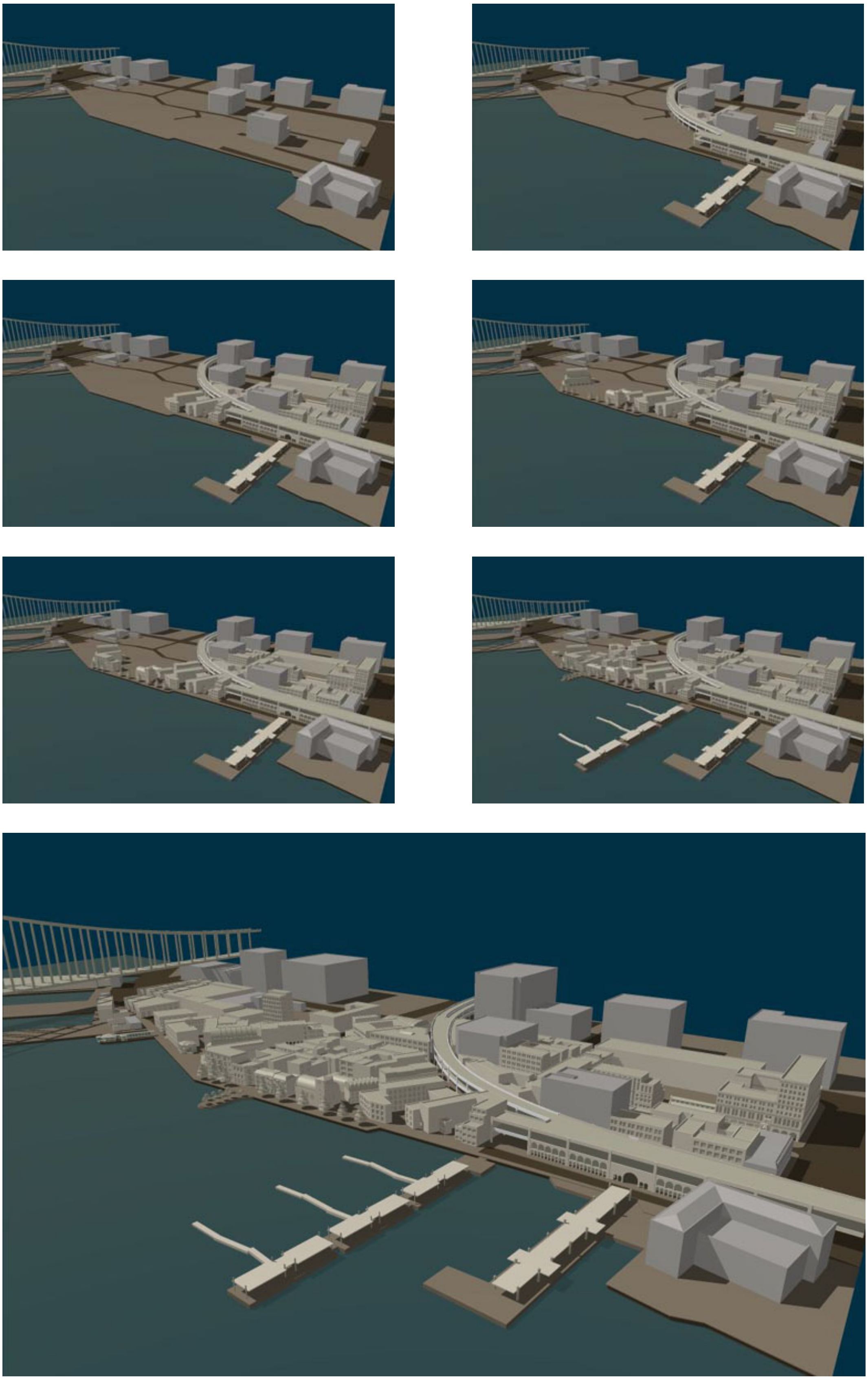

Figure C.5 Perspective views - camera 2