Dynamic Urban Information Model: Integrated Approach to Strategic Urban Redevelopment

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This paper describes a prototype Dynamic Urban Information Model (DUIM) designed to facilitate strategic urban redevelopment, that is, the process of determining precise architectural interventions to set off, guide and condition redevelopment activities. The idea of the DUIM is based on the notion that in order to attain effective strategic redevelopment, an integrated approach addressing the complex interactions of the factors involved in urban life and growth is required. Accordingly, an urban model for this purpose must include not only spatial and formal considerations, but also social, political, economical and ecological aspects. Through a case-study involving the redevelopment of a post-industrial site, this paper explains the rationale of the DUIM in terms of its formal structure, its database, and its application.

Keywords: geographic information systems; urban design, integrated environments; simulation; real-time animation

1 Introduction

Cities cannot afford to waste the investment of infrastructures and materials contained in the existing urban fabric and expand further in the periphery. One consequence of this insensitive urban resource management is the phenomenon of urban blight, as found in many industrial cities today.

This paper describes a prototype Dynamic Urban Information Model (DUIM) designed to facilitate strategic urban redevelopment. In this paper the term strategic urban redevelopment is used to denote the process of determining precise architectural interventions to set off, guide and condition redevelopment activities. It addresses the procurement process in architectural and urban design that has been widely neglected in architectural design research, that is, the very upstream stage in design when most strategic decisions are made. The DUIM has been originally developed as part of a design studio offered at Harvard Graduate School of Design. Technically, it builds on an available threedimensional urban model and combines it with Geographic Information Systems (GIS) and referenced video images. It thus provides an interface

(a) to experience and understand the morphology and architecture of the site,
(b) to analyze and visualize relevant urban data,
(c) to examine the image quality of the cityscape, and
(d) to simulate design proposals.

The idea of the DUIM is based on the notion that in order to attain effective strategic redevelopment, an integrated approach addressing the complex interactions of the factors involved in urban life and growth is required. Accordingly, an urban model for this purpose must include not only spatial and formal considerations, but also social, political, economical and ecological aspects. Urban databases from federal agencies (U.S. Census

data and Tax Assessment data) containing information relevant to urban redevelopment, such as demographic distribution, land use, building value, construction year and ownership, are imported into the DUIM and linked to the three-dimensional model either by block/lot geography or addressed-matched on a block/census tract level.

The remainder of this paper is organized as follows: Part 1 reviews current developments in urban design and related previous approaches in CAAD. In part 2 the underlying design principles of the DUIM are outlined. Part 3 introduces a prototype DUIM. and describes a case study in which some of the design principles have been implemented. Using the redevelopment of Pittsburgh South Side as a case study, the rationale of the DUIM is explained in terms of its formal structure, its database, and its application. Part 4 discusses the potential of the DUIM and offers an agenda for future developments.

2 Background

2.1 Problems of urban redevelopment

It is a common phenomenon that many post-industrial cities suffer from the loss of their capital base. Their urban structure is characterized by vacant buildings, underutilized land and empty lots. Some efforts have been made to revitalize these urban areas. However, it is difficult to deal with the large stock of abandoned structures. The problems of urban redevelopment are manifold:

(a) The abandoned sites and recyclable buildings are scattered around a vast area and are not registered in community zoning plans or in conventional master-plans.

(b) Their pattern changes over time and is difficult to capture.

(c) Different interests and factors are involved in urban redevelopment: ecological, political, social, economic, architectural.

Traditional urban design approaches often lack adequate instruments for dealing with these situations, as their primary focus is the creation of new formal urban ensembles, such as business and commercial districts, and not the coordination in space and time of the dispersed independent developments. Large formal and spatial gestures of rebuilding an entire new urban systems, such as Hausmann's interventions in Paris or the Stalin Allee in the former East Berlin, have become impossible in democratic times. The governments have not the power and the financial means to dictate the design and implementation of large urban transformations. In a capital-driven society the realistic task pertaining to the urban designer is to choreograph the individual interventions in such a way that they provoke a meaningful urban development. Different architectural and urban theorists [1][2][3][4] and design professionals [5][6][7] have postulated this necessity to shift from traditional formbased to strategic process-oriented urban design.

2.2 Integrated approach

The collaboration of participants from the public and private sector, known as public private participation (PPP), represents a possible approach to facilitating strategic urban redevelopment: the public party provides land, legislative and political support, while the private provides money in the form of investments [8]. The key problem however, is the diverging motivations behind a PPP. The public party has a complex agenda to fulfill, e.g. to attract a solid tax base, to guarantee social equilibrium, and to address cultural and spatial issues. The private party is primarily motivated by profit. This doesn't mean that it is not interested in good architecture or urbanism, but only insofar as an additional effort to design is justified by additional profit. Thus a coordination of these interests is crucial for a successful PPP collaboration.

In order to be able to maneuver effectively through the various layers of the urban constructs the urban designer needs to overview the very precise data and facts about the economic/legal/political situation of any available site. The urban designer can thereby understand the interrelationship and implications of these site data and facts. Based on this understanding, he or she can decide where and what to build, and estimate what it will affect. The impact of an intervention must be taken into account as integral to the procurement process, that is, when determining the location and programming of the interventions, and not as developments to be dealt with and mitigated subsequently to an intervention.

With the advent of information and communication networks, the urban reality is becoming even more complex, and anticipates a strategic process-oriented thinking [9]. For example, a large company needs not any longer to establish itself in a single large container in the periphery, but can be separated into smaller distributed, yet telematically interconnected entities. The company can thereby take advantage of the different infrastructures and allocations offered by the distinctive sites within an existing city.

2.3 Previous approaches in CAAD

Recent developments in research of Computer Aided Design, information technology and networking hold some promise with regards to supporting strategic urban redevelopment. In particular, three developments are relevant: a) the availability of urban data on the net [10], b) the integration of multimedia information into three-dimensional geometric models in Computer Architectural Aided Design (CAAD) systems [11], and c) the improvements in terms of speed and accessibility of Geographic Information Systems (GIS) which allow to identify interconnections and relationships not detectable before [12].

This research aims at integrating these developments into one dynamic urban information model (DUIM) to support strategic urban redevelopment. The approach of combining urban data, multimedia, geometric model and GIS in one urban model is not new, and has been tried for other purposes before: e.g. for urban analysis and design development [13], for pedagogical intents [14], for design decision support [15]. However, what distinguishes the DUIM developed in this research from prior efforts is the fact that a) it addresses the determination of strategic interventions, emphasizing thus the reading and design of interrelations and processes, not of spaces and built volumes, b) it provides a link to readily available urban data (Census data and Tax Assessment data) through GIS and thus operates on objective "neutral data, c) it allows real-time visualization and manipulation of all the data and actions and thus supports and anticipates the creative phase of design, and d) it provides a basis for measuring the implications associated with urban intervention, such as the costs, benefits and damages.

3 Design principles

The development of the DUIM was guided by the following four principles:

3.1 Multi-level lecture of site

To address the problems of urban redevelopment as outlined above, the DUIM must be able to provide a lecture of the site from different backgrounds and through different modes of representation.

On the data level, a variety of urban data must be made available. Of particular relevance to the redevelopment process are: data revealing substance and ownership of existing buildings and land, social and ethnic distribution, transportation patterns, and placement of work base and public buildings. These data must permit different ways of representation in order to enable comparison, overlay, and manipulation.

On the architectural level, a combination of three-dimensional model and video images must enable the analysis f the spatial and tectonic potential, as well as the reading of the image quality of any given site in a level of detail appropriate for urban redevelopment. Furthermore, the DUIM must permit the smooth change of viewpoints, such as fly-through from a bird-eye overview to the street level view using real-time animation, and support the kinetic experience of urban space.

3.2 Modular approach

Recent discussions in CAAD research deal with the advantages and disadvantages of using "all-of-one-piece" models versus the combination of separate, specialized software programs [16]. This approach further advocates the position of using many well defined software, each of which exploiting its specific strengths.

The DUIM must be designed in a modular fashion, that is, composed of autonomous, but interrelated programs. As improved programs become available, they could be smoothly integrated into the DUIM. A common platform must then be able to combine the modules, and an interface must provide access to the individual, distinctive sets of information.

This modular approach mandates that a common basic unit is defined as "footprint" to which the different modules can be referenced and linked. One possibility would be to take the parcel as the basic unit. The individual modules could then be georeferenced to the relevant parcels. The use of a basic unit and interchangeable modules would provide the DUIM with a certain degree of flexibility: it would allow to substitute entire sets of information, and, for instance, to map data from different time periods. The continuous feeding and superposition of data coverages from different time-periods would then allow a reading of temporal relationships.

3.3 Simulation model

Simulation is of central importance for strategic urban redevelopment, as it allows to see and evaluate the implications of the individual interventions. Only thereby can the "whole picture" of the redevelopment area be understood and controlled. We distinguish between product design simulation and process design simulation. Both simulations have to be supported by the DUIM.

In product design simulation, the impact of a building product is simulated, e.g. the insertion or a new building in an urban context or the transformation of an existing building. The visual effect of a physical construct is made comprehensible.

In process design simulation a process of development is simulated. It is based on the statistic reading of a situation, that is on empirical or measurable facts. For example, the accessibility to working places, schools, shopping opportunities, and recreational opportunities is widely recognized to be one of the most important determinants of longterm developments. The measurable factors of accessibility can provide prognosis for future developments, and be used as design criteria.

3.4 Customizable interactive Interface

The complexity of the interrelationships between the different phenomena of the sites can only be approached by a playful generate-and-test approach. In order to allow this playful design approach, all actions must be highly interactive and have real-time feedback. Only then can the DUIM be integrated into the seeing-moving-seeing cycles of creative design activity. In addition, the quantitative data of new interventions, such as building height, volume and cost, must be provided simultaneously, so that their impact can be measured.

Most urban models make sense to the analysts and specialist who develop the software but not necessarily to the designer who uses them. Thus simply understandable and customizable interfaces were a further important design principle: it should be possible to address the specificity of the different disciplines, as well as the different visual experience and literacy of the users through personalized interfaces.

4 Case-study: a first prototype

For the redevelop of a post-industrial site in Pittsburgh South Side, the abovementioned issues of a DUIM are discussed. First, the specific problems and requirements of the situation in which the DUIM is developed are described and the necessity for a strategical approach is stated. Next, the components of the prototype DUIM are outlined. In particular, the techniques related to collecting and integrating urban information relevant to the strategy are discussed. Finally, example applications are presented.

4.1 Pittsburgh South Side

The existing site in Pittsburgh South Side poses problems at different levels. The flow of capital out of South Side, due to the closing of the steel-mill industry, has paralleled a diminution of job opportunities, and left behind an overaged and poor population with a large stock of vacant buildings, underutilized land and empty lots. One result of this development is a weak public and social infrastructure which remains only active thanks to governmental subventions.

The proposed new casino center on the site of an abandoned steel-mill in South Side is expected to engender some changes. The spin off opportunities generated, and the job potential created will attract further investments. Thus, the expected cash-flow represents an opportunity to set off processes of redevelopment. The key questions are then: how to leverage the expected investments for urban redevelopment, and how to determine the

location, timing, programming, and size of the interventions: where, when, what, and how much

Furthermore, from an architectural point of view, how to integrate the new infrastructures with the existing context (one of Americas best-preserved Victorian mainstreets) into a new civic ensemble. In order to coordinate these activities, a strategic approach to urban redevelopment is necessary. It is in this context that we have developed and tested a first prototype of the DUIM.

4.2 Components of DUIM

Figure 1 shows the steps and modules involved in the development of the prototype DUIM used for the Pittsburgh project. Starting with the GIS data, the individual modules (2D model of parcels, 3D model of terrain and buildings, video images) are subsequently added and the information distributed and passed from one module to another. Different interfaces are eventually programmed on top of the information model and customized to meet the user requirements.

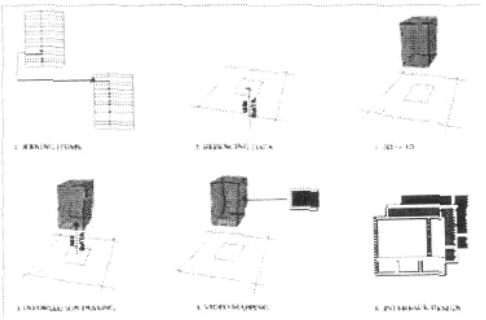

Figure 1. Generation of the prototype DUIM.

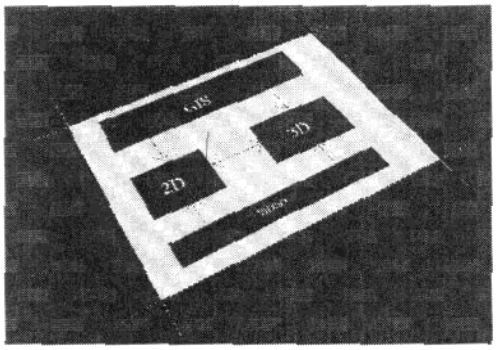

Figure 2. The information contained in one parcel (basic unit).

The prototype DUIM was implemented on Silicon Graphics workstations using the Software PolyTRIM for combining the different modules, and the Software TrimCARD for the user interface [17]. Both software were originally developed at the Center for Landscape Research, University of Toronto. For the individual modules we used standard software that were adapted for our purpose. In the following, we will give a detailed description of the components of the prototype DUIM, the individual modules and the interface.

4.2.1 GIS

The first phase in the development of the GIS consisted of an inventory of data available and useful for the study area. Two primary agency sources were selected: the U.S.

Census Bureau and the Bureau for City Planning in Pittsburgh. The U.S. Census Bureau provided the TIGER (Topologically Integrated Geographic Encoding and Referencing) Files with the attached data layers. The data included: land use data, demographics data, household income, mode of transportation. The Bureau for city planning in Pittsburgh provided Tax Assessment data: construction year of the building, ownership, land value, building value, function (class) of the building. The data sources were linked to the GIS module. The assessment data not compatible with the TIGER files had to be re-parsed and prepared in a spread-sheet program (Microsoft Excel) before they could be imported into the GIS and joint (address matched) with the TIGER files on a parcel tract level. The GIS module has been developed on ARC /INFO from Environmental Systems Research Institute, Inc. (ESRI). The advantages of using the ARC/INFO package are its speed, flexibility, its support, and the fact that it is the industry standard most widely accepted [18]. The ARC /INFO GIS software is based on simple models called coverage. It offers an extensive set of tools that allow a series of operations on the coverages [19].

The spatial joining of the tax assessment data and the census data provides information for various levels of analysis. The GIS enables the access and combination of different data. It has the capability to answer questions ranging from very simple questions regarding unfiltered information from the database to complex questions requiring overlay of different information layers and different coverages. In the Pittsburgh case-study three general levels of analysis /queries are provided within the framework of the GIS:

(a) On the most simple level: direct spatial and quantitative information retrieval from the data base displayed on a map. An example could be "Show city owned parcels" or "show poverty distribution". This simple query reflects one thematic layer of information within a coverage. The desired information is highlighted on the given map.

(b) More complicated queries such as "show vacant buildings on city owned parcels in areas with high poverty rate" or "show underutilized sites not exposed to street noise and pollution" require the GIS to synthesize disparate sources of spatial information through polygon overlay. The GIS combines two or more coverages (e.g. street coverage with buffer zones and assessment coverage with underutilized sites), finds all intersections and writes the resulting integrated coverages as a new coverage. From this new coverage the initial query can be answered.

(c) Dynamic analysis: Simulation of possible scenarios. Programs are given a "weight" indicating the extent of its influence on urban flow. Buildings with different weighted programs become weak or strong urban attractors. The weight depends upon the size (mass) of the programmed building and upon its accessibility [20]. Attractors are represented by a "buffer circle" where the radius is equal the attributed weight. The proximity of two or more attractors creates a zone of attraction which is represented by a synergetic buffer circle" (sum of single building weight multiplied by a synergy constant).

Furthermore, the interference of two such synergetic buffer circles forms a "line of flow", a buffered line which encompasses a linear zone between the two center points of the circles. An example would be the concentration of office buildings and different public functions, such as a church, a school and a shopping market, in one site. The GIS would calculate the combined weight of the attractor-buildings and show the potential areas for redevelopment affected.

4.2.2 3D model

In a next step, the GIS information was passed from the two dimensional base map to the polygons of the three-dimensional model. This was effectuated by a set of tools programmed at the CLR in Toronto. The result of this combination of GIS information and geometric model was a three-dimensional GIS model, which contained the urban data relevant to the strategic redevelopment of Pittsburgh South Side. It was now possible to go through the city and query the GIS information in real-time, i.e. "on the fly". The congruency of information navigation space and real urban space meant an intuitive and logical organization for data query and manipulation. With the acceptance of digital representation, three-dimensional city models have become increasingly available. For example, Berlin, Los Angeles, Paris all have their own detailed digital city models. The problems associated with the building of three-dimensional urban models have been discussed extensively elsewhere. For this project the three-dimensional model was already available from a previous study. Macro programs were used to extrude the two-

dimensional polygons into a three-dimensional volume and the terrain was modeled using specific TIN generation tools [21].

The level of representation for three-dimensional urban models is another known issue in CAAD research. Typically, there is a trade-off between the level of detail and the speed of interactions. Here, the modular approach of the DUIM allows different levels of representation. Different modules with different level of detail can be interchanged. However, for our purpose, strategic urban redevelopment, the representation of buildings as simple volumes were sufficient, since the buildings were primarily seen as carrier of information, and video images were available for more realistic representation.

Nevertheless, the detailed modeling of some significant larger building, like churches, emblematic fabrics and industries, were helpful in providing points of orientation in the architecture of the city.

4.2.3 Video images

Finally, video images of selected area taken on site were linked to the corresponding addresses onto the three-dimensional polygons. Two techniques were used for video data capture: hand held drive-through shootings of the streets (strip-sequences), and 360 degree views from high buildings and towers (panoramic-sequences). These captures were digitized and split up in short sequences and in single snapshot images. Relatively low resolution images (mpeg and jpeg, 72 dpi, 4' x 3') were found to be sufficient for our purpose.

The integration of video images is important to escape from the abstract realm of computer models. They are useful for the control of the image quality of the cityscape and for the imagination of a future intervention.

4.2.4 Interface

The user interface is customized for meeting the individual needs of the users involved. Using TrimCARD, different interfaces can be conceived on top of the same urban model. This is important in dealing with projects in which the interests of the participants diverge, such as in PPP projects. Windows showing the information of particular interest can thus be enlarged and emphasized, depending on the party addressed. Figure 3 shows a screen-capture of an interface conceived at the initial stage of the case study. The elements in this interface are: the large window showing the interactive urban model, in which the user can fly and walk through and click on buildings and parcels to get information, the video window displaying the video images of the activated buildings, the GIs window revealing the corresponding set of relevant urban data, and a number of buttons representing each a predefined action: GIs query buttons, such as Empty Lots, City owned buildings, schools, Churches, activities pertaining to the Community, etc.

Furthermore, buttons for inserting new buildings, for testing playfully the interventions, and for other not predefined queries are provided.

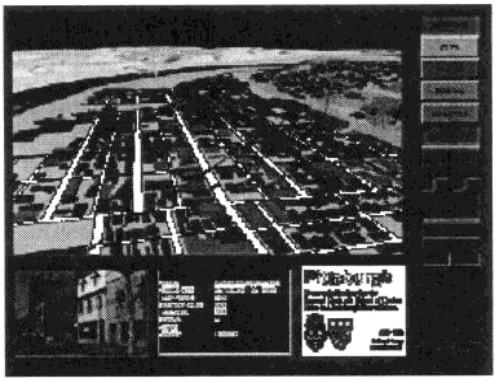

Figure 3. Screen-capture of a DUIM interface developed for the GSD Design Studio.

4.4 Application

Example applications of the DUIM are best shown in a real-time session or in a video. Three general levels of operations can be demonstrated: a) kinetic experience of urban space and form, b) multi-criteria reading of the potential of the site: spatial, financial, economical, social, political, architectural, c) design intervention and impact simulation. Using the DUIM, the buildings and parcels of interest could be visited "in situ". The various sources of information available there allowed to examine in a very, intuitive way the potential of each site. The superposition of different media and sources of information revealed causal relationships between phenomena not detectable otherwise. For example, by switching from one set of data visualization to another, (a kind of temporally sequenced small multiples), we could identify the reasons for the We of certain areas that, despite the decreasing tendency, kept attracting people. We could thereby deduct strategies for the other areas. In particular, observations could be made on the relationship between urban infrastructures and the housing situation. The data found to be of greatest importance in this case study were:

the household income, the land value, and the building value data derived from the tax assessment data, which enabled a mapping of the quantity and the pattern of distribution of empty lots, vacant buildings, and underutilized parcels in relation to the corresponding land and building value, as well as to the conditions of their ownership. With the Census data, the ethnic and class distribution around the site could be plotted, and the "accessibility" to working places, public buildings, and places for recreation could be examined.

The critical reading of the site using the DUIM, allowed us to craft a decentralized network of redevelopment interventions, and to make precise recommendations for programming on specifically chosen sites. Subsequently, the proposed interventions could be simulated using the tools for design product simulation. The interactive extrusion of two-dimensional footprints gave a first idea of how a future architectural intervention might look like. A linked dynamic spreadsheet allowed to see and control in real-time the size, height and cost of the volumes in their future context. For design process simulation, the impact of the interventions on the neighborhood could be visualized in the GIS program as a factor of the assigned "weight" of the program of the intervention. By "playing" with the different scenarios, it was possible to propose an appropriate phasing for the individual interventions.

Furthermore, the simulations allowed to choreograph programmatic injections at three distinctive levels: for the different hours of the day, to address the local and the regional population, and for cross-programming, that is, to combine different complementary activities. For the case study, most of these simulations were only implemented in two-dimensional plans, thus the potential of design process simulation in DUIM had not yet been fully exploited.

5 Discussion

The objective of developing the prototype and implementing it in a real project was to better understand the relative strength and weaknesses of the DUIM. Whilst the application for a strategic redevelopment of Pittsburgh South Side turned out to be convincing, and lead to several interesting proposals for the site, it also raised some issues that merit further investigation. These issues and the related agenda for further research can be organized into the three following work areas:

5.1 Link between modules

The link between the modules is the Achilles' heel of an approach using different independent modules: how do individual modules communicate with each other. In the case study inconsistencies could be observed in the transmission of GIS information from the parcel, which represented the basic unit for information referencing, to the polygon-based three-dimensional models. For example, in situations in which neighbor buildings were built together, the in-between walls represented by overlapping polygons created ambiguity: to which parcel did these polygons belong, and which set of data should these receive. Furthermore, as the walls between two neighbor buildings had to match with the parcel edge lines, a very precise superposition of the modules was mandatory. Since the modules came from different sources, mismatches were often unavoidable.

Therefore, in order to facilitate a more accurate transfer of information from one module to another, a different communication structure is necessary. At this stage, we envisage to use internal representations, as e.g. found in object-oriented design [22], that is, to supplement the geometrical objects with an indication of what they represent: volumes represented as buildings' and not just as a quantity of polygons. Then, using the same example, the GIS information could be passed to "the church" and not to 32 polygons.

5.2 On-line data

If the parcel represents the basic unit of the DUIM, the GIS module with its unique characteristics in spatial analysis is the engine of the DUIM. The GIS relies on the availability and consistency of urban data. For the case study we used Census Data that are assessed every decade. Compared with the rapid changes in areas of urban redevelopment, this ten year cycle is not sufficient.

In order to be able to determine (temporally and spatially) precise strategic urban interventions, it is crucial to overview recent developments. For example, in our case study, the number of vacant buildings in the flat and slope area of Pittsburgh South Side had increased from 654 units (in 1980) to 760 units (in 1990). Although we were able to map the distribution and to see where the vacant buildings were, we could not detect how the developments occurred. Furthermore, the fact that we were able to see the effective changes in the area only after the decade had elapsed, makes a preventive approach difficult.

It would thus be desirable to have on-line information of the changes occurring in the area under urban redevelopment. This could be effectuated by a direct link to the city planning office, where the changes of the building stock are registered daily. The linking of such a city planning office to the network raises problems of technical and organizational nature that need to be further investigated.

5.3 Collaborative design

Finally, the case study showed that, because of its integrative nature, the DUIM could serve as a communication base for collaborative urban design. The DUIM represents an ideal common denominator for group work. Using a DUIM, each group has access to all the resources. Investigations and operations can be coordinated, and specialists from different domains can navigate through the information space of the DUIM. The "objectivity" of the DUIM (the neutrality of the data) anticipates an unbiased discussion, in which the participants can concentrate on the content of the projects, and not on positions represented.

Collaborative design projects that intended to be interdisciplinary often end up "multidisciplinary", that is, side-by-side work of different disciplines without interaction. This is due to the fact that each group has its own methods, models, and language [23]. Because of its integrative character, the DUIM has the potential to foster computer supported cooperative work (CSCW) in urban design: using one and the same model, it allows the participants to evaluate ideas ad-hoc, and to adapt their goals and objectives dynamically during synchronous or asynchronous collaborative sessions. It thus represents a solid basis for future interdisciplinary, collaborative urban design within networked working groups. Further work in this area includes the definition of a format for "design protocoling" in order to keep track of the authorship and the underlying intentions of the individual contributions and design actions.

6 Conclusion

A Dynamic Urban Information Model to support the redevelopment of cities using a combination of GIS, Three-dimensional Modeling, and Video Images has been presented. It is based on strategic process-oriented design concepts, and offers a tool for determining interventions to set off redevelopment processes. Fundamental to this strategy is the consideration of a wide spectrum of concerns including economical, social, political, and architectural aspects. It is through this integrative approach that the proposed strategic urban redevelopment becomes feasible. he DUIM anticipates a new approach to urban redevelopment. It allows to determine decentralized design interventions and to control their spatio-temporal implications. It thus addresses the whole picture of a region, without neglecting the fine melodies played by the individual genius loci. With this understanding of

the potential of a site, the urban designer is e.g. in the position to direct PPP investments to engender urban redevelopment.

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