Interactive urban design using integrated planning requirements control

Bauke deVries*, Vincent Tabak, Henri Achten

Faculty of Architecture, Building and Planning, Eindhoven University of Technology, P.O. Box 513, MB Eindhoven 5600, The Netherlands

Abstract

Urban planning and urban design are separated disciplines. As a consequence, there is hardly any feedback from the urban design process to the urban planning process. To improve interaction between these two, an interactive urban design (IUD) tool has been developed. The tool is implemented in a Desk-Cave allowing for direct manipulation of masses and with immediate feedback on the urban planning programme performance. In a small-scale experiment, the tool proved to improve compliance of the urban design with the planning requirements without obstructing the design process.

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1. Introduction

Urban planning and urban design are strictly separated disciplines, which causes a time-consuming feedback loop when plans are translated into masses and spaces. Urban planners work on the city level or regional level making calculations about the number of households per square meter, the demand for schools, shops, etc. and a global design of the traffic infrastructure. Urban designers start from these requirements and they have to comply with building regulations when developing solutions for allocating the houses, shops, road, parks, etc. To evaluate the spatial consequences of design and plans, scale models of cardboard, wood or foam are used. Not until then, interaction between plan and design becomes visible and accessible not only for the experts but also for potential buyers, citizens, etc. This often leads to revision of the urban plan. It is therefore desirable to already assess in the urban planning phase the potential spatial impact of decisions in terms of the relationships between densities, general building height guidelines, public/private space proportions and so forth. In collaboration with the municipality of a medium large city, we have developed a tool that will feed back such urban design aspects into the planning phase.

Planners and designers both developed their own tools, in particular CAD systems and GIS systems. In
research, examples can be found to encourage citizen participation [1], to support urban design evaluation [2] and to link VR to GIS [3]. Unlike CAD systems, our system offers a very limited, but dedicated set of tools for the design of urban plans. Unlike GIS systems, our system offers no geographical data and analyses tools, but just those data that determine the requirements for the urban plan and a control mechanism to test the limits. In this way, the tool should offer for urban planners a fast and easy possibility to quickly check the spatial feasibility of a plan without going into any detailed urban design activity.

Our research focuses on closing the planning–designing gap in an innovative system allowing for immediate feedback from a planner on design solutions and vice versa. Closing the gap will reduce the time of design evaluation and thus increase the number of plan alternatives that can be studied.

2. Urban planning and design

In urban planning and design, requirements from environmental planning studies are translated into spatial components. Although there are some dimensional conditions from national standards to comply with, the design of the building blocks, the open spaces and the infrastructure is a typically ill-defined problem that demands a lot of creativity. Evaluation of urban design solutions is often a very subjective process, which sometimes is performed in cooperation with the present or potential citizens.

Traditionally, urban planning and urban designing are two separated disciplines, each with their own methods, techniques and tools.

2.1. Urban planning

Urban planners make 2D maps and attach additional data to the components. Nowadays, this process is supported by geographical information systems (GIS). Governmental institutes are responsible for collecting data and maintaining the GIS systems. Current situations can be analyzed by urban planners using statistical methods and new plans can be evaluated. Political, economical and environmental strategies are integrated and transformed into one plan. Finally, an urban planning programme is produced that depicts a vision and describes how this vision can be realized. The vision is expressed with maps and tables describing which and how many building types (e.g. houses, schools, etc.) and spatial components (e.g. parks, parking lots) should be developed in a specific area of the plan [4].

2.2. Urban design

Starting from the urban planning programme, the urban designer will make mass studies using mass models and sketches. He/she designs the locations and the global dimensions of the buildings and of the infrastructure. The traditional means are foam, wood and paper. Sometimes, 3D modeling tools are used, but to our knowledge they are not very popular among urban designers. A possible explanation for this might be that the traditional means like paper and pencil are unbeatable in regard to interactivity between the designer and the model. In practice, this means that checking the design against the urban planning programme is a manual procedure. Urban designers usually will first generate alternative solutions and then select the one they like best to be tested against the original requirements.

2.3. Closing the gap

Organizations such as municipalities experience the separation of the urban planning and the urban design disciplines as an obstruction for a fluent planning and design process. There is hardly any feedback from the design process to the planning process. The assumption of this research is that closing the urban planning and design gap will:

- Improve interaction between planning and design strategies.
- Encourage communication between planners and designers.
- Reduce time and cost.

3. Interactive urban design

A visual tool for urban planning and design will provide the required interaction between the designer
and his/her model. Visual representation is also necessary to communicate the proposed design with the planner and with potential citizens. We therefore developed a system that includes that data from the urban planning programme and offers an intuitive interface to urban designer or planner for creation and manipulation of masses and spaces. In the following sections, the functional specification of such a system is described in more detail.

3.1. Functional specification

The system supports the user in designing simple 3D models on an urban scale. The system cannot handle complex 3D shapes like CAD programmes, but does support the creation of mass models in an intuitive manner.

The mass model is constructed from simple 3D object types. Studies on site of urban design offices showed us that the following basic design blocks are used: boxes, strokes, roofs and groups. For each of these 3D objects, the specific functionality is as follows:

- **Boxes**: boxes represent a specific dwelling function such as, house or school. The color will specify a function, which is retrieved from the urban planning programme. At initialization, the user specifies a box type for each function. Boxes are instantiated from a box type, carrying the properties (e.g. function) of that type. Box dimensions can be adjusted by the designer after creation.

- **Strokes**: the strokes are used to model non-residential areas like roads, parks, etc. A stroke can have any color. At initialization the user specifies a stroke type for each function. Strokes are instantiated from a stroke type, carrying the properties (e.g. function) of that type. Stroke dimensions can be specified by the designer on creation.

- **Roofs**: roof shapes are considered important for the visual perception of an urban design. At initialization, the user specifies a roof type for each function. Roofs are instantiated from a roof type, carrying the properties (e.g. function) of that type. Roofs are added on top of boxes and will align with the underlying boxes. (This function was not implemented in the prototype system.)

- **Groups**: groups consist of a collection of boxes, strokes and roofs. Some manipulations can be operated on groups. (This function was not implemented in the prototype system.)

Object modifications supported by the system are: (1) move, (2) rotate, (3) change dimensions and (4) delete. In order not to obstruct the user with the invocation of commands (e.g. by menu’s), we decided to attach all modification options to the object itself. When an object is selected, handlers will be shown that represent the modification options. The handlers are: three rotation axes, for each rotation axis two dimension grips and one floating trashcan (Fig. 1).

By selecting the rotation axis or the dimension grip, the object can be rotated and stretched, respectively.

The system can import 3D models from other CAD systems. We deliberately did not want to develop a complex 3D modeling programme, because this would destroy the intuitiveness of the system. Moreover, the environment is often a fixed asset that is retrieved from existing map libraries. The environment is divided in regions with area and function as attributes.

At initialization of the model, the user defines on which parameters he/she prefers to have feedback on. Examples of such parameters are: total floor area, housing density and the number of objects in the model of specific type. While creating the mass model, the user will constantly receive feedback on the consequences of the design actions. Feedback is not only possible for the entire model, but also for

![Fig. 1. Object manipulation handlers.](image-url)
individual objects. For example, the system will respond to prohibited location of houses in green regions. The response is visualized by changing the object color.

The constraints that should be imposed can be retrieved from the urban planning programme or can be added by the user. Equivalent to the feedback parameters, constraints can be imposed on the model level (e.g. maximum housing density), but also on the object level (e.g. houses only in the dwelling area). Constraints that follow from (inter)national standards and codes are currently not included in the system and must be added by the user.

A list of architectural and urban parameters that can be deduced from the model is presented in Table 1.

Apart from the numerical feedback, there are many visual feedback parameters related to architectural perception such as: sight lines, shadow casting, orientation, accessibility and skyline.

### Table 1

<table>
<thead>
<tr>
<th>Feedback parameters</th>
<th>Entire model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>Total number of a specific object type</td>
</tr>
<tr>
<td>Area</td>
<td>Area per region</td>
</tr>
<tr>
<td>Volume</td>
<td>Total area of object type per region</td>
</tr>
<tr>
<td>Function</td>
<td>Total cost per region</td>
</tr>
<tr>
<td>Cost</td>
<td>Total cost</td>
</tr>
<tr>
<td></td>
<td>Total volume per object type</td>
</tr>
</tbody>
</table>

4. Desk-Cave platform

The Desk-Cave platform [5] has been developed as a low-budget alternative for the well-known CAVEs. The platform is used for research projects that require interactivity between a 3D model and the designer/user.

#### 4.1. User interface

The Desk-Cave (Fig. 2) consists of a table desk with three translucent screens around it. Sitting in the Desk-Cave the model is projected on the three screens and the desktop. The effect of being in the model is strongly immersive and provides a good method for experiencing the urban environment.

Next to the creation of virtual, immersive environments, the Desk-Cave can also be used to show different views of the model using the four projections. For the interactive urban design (IUD) system, the floor plan will be projected on the desktop, and a 3D view with feedback parameters is projected on the back screen. In this mode, the designer will have a complete overview over the design and over the spatial and visual implications.

The dominant input device is an ultrasonic mouse positioning system, namely the Mimio mouse pen. With this mouse pen, the desktop becomes a full-size touch screen. By projecting the urban plan on the desktop, the designer can use the mouse pen for...
manipulation of the 3D objects. For entering alphanumeric data, a keyboard is projected.

5. Experiment

A test case from practice is used to set up a small-scale experiment to investigate the IUD system performances. Around a small village in the Netherlands there are five areas that should be developed in the next years. Currently, these agricultural areas are bounded by the village on one side and roads on the outside. The urban planning programme states that the area is well suited for dwellings especially for elderly people. The five areas should keep their quiet, friendly atmosphere. In the total area on 152 km², approximately 1500 dwellings must be situated. Each of these five areas must be designed having its own characteristics. Using the test case, the system will be evaluated. In the experiment, architectural students as well as experienced urban planners and designers took part. The performance criteria that were identified are:

- The number of alternative designs.
- The degree in which the urban design meets the urban planning programme.
- The user appreciation of the tool.

The subjects in the experiment will be asked to create a design for one of the five areas. The subjects are divided in three groups, one group working with the UID system, one group working with AutoCAD and one group working with pen and paper.

The design task must be fulfilled within a fixed time frame of 40 min for each design medium. Within this time frame, the subject is asked to generate as many design alternatives as possible. After the experiment, the subject is requested to fill in a questionnaire about the appreciation of the used tool. The subjects consisted of three staff members and one student from the department of architecture and planning from the university and two staff members of the urban design department of a municipality.

6. Results

6.1. The number of alternative designs

The critical issue here is a clear definition to determine a design alternative. In principle, every design modification can be considered a new design alternative. However, in this experiment, a design is identified as a new alternative if (i) the design cannot be reconstructed from another design by move and rotate operations and (ii) the requirements fulfillment does not deviate more than 10% from the target (if that happened, we considered it as an unfinished variant). With these criteria, all design output was analyzed and the results are presented in Fig. 3.

Pen and paper is by far the most productive design medium. The UID system performs significantly better the AutoCAD/VIZ but not as good as pen and paper. Not visible in this figure is that there is a great variety in the number of design alternatives between the experiment subjects. Given the low number of

![Fig. 3. Number of variants.](image-url)
participants in the experiment, such a wide spread in outcomes can be expected.

6.2. The match between design and planning

For each design alternative, a comparison was made between the numerical data such as number of houses, floor area, minimal distance between buildings, etc. that were retrieved from the designs and the requirements from the urban planning programme. The participants created 37 alternatives in total. Due to the low number of buildings to be realized (32) in the test case area, the performance margin was set to one. Over and under performance are reported in Fig. 4.

The results confirm our expectations that pen and paper cause substantial deviations from the urban planning requirements. On the other hand, AutoCAD/VIZ demands exact input and thus forces the designer to be very precise. The UID system performed less good as expected which was caused by a user-interface problem. New copies of existing objects (buildings) were created in exactly the same location as the original ones and not noticed by some of the participants.

6.3. The user appreciation of the tool

The questionnaires revealed the over-all user appreciation for the design medium in this experiment (Fig. 5).
The UID system was generally perceived as best supporting this particular task. The results underline that dedicated design tools can perform even better than pen and paper if the extra effort on the use of the medium is counterbalanced with valuable support features.

7. Discussion

7.1. Is UID a tool for designers or planners

A fundamental question is whether the tool should be used by designers or planners. The UID tool closes the gap between designers and planners by providing a method that integrates both aspects of the urban project development process. Designers can apply the UID system for easy and quick generation of design alternatives, even together with potential inhabitants of the urban area. Planners can apply the UID system for testing the requirements they have stated against the spatial consequences. Nevertheless, we have to emphasize that the UID system is not intended as a full-fledged urban design tool. The design itself is not the most important product of its use, but the insight in the interaction between urban design and planning requirements. This insight improves communication between designers and planners and thereby reduces unnecessary revisions.

7.2. System improvements and extensions

Many improvements are possible, of which the most obvious are the not yet implemented features of roof shape and group. Other possible extensions can include curved and skewed building shapes, calculation of distances between buildings and along routes, building lots, array generation of building objects, etc. Another obvious extension is the connection with a geographical information system. From the GIS system, maps can be retrieved and a variety of analyses can be performed.

However, we feel confident that the strength of the system lies in its simplicity. Adding more shapes and more functionality could easily destroy it intuitiveness. Therefore, we feel it is more prudent to resist a call for adding much functionality, and to look for extension more by means of fast transition to other software that offers different functionality.

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References