

# A Parametric Approach to Urban Design

## *Tentative formulations of a methodology*

*Nicolai Steinø and Niels Einar Veirum  
The Urban Design Research Group  
Aalborg University  
School of Architecture and Design  
Østerågade 6  
DK – 9000 Aalborg  
www.aod.aau.dk/ud  
steino@aod.aau.dk  
nev@aod.aau.dk*

**Abstract.** *It is the thesis of this paper, that the application of a parametric design approach to urban design has great potentials for improving the systematic testing and subsequent argumentation for urban design proposals. Parametric design has so far mainly been applied to engineering. However, the ‘components’ constituting an urban design also share similarities that may be defined parametrically.*

*Aspects such as density, use, mix, form, space, and typology may all be defined parametrically. By doing so, it is possible to not only perform a systematic design process, but also to evaluate the pros and cons of scenarios with different parametric settings.*

*On the basis of a theoretical discussion, followed by a case study in the form of a student workshop, the paper will discuss the nature and scope of parametric urban design, draw some preliminary conclusions, and outline some possible perspectives for the development of parametric urban design.*

**Keywords.** *parametric, parameters, urban design, methodology, workshop, CAD*

## **Introduction**

Urban design differs from other design disciplines in a number of ways. While architectural design or product design is typically targeted at designing objects to a level of detailing at which they can be produced on the basis of the design, urban design is not always targeted at a unified end product (Steinø, 2003, p. 171). As expressed in Jonathan Barnett’s famous maxim that urban

design is ‘designing cities without designing buildings’, urban designs are often conceptual designs defining overall principles for urban development, rather than detailed designs.

As urban designs must often be negotiated among several stakeholders, the question of documentation and validation of the design is important. In other words, if the urban designer cannot convince the stakeholders that the design meets their requirements, the design is likely to fail. But

as not all urban design criteria are necessarily quantifiable, and as the goals of urban design cannot necessarily be agreed upon among stakeholders, validating an urban design often becomes a matter of argument. When validation is argumentative, it is important that the criteria for validation are transparent in order to support the argument. Therefore, fields of investigation must be laid open and design criteria must be transparent to the extent possible.

Another implication of the complex setting of most urban designs is that as the process of urban design must be argumentative, collaborative and inclusive in order to achieve a viable design, it must be open for alterations as a result of negotiations. Hence, the design process must be kept open for as long as possible, as it can be very time and cost consuming to alter designs which have been carried to a high level of completion.

Given the nature and institutional setting of most urban design projects, the ideal design methodology for urban design should be transparent and flexible. Transparent, in order to strengthen the argumentative power of the design, and flexible, in order to be able to allow alterations during the design process.

## Parametric Design

Parametric design is an established concept in CAD-modeling, although it does not have a clear definition. In its most basic sense, parametric design is designing by means of objects which are defined by a set of constituent parameters. A line, for instance, may be thought of as an object defined by three parameters, position, direction and length, all of which may be defined and redefined individually.

Where parametric design differs from CAD modeling in general is when the computer interface allows for an intelligent use of this way of defining objects. This is typically applied by means of either components or constraints, although some

CAD pro-grams offer more complex and sophisticated applications. Components are predefined objects which are inserted into a CAD model. A relationship is maintained between each instance of the component and the original component. When the original component is modified, each instance of the component is updated, allowing for a more flexible design process.

The concept of components largely covers Anderl & Mendgen's (1995) definition of parametric design:

*In a parametric CAD system the designer has to model the shape of a part or assembly only once and may derive variants by changing dimension values, engineering parameters (to create geometric variants), or the feature history of the part (to create topological variants). The shape of a part is modeled as a combination of features, each described by geometric parameters (dimensions) for its shape, position and orientation with respect to other features of the part. – ibid., p. 7*

Parametric constraints on the other hand, are relations that limit the behavior of objects or groups of objects (ibid.). Constraints may be either dimensional or geometric. While dimensional constraints maintain a measurable relationship by limiting the object's geometry to a particular value, geometric constraints maintain a physical relationship by limiting the allowed orientation of objects (Nemetschek, 2004, pp. 4.13-14) (Fig. 01).

Because of the central role of constraining relations in this definition of parametric design, it is sometimes referred to as relational modeling, variation design or constraint based design (Monedero, s.d.).

So far, our description of parametric design only includes geometric and dimensional parameters. In engineering it may be relevant also to model non-geometrical parameters representing other qualities associated with objects, such as material properties or technology and manufacturing properties (Anderl & Mendgen, 1995, p. 2). And in architectural and urban design it may be relevant to

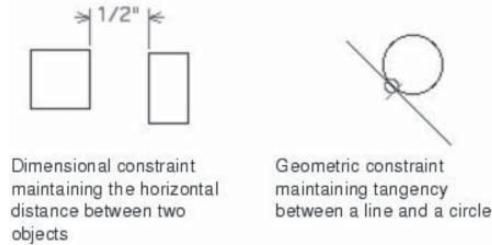


Fig. 01: Dimensional and geometric constraints (Source: Nemetschek (2004) *VectorWorks: Version 11, User's Guide*. Columbia, MD: Nemetschek)

include programmatic parameters, such as the use of buildings and exterior spaces.

Parametric design may also be discussed in the context of configuration design:

*In a large number of real-world applications it is possible to assume that the target artifact is going to be designed in terms of predefined design elements. In such a scenario the design process consists of assembling and configuring these pre-existing design elements in a way which satisfies the design requirements and constraints, and approximates some, typically cost-related, optimization criterion. This class of design tasks takes the name of configuration design.* – Motta & Zdrahal, 1996, p. 1, emphases in original

Designing by means of parametrically defined objects and constraints have obvious advantages compared to conventional design techniques, whether computer based or manual. First, it allows the intelligence added to tentative designs to be maintained at later design stages, as rough initial designs may be updated through the use of components as more detailed information is added. Second, it allows for conceptual designs where basic relationships are tested through the use of relational constraints.

These aspects of parametric design relate to the early stages of design. While conventional design techniques require much design work to be redone whenever a design is altered as models or drawings must be redone to various degrees, a parametric design approach allows to keep the design 'open' for a larger part of the design pro-

cess without loss. As Anderl & Mendgen note, this makes it more feasible to start modeling in the in the conceptual design phase, rather than in the design presentation phase (ibid., p. 1).

Finally, as stated by Motta & Zdrahal, whenever design tasks take on the form of configuration design, a parametric design approach also has clear advantages, as this kind of design tasks are a question of configuring pre-defined design elements which can be defined as components.

This latter quality of parametric design may be a reason why parametric design has so far mostly been applied in engineering and only to a far lesser extent in architectural design (Burry, 2003). Architectural design traditionally makes a virtue of unique design, and designing by means of parametrically defined objects may induce a certain feeling of 'loss of authorship' (ibid.).

With the first fractal visualizations decades ago it became obvious that rather complex spatial worlds could emerge from very simple mathematical expressions governed by a few parameters. The recent bio-genetic triumph in mapping the human genome has now inspired Karl Chu to a revival of the quest for the DNA of the built world and ultimately the merge with autonomous organic processes:

*If architecture can once again be in the position to embody the concept of autonomy, it must do so not in terms of classical metaphysics but in terms of a yet to be discovered metaphysics of modality that takes into consideration developments in cognitive science, neural networks, computation and genetics in order to develop what at present seems unthinkable: the genesis of subjectivity that constitutes the artificial life of architecture.* – Chu, 2005

Chu has made his far-reaching concepts more operational with the notion of architectural agents:

*An architectural agent, like all agents, must somehow be in a position to embody an internal principle of its own which can then give rise to the development of an internal will to being: the will*



Fig. 04 and 05: Student workshop. Left: Programmatic parameter model and projected computer model. Right: Formal parameter model with spatial coordination across individual blocks. (Photos by Mario Hesse and Nicolai Steino)



Another application of parametric thinking in urban design is introduced by Lykke-Olesen (2000) in his thesis work, in which he examines the design potential of viewing the city as consisting of inter-related and constantly changing systems of data. In order to be able to handle the data in a computer model, Lykke-Olesen attempts 'parameterize' them, that is to "... combine their relationships mathematically so that the model can be brought to life when these relationships are impacted" (ibid., authors' translation).

A third development adopting a parametric approach to urban design is presented by Haff-Jensen in the form of a competition entry, the Myllypuro Dynamic Masterplan (fig. 03). In this project, both form and program is defined parametrically, as a set of building typologies and different dwelling sizes respectively. By means of a dynamic web-interface, different building typologies, as well as different combinations of dwelling sizes may be set for different parts of the dynamic masterplan (Haff-Jensen, 2003).

These examples provide interesting contributions to the development of a parametric approach to urban design. However, in their search for a format which can be handled by means of various software applications, they tend to focus on quantifiable data and to forget the issue of values – what should the different parameters be set to and why – which is a fundamental prerequisite for all design

decisions.

### Case: Student Workshop

We have made a tentative formulation of a parametric urban design methodology, comprising both spatial and programmatic parameters. This methodology was tested in a student workshop for some 75 students in the 4th semester of the Architecture & Design program at Aalborg University, Denmark, in April 2005. The student workshop, contained two major design sessions. In both sessions, each student had to make a scale model of an urban block measuring 70 by 200 meters. The finished models were combined into a Manhattan-like grid of 5 by 15 blocks.

In the first session, the students worked with programmatic parameters on a scale 1:200 (fig. 04). While these parameters, density, open space and types of use, had fixed settings for each block, the students were free to distribute the specified program as they wished, as long as they did not violate the specified setting for the amount of open space within the block.

As the parameter settings for each block were distributed according to a larger logic regarding the overall grid of blocks, different patterns for each parameter were clearly detectable as soon as all the individual blocks were combined into the grid. Nonetheless, the combined model (measuring al-

most 6 by 6 meters) featured an amazing variation of site layouts and formal compositions.

Apart from producing a foam model of their site designs, the students also had to make a corresponding CAD model. The individual CAD models were then combined into a joint model, which was projected in the workshop room during the evaluation. While the physical model had obvious tactile qualities, as you could actually walk around it and touch it, the projected CAD model offered an overview as well as the possibility to make close-up analyses, which were hard to achieve through the 6 by 6 meters physical model.

In the second session, the students worked with formal parameters on a scale 1:500 (fig. 05). While no attention was paid to program, they had to negotiate their individual designs with their neighbors in groups of five students. Six pairs of formal parameters, geometric/organic, regular/irregular, dense/sparse, high/low, enclosed/open, and big/small were distributed in different combinations and set to different values across the grid.

Each student had to consider three parameter pairs at different settings, such as 'predominantly dense', 'regular and irregular', and 'high'. However, they were free to decide how the parameters should be applied in the design. Hence, the parameter setting 'geometric and organic' for instance, could result an organic site plan with geometric blocks or vice versa, or in blocks consisting of both geometric and organic elements, without applying this parameter to the site layout at all.

Again, parameters and parameter settings were distributed across the grid of the combined models according to a larger logic. And although the formal parameter pairs of this session could not be quantified like the programmatic parameters of the first session, a clear pattern of variations could be detected across the combined model. Also, the ways in which the students had interpreted the issue of coordination across individual blocks within the different groups produced interesting results.

From a research perspective, the latter session

proved more interesting than the former, as it produced less expected results. First, it was surprising to see the extent to which differences in vaguely defined settings for soft, qualitative parameters actually led to visibly different results. Second, it was interesting to see how the framing of the design task in terms of formal parameter sets triggered the students to generate formal ways of coordinating their designs which they would otherwise have been unlikely to come up with.

## Discussion

Although still in its formative phase, we believe that a parametric design approach to urban design has great potentials for a number of reasons. Conceptualizing the design process in terms of parametric design allows for systematic analysis and design, as objects of inquiry (parameters) are made explicit – for the urban design herself, for the design partners, as well as for other stakeholders. Analyzing by means of changing parameter settings allows for systematic scenario building, as different scenarios express different settings for fixed sets of parameters.

This is ideal for collaborative and communicative design processes, as alternative scenarios can easily be tested parametrically. As Burry (2003) concludes from a parametric architectural design process for Gaudi's famous Sagrada Familia church in Barcelona: "Each time we met on site, alternative design strategies could easily be tested parametrically in real time, thereby accelerating the normal change-represent-reflect-communicate cycle" (p. 114).

A parametric design approach also corresponds well to the generic level of many urban design activities. When 'designing cities without designing buildings', a parametric design approach may facilitate the formulation of design intent on a conceptual level, thus improving the operational quality of performance based design criteria over prescriptive design criteria.

For the urban designer, a parametric approach may trigger new design solutions as thinking in terms of parameters has the potential to set design thinking free of conventional and habitual ways of approaching design problems. A parametric approach, in other words, offers a different framework of thinking of design. As an important aspect in this context, a parametric design approach has the potential to share the creative process rather than to constrain it to the intellectual domain of one person, provided that meaningful protocols can be developed (Burry, 2003).

Notwithstanding the potentials of parametric urban design, it also has its challenges and limitations. First of all, many urban designers – especially if trained as architects – may oppose to the very idea of abiding by any explicit design methodology as opposed to letting themselves be guided by their individual design talent and experience. As already mentioned, the deeply founded notion of the sole author producing unique designs is challenged at its core by the parametric design approach. And for sure, it may to some extent reduce individual freedom of design.

As we see it however, it presents a far greater risk that design thinking may be constrained by a too narrow interpretations of what may be considered a design parameter, as important aspects of design may thus not be made subject to explicit investigation. A similar risk consists in that only quantitative aspects of design which can easily be parameterized will be taken into consideration, leaving important, but more subtle and qualitative aspects of design out.

As Burry (2003) suggests, it seems crucial, that the basic premises for a parametric design approach are shared among design participants in order to be able to make the most of the parametric potential of design models. This implies some consideration for ‘designing the design’ (meta-design), as the designer will have to “take the trouble to organize his or her design so as to be intelligible to his or her colleagues” (Burry, 2003, p. 116), i.e.

to strategically plan some kind of conventions which can be understood by the entire team collaborating on the design (ibid.).

## Conclusions and Perspectives

Although we have drawn from the CAD world by our definition of parametric design, the application of CAD tools to parametric urban design has not been part of our explorations so far. On the contrary, we have made a point of the fact that we consider parametric urban design as a framework of thinking of design which may be applied to analogue ways of working as well as to CAD. Nonetheless, the application CAD tools to parametric urban design has obvious potentials which are worthwhile investigating.

One such potential is scenario building, where CAD may facilitate the configuration and reconfiguration of different design scenarios. Another potential – as in architectural design – is the capacity of some CAD applications to preserve design intelligence across different design phases, as initial bulk design may be refined along the way.

A challenging perspective is to investigate Chu’s approach at an urban scale, e.g. to define and implement urban agents capable of handling complex parameters and parameter dependencies. The promise of this is to substitute confusing, poorly communicable and time consuming single parameter decisions with more prominent value oriented design decisions at a meta-level.

Our test case for parametric urban design was a student workshop for 4th semester students of urban design. It would be interesting to see not only how more experienced students would put the concept to use, but also how it could possibly be implemented in a real-life context, where the aspects of communication, argumentation and validation would be put to test.

## References

- Anderl, R. & R. Mendgen: 1995, Parametric Design and its Impact on Solid Modeling Applications. Salt Lake City: Solid Modeling '95, 12 pp.
- Burry, Mark: 2002, Blurring the lines: an exploration of current CAD/CAM techniques, parametric design and rapid prototyping - mediating between analogue and digital skill sets. *Architectural Design*, no. 73, vol. 2, Mar.-Apr., 2003, pp. 110-118
- Chu, Karl S.: 2005, Architectural Agents. <http://www.arch.columbia.edu/gsap/47060>, 1 p., downloaded 22/05/05
- Haff-Jensen, Robert: 2003, The Myllypuro Dynamic Masterplan. Competition entry, 2003, quoted from <http://www.rohaje.dk/myllypuro/docs/>, downloaded 28/05/05
- Lykke-Olesen, Andreas: 2000, Dynamiske byanalyser. Master thesis, Aarhus School of Architecture, 2000, quoted from <http://www.daimi.au.dk/~alo/html/thesis.html>, downloaded 28/05/05
- Monedero, Javier: s.d., Parametric Design: A review and some experiences. <http://info.tuwien.ac.at/ecaade/proc/moneder/moneder.htm>, 6 pp., downloaded 20/03/2005
- Motta, Enrico & Zdenek Zdrahal: 1996, Parametric Design Problem Solving. <http://kmi.open.ac.uk/people/motta/papers/pardes-banff/pardes-banff.html>, 13 pp., downloaded 20/03/2005
- MVRDV: 2002, The Function Mixer. *El Croquis*, vol. 3, 2002, pp. 24-29
- Nemetschek: 2004, Vectorworks: Version 11, User's Guide. Columbia, MD: Nemetschek
- Novak, Marcos: 2005, quoted from Marcos Novak interview by Alessandro Ludovico <http://www.neural.it/english/marcosnovak.htm>, downloaded 22/05/05
- Steinø, Nicolai: 2003, Vision, Plan and Reality. Aarhus: Aarhus School of Architecture, PhD Thesis, <http://www.aod.aau.dk/staff/steino/phd/>