Organised Complexity

Application of Statistical Design in Large-Scale Building Projects

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The objective of the paper is to demonstrate the application of architectural research and design methods from the fields of strategic design, digital production and design chains to facilitate the completion of demanding large-scale building projects.

Since we have concentrated the efforts of the past few years on various aspects of building practice while applying and testing the “Digital Chain” method to several concrete projects, we are now engaged with linking the individual phases in order to make the final step towards the reality of building practice.

With this knowledge, we attempt to propose a new way of thinking in the design and building sector based on digitized planning processes.

Keywords: Collaborative design; parametric design; user participation in design; strategic design.

Introduction - context

What follows is a description of the necessary steps of a programmed planning process with focus on the previously missing area between statistical design and “Digital Production”.

While working with classical architecture offices, we note the tendency of the development of an unintentional rivalry situation, because the architects see their position as head of the design process as being threatened. Often the first reactions are questions such as “Can good architecture be programmed?” or “Can a program replace an architect?”, which illustrate the misunderstanding between the architects and our research in a simplified manner. As a result, it is necessary to emphasize that the individual programs do not compete with an architect and his or her competence, and therefore do not generate architecture, but rather provide a tool representing a logical technical advancement complementing architectural practice.
Design steps

The study is structured into five main application fields of technology and process:
1. Statistical Design
2. The Individual Ground Plan
3. Parametrical Design
4. Parametrical Façade
5. Digital Chain

Each field is based on its individual demands and has to be able to communicate and exchange data with related fields via interfaces and through appropriate exchange formats. When a specific parameter is changed in a process, neighboring programs receive a feedback and are automatically updated to reflect the current situation. The work sequence parallels the classical design process.

Statistical design

The “Statistical Design” is a tool for the first stage, or the preliminary planning involved in the urban design. The aim of this planning stage is to localise the different possibilities for the urban design itself. Here, the specific investment interests for a concrete site are examined and applied. The advantages to
“Statistical Design” are its time-saving attributes as well how it is able to review in detail specific project goals and optimize them. As a result, extreme solutions with maximum building volumes as well as various architectonic approaches can be investigated in parallel and weighed against each other.

To accommodate the iterative nature of the design process, a program has been developed which takes this into account. Planning and computer-controlled iterations alternate, and the computer-controlled results are judged and optimized by the planner. The main goal is to achieve a variety of solutions for comparison and evaluation. After each test planning phase, the program is able to deliver meaningful project data in the form of cost tables, apartment appraisals, number of apartments, circulation systems, noise exposure etc. This allows one to objectively compare the qualities of the individual solutions.

In addition, specific components can also be tested independently of each other; as a result, one is able to change the apartment make-up and review the resulting consequences using the same urban design schema.

The strength of this tool is its high flexibility and adaptability to the specific task involved, thereby minimizing investment risk, but is not able to generate complete urban design solutions alone.

The individual ground plan

The second stage, “The Individual Ground Plan”, develops a system to gather a repertory of ground plans according to the individual demands of the inhabitant or owner. The advantages of this method are the fast reaction to changes on the market and the control of the effects on the total system in a sufficiently fast and precise manner.

Following extensive research on contemporary examples, a library of ground plans is prepared.

This library consists of on the one hand, exemplary ground plans in various sizes as well as their meta-data and, on the other hand, their description in XML format. The description of the apartment ground plans is based on a previously defined framework, in which the interdependencies of the rooms, natural lighting and circulation requirements

Figure 2
Different layouts of the “Statistical Design”, showing solutions for the desired requirements
are determined. Using the Case-Based Reasoning\(^2\) method, the quality of the results is directly related to the quality and quantity of examples in the ground plan library.

The program builds directly on the “Statistical Design” phase: it uses the perimeter of the building and key specs such as the different ground plan layouts, building access, apartment orientation, noise exposure, and the size of the individual units. Finally, the program compares requirements with the ground plans in the library database and looks for the best match. The rules of the chosen plans are loaded into the building parameters and optimized over several steps. However, the essential characteristics of the ground plans are maintained throughout this process.

Here, no architectonic final solutions are delivered, which reflects the intent and results of “Statistical Design”, but rather a starting point from which decisions can be made and the design can be improved.

This step offers several possibilities to connect with the classical design process. Depending on the task, only individual elements of an apartment can be applied by the software, for example kitchen or bath units. Since these elements are also based on parametric information, they too can be fit into ground plans and the data elaborated further in construction documents and shop plans.

\(^1\) Extensible Markup Language (XML). Its primary purpose is to facilitate the sharing of data across different information systems.

\(^2\) Case-Based Reasoning (CBR) is the process of solving new problems based on retrieving and applying solutions of similar past problems.

**Parametrical design**

The mathematical basis ensured by “Parametrical Design” is essential for industrialized construction without a grid. We can observe that more and more clients seem to be fascinated by the opportunity to
burst the bonds of regular grids. Modern parametric CAD technology, in turn, is capable of distorting the shape of an element without changing the structure.

All planning steps are based on the parametric design framework, and there can be adjusted at any moment without losing additional time. Changes in plan are automatically reflected in the façade and vice versa. The planning information is continually updated to reduce the margin of error to a minimum. Similarly, individual areas can be worked on independently from each other and connected and adjusted together at the end.

**Parametrical façade**

Since the façade continues to gain significance as the exterior cladding and essential bearer of architectural language, one often would like to use it to examine and test different concept approaches. As a result, a library of reference buildings is created just like with the individual ground plans. This library contains documented façades and the rules they follow, described by parameters. After an appropriate example is chosen, these rules are applied and adjusted to the current building.

The program that generates parametric façades includes information on building form, the location of openings and preliminary programming of specific ground plans. By applying a chosen style sheet, one can now generate a parametric façade. In addition, all of the data of this phase necessary for production can be automatically called up in the form of data, tables, or object lists.

**The digital chain**

The essential advantage of this way of working lies in the flexibility and time saved in the generation of variations, which in turn allow for a well-founded
basis for decision-making and optimization. The “Digital Chain”, a term used to represent the uninterrupted digital planning and production process from “Statistical Design” to construction, constitutes the foundation of our research.

**Discussion**

The technical solutions we describe should not be regarded as a completed tool. Since there is an established knowledge of the individual fields of the “Digital Chain”, the focus now rests upon the interfaces between them and their implementation into the entire building process.

Each step has to be carefully controlled by the planner and adjusted to the concrete design and construction project. Especially the first two fields that were described, “Statistical Design” and “The Individual Ground Plan” do not deliver “finished solutions”, but rather sketch out the parameters established by the planner. The architect’s task remains to achieve architectonic quality. Our experience in this area has shown that this cannot happen solely through the optimization and laborious adjustment of rules defined by a computer program, but rather through the traditional craftsmanship of an architect.

The potential of digitally-supported project realization based on the aforementioned five steps: Statistical Design, The Individual Ground Plan, Parametrical Design, Parametrical Façade and Digital Chain, is the rapid identification of specific – to the present
still unknown – problems. The introduced approach should minimize building risks associated with these unknowns and increase architectural freedom and quality.

Acknowledgements

The research was partly funded by Halter Unternehmungen. We would like to thank Prof. Dr. Ludger Hovestadt, head of the CAAD chair at the ETH Zurich, and all of the assistants participating in the research project of the CAAD chair, with special thanks to Sabine Herzog, a student assistant at the CAAD chair.

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