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Søren Nielsen

### **Industrial systems and architectural concepts in projects by Vandkunsten**

#### *Abstract*

*In three cases of industrialized building projects by Vandkunsten, the interface between tectonic articulation and the production system is investigated.*

*It appears that architectural concepts and technological systems are largely independent parameters and the interface between them is highly negotiable. However, the cases also indicate a convergent potential between resource-optimization and further development of prefabrication when methodologies for disassembly and spatial transformation are introduced as a precondition for reusability. When viewed together, these findings point towards the optimistic vision of a resource-saving industrialized building culture without loss of identity or architectural multiplicity.*

In the production of Vandkunsten, low-budget commissions are a rule rather than an exception. This condition marks our perspective on industrialised methods of building. Like any other Danish architects, our everyday practise takes place within the well-known regime of concrete-elements. Concrete elements are enjoying a strong and competitive position, favoured by the building code and a well established production platform. However, a number of times in the recent years we have had the opportunity to do excursions into light-weight, industrially rationalized production systems, and always induced by even tighter budgets than concrete building is able to perform within. The following three projects are very different in terms of production system and architectural concept and the comparison between them might reveal some information about the relations between the systems and the concepts.

#### Kvistgård

The housing scheme Kvistgård, marketed under the slogan 'Better and Cheaper Housing', is a terraced-house typology arranged in 20 four-winged courtyards in a rural landscape but with easy access to public transportation. The program of

the competition, won in 2004, was focusing on housing types suitable for prefabrication. The client's vision was to create more value for money by controlling all parts of the building process with Toyota's concept of *lean production* as a model. Thus, the contractor considered himself to be a Brunellescian master-builder<sup>1</sup> - with a little help from the architect. The surplus value was shared with the customers in the form of extraordinarily competitive sales-prices.

The collaboration between the architects and the client's process managing staff, which was responsible for the constructive details, was exemplary. The architects were allowed, within the budget, the right to design and decide about all visible parts of the building – façade materials and details, windows and interior surfaces. As an example, the bamboo floor parquet and the dark impregnated heat-treated fir-board façade-cladding were introduced by the architects.

It is worth noticing, that the production drawings were not made by the architects but by the process engineers on the basis of the architect's sketches. They were not even accessible for the architects as the client self-consciously protected them as 'possibly patentable industrial secrets'. How ominous this deprivation of the architect's right to control the structural details might seem, it had in this case no visible influence on the architecture. Architects are still needed to add the value of significant identity to the commodity of housing.

Kvistgård is an example of prefabrication in a relatively open production system, consisting of wooden-frame slab-elements for walls and roof. The elements are stacked on trucks, transported and assembled on site. It is a model of semi-prefabrication, as the on-site assembly demands a longer building period in comparison with volume-elements. The production of elements took place at mounting boards in an assembly hall about 150 km from the site. The prefab, light-weight bathrooms were fabricated in Italy. Even though the production system allows a high degree of variation, the elements are kept geometrically uniform primarily for economical reason but also for architectural; the design of the scheme presupposes the repetitive structure of mass production and the architectural motive nurtures by the aesthetic of the generic container-like volume. Nevertheless, the concept offers a large variety of housing types, based on combinations between a pair of basic volumes at the ground floor and additional volumes at the first floor. The purchasers configure the housing units themselves according to a set of variations. It is possible to add build-on elements and change positions of interior dividing walls.

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1: Kieran, S., Timberlake, J. *Refabricating Architecture*, McGrawHill, New York 2004 p. 26-29

Similarly, the terrain is prepared as flat terraces which make the foundation and the on-site assembly less complicated. No special elements are needed in order to serve jumps in the building volume. The levelled building plateaus demand a considerable adjustment of the terrain, but again this facilitating of the building system is also an important architectural concept; flat, square courtyards gently rotating within an undulating green landscape.

The first 6 courtyards with 54 units in total are now successfully completed. However, the process did not work out according to the carefully planned schedule. Firstly, the levelling of the terrain demanded more gravel for landfill than calculated, and the consistency of the ground on the site became a logistic complication when unusually heavy rainfalls set in. Secondly, the rain damaged the elements stored at the site together with the half assembled buildings which were not properly covered. After the completion of the first 5 courtyards, mold started to grow inside the elements. This was luckily detected before the new owners had moved in. The client decided to save his reputation and demolished 42 completed housing units which caused a loss of 50 mio. Dkr (approx. 10 mio USD). Thus, the buildings ended up being built twice!

The case witnesses about the hardness of trying to develop new methods in the building industry. Even though the design did not imply any attempt to challenge the building system whatsoever, it was not possible to harvest initially the full gains from the logistic improvements. Partly because of the lack of routine and partly for 'traditional' reasons such as unfortunate and unforeseeable conditions, in this case the rain and the muddy ground. Like most other present housing projects, the building of additional courtyards schemes has been stopped due to the deep crisis of the housing market. This is obviously one of the simple explanations of the slow evolution in the building industry compared to the vehicle industry: Every investment in facilities for mass production is soon met by a periodic downturn of the housing market. The demand is highly unstable over time and the financial risks of experiments are considerable.

The Kvistgård-concept is based upon a somewhat premature kind of prefabrication system which needs further development especially regarding the on-site logistics and a lot of support from the architectural concepts in order to be profitable. Still, it represents an attempt to take a step towards a new practice of mass production. The future potentials of the system include more complex geometry as well as a higher degree of variation.

#### **Bolig+**

Bolig+ project was a competition projects for 60 apartments in a 6-10 storey housing block in Aalborg which aimed at energy-neutrality; the building was

supposed to be self-supplying with energy for operation by means of passive and active strategies. All though renewables like wind-turbines and solar-cells were involved, our proposal focused on passive strategies: Insulation, heat-recovering and energy-storing capacity. The proposal was not linked to a specific building system but suggested a structural system of solid wood-slabs as a replacement for the, in Denmark almost inescapable, concrete slab-system. As such, the proposal was relatively openly articulated in relation to the production system.

When it gets interesting in an industrialisation context, is it because we put a strong focus on maintaining intact the energy capital embedded in the building materials by regarding the entire lifecycle of the building. When the consumption of operational energy become extremely low, due to passive strategies, the material energy becomes proportionally the most important CO<sub>2</sub>-factor. Thus, a long lifetime of the building and its materials are crucial in a resource-saving perspective.

The principles used were, firstly, a high degree of general usability which made functional conversions easy and, secondly, a hierarchical assembly structure, which allowed disassembly for purposes of maintenance and upgrade, change of identity, or installation of new technical facilities. As an example, the façade consists of multiple separated layers with individual, technical functions: Structure, wall-filling, insulation, rain membrane, and protection screen providing a sheltered zone in the windy local climate.

In order to secure the highest possible transformation capacity of the building, we had to carefully define every attachment in terms of its technical ability to be detached without material damage. To document the disassembly potential, the building parts were arranged into a diagram within which the most important rule is that the lines signifying the attachments of the building parts to each other must never cross. A hierarchical structure is crucial. This is impossible within the Danish traditional concrete regime in which all joints are cast. Disassembling methodology implies dry and mechanical connections rather than wet and chemical, and the mechanical should all be reversible; screws and bolts are used instead of nails, if possible without penetrating the material etc. The green colour-code shows the degree of recycling potential.

The important point is, that when mapping the building parts for the disassembly documentation, a diagram for a possible distributed assembling process are simultaneously being produced. The disassembly hierarchy becomes a tool for distinguishing independent elements which can be individually optimized, and it is organized in exactly the same way as KieranTimberlake's diagram for modular

production<sup>2</sup>. Many of the groups of elements are suitable for sub-delivery to be assembled on site as smaller or larger 'chunks'. Of course this happens already – typically with prefabricated bathrooms or curtain-wall facades, but the principle might be taken much further. In this way there seems to be an emerging potential for industrialisation as a kind of side-effect from designing for disassembly and recyclability of building materials.

The profits of the industrialisation potential will probably also be needed in order to finance the slightly increased expenses imposed by many of the resource-saving systems. This industrial evolution can be pushed forward by regulations: If certain qualities are demanded through the building code, such as airtight joints or easy disassembly for recyclability purposes, these can in the long run only be obtained competitively within an industrialised regime of production. If reuse or lifetime responsibility for building materials becomes statutory, this might stimulate an industrial evolution.

Unfortunately, we did not win the Bolig+ competition but it served as a pilot project for the next project – which we won.

#### Almen+

We made the Almen+ proposal in close collaboration with a supplier of prefabricated room-sized wooden-frame elements. The project included 240 social housing units, mostly terraced houses in two to three storeys. The program demanded a maximal operational energy-consumption of 25 kWh/m<sup>2</sup>/year. Furthermore was the buildings demanded to be without need of exterior maintenance for a period of 30 years. A low-key everyday-architecture was wanted and, accordingly, the budget was extremely low. The client, a cooperative housing society, was aware of the need for industrialization to solve this task and only teams with contractors who had capacity for prefabrication could prequalify for the competition.

The overall solution is a box-like volume containing all necessary service: access, installations, kitchen and bathroom. This basic element is combined with one, two or three generic box-elements without any dividing walls as the occupants are supposed to provide those themselves according to their individual needs. Like the previous case, the rooms are generally usable and can be merged in pairs into larger spatial volumes. The sizes of the modules are kept homogeneous to improve the rationality of the fabrication process as well as a low price. All openings for windows are alike but they can be filled out in various ways: With windows, doors or covered up as a part of the façade.

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<sup>2</sup> Op.cit. p. 86

In order to increase the lifetime of the façade the roof-hang was reinvented, not in search of a vernacular or pre-modernism atmosphere but simply to protect the façade from rain. The roof-hang generates a spatial zone along the façade which is emphasized by adding a wooden terrace that gives level-less access to the entrances of the housing units.

The cladding of the façade is horizontally divided in self supporting boards of various materials. The boards can be dismantled when assembling the box-elements and for maintenance. The attachments are made with adjustable consoles to which the boards are tightened without penetration. If, for instance, a board of cement-fiber is used, it can be dismantled, flipped and remounted. The procedure can be used for both sides of the board and thus increase the lifetime of the board. Furthermore, the horizontal division serves to hide the joints between the box-elements.

Again, the manufacturing process might easily be distributed to a number of sub-deliveries. The façade, with its system for rapid mounting and dismantling, would be suitable for a sub-delivery with a specialized production capacity. However, in the actual case the contractor calculates with a turnaround including as many as possible parts of the building which will probably result in a rather low-tech detailing. As long as the architects are able to provide robust, well-functioning low-tech solutions there is neither a technical, nor a financial motivation to involve specialized sub-deliveries.

## Conclusion

The learning from the three cases can be summarized as follows:

### 1. The flexible interface

Since the tectonic articulation can take place on several scales, the manufacturing system might not be compliant with the architectural motives. An architectural motive might 'find' a matching production system within a number of solutions available (like in the Kvistgård project) - or the other way around: a well-defined system might provide a relatively flexible media for multiple architectural configurations (like in the Almen+ project).

While the architectural concept of Kvistgård pretended to exhibit an industrialized building system that did not become the actual solution, the Almen+ project completely dismisses the box-element as a narrative element although the motive is exceedingly available from the system's part. Instead there is, within the individual building parts, a small-scale tectonic articulation, motivated by the lifecycle perspective. There is a dominant scale beyond the main element, since the building system is configured for providing traditionally

scaled housing blocks, motivated by the tight budget and the low-energy standard.

This indicates that architectural concepts and industrial building systems do not need to be generated symmetrically in an integrated process although this might be the case (like in the Bolig+ project). They can be generated in separate processes and the interface between them is negotiated dialectically through the design process. Industrial architecture does not need to be a function of the production system as less as production systems need to be a function of the architectural concepts. Thus, the interface might be defined as a field, open for possible tectonic articulation in terms of elements, joints, fixations, scale etc. - an architectural solution space between concepts and systems.

## 2. The potential of disassembly

On the basis of an agenda focusing on reusability, the employment of disassembly strategies will be needed in a future industrial practise. As seen in the Bolig+ project, the implementation of such strategies in terms of process analyses have the ability to make the potential for distributed production become visible and concrete. When making the assembly/disassembly-processes an architectural discipline, a platform is established for a new evolution in industrialized building practise which regards the production system as well as the architectural appearance. The potential of planning for disassembly draws, together with the highly negotiable interface between systems and concepts, an optimistic perspective for a future resource-saving architecture which will be able to:

1. Escape the monotony of first generation of industrialized building by being individually configurable and exchangeable at several levels
2. Maintain a recognizable local identity if wanted (a notion formerly known as 'context')
3. Impart a high capacity for transformation by the buildings produced, which will in turn lead to a longer life-time and alluring visual aesthetics as the building has aquired the ability to be changed and therefore will develop in an unpredictable and dynamic way over time.

## Literature:

Kieran, S., Timberlake, J. Refabricating Architecture, McGrawHill, New York 2004