TECHNOLOGICAL INNOVATION FOR INFORMAL URBAN CONTEXTS

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ABSTRACT

For a long time technological innovation in the building sector has been seen as strictly linked to industrial production and prefabrication. The great investment costs required for the start up of large-scale intervention make it difficult to spread similar approaches among less developed contexts. Some recent architecture designs, though still being realized with the help of performing and well developed enterprises, are characterized mainly by an innovative use of information. Not the employed machine or the transformed material constitutes the innovation but the way of assembling already available resources. Is it possible to use the weightlessness of information to bring virtuous impulses to realities that are cut off from technological innovation at the moment?

The present paper is based on an analysis of different recent projects that seem to be characterized by their use of information as a resource. A special focus is given to lightweight structures, as there seem to be opportunities for direct feedback effects within the design and building process due to an intrinsic physical behavior of such systems.

For single projects, specific aspects are investigated with a process of splitting up and remodeling through physical or digital models in order to dig out aspects that can be applied under different constellations in terms of local
skills and material resources. A range of technological approaches, each of them with its specific environmental value, emerges with this method and can be evaluated.

A special focus is given here on environmental transformations of informal contexts in developing countries.

Keywords: Building techniques, Technological innovation, Information

Introduction

If technology is seen as the current knowledge of how to use available resources in terms of matter, energy and information to fulfill needs, solve problems or produce desired goods, technological innovation is nothing else than the evolution in time of this concept and its adaptation to a change in needs of the contemporary society or its individuals. Knowledge, the central factor in this interpretation, is weightless. Technology includes methods, skills, processes or techniques, which as well don’t have any physical presence on their own. Yet, the notion of technology has a strong impact on the physical world.

A quick look at innovation in construction technology along the 20th century shows a shifting balance between light and heavy achievements. A main effort of modernist architecture was the rationalization of design decisions especially in the fields concerning function and comfort. In a first state, this technological innovation consisted in spreading newly achieved knowledge on issues such as the relation between building height and shading angle or the optimization of movements in a kitchen. This rationalism led to the idea that a straight reiteration of successful solutions could raise the general living conditions; think once and use the found results many times. It was only a little step from this idea of efficiency to the definition of standardization and further to industrialization. Modernist thinkers like Walter Gropius were convinced that the involvement of industrial production in design could make architecture more democratic and thus contribute to the definition of a better society.

Today it seems as this well-intentioned belief has been fulfilled in those societies that were already developing democratic structures of space occupation, solutions for mass housing and management of production processes while other realities were completely cut off from the potential benefits of this process. One explanation consists certainly in the fact that an industrial production of goods, building components included, requires heavy structures and high investments. Such productive systems do not generate
benefits for the local context they act on until their realization is not completed.

This risk linked to high investment requirements and badly distributed outcomes, joined with the rather high environmental impacts of industrial systems, is a clear limit of conventional technological innovation, especially referred to developing countries. It is in these contexts that the idea of mass production itself applied to housing shows its largest limits. Hardoy and Satterthwaite (1989) explain the modest successes of mass housing as a means of improvement of living conditions with the lack of social networks and the constrained possibility of adaptation to individual needs in the new estates. The building quality itself makes the rest. Uncritical reiteration of fixed concepts and their exportation to geographic contexts with completely different characters and requirements provides largely unsatisfactory environments in all continents with living standards that can even be lower than in self built shacks.

Nowadays, the enthusiasm on big scale and large numbers has been reassessed and individuality as or diversity are generally acknowledged as determinant factors for environmental quality. A recent phase of architectonic experimentation is dealing with the challenge of making spatial complexity feasible. Evidently, the main achievements related to buildings and structures with complex geometry are reached thanks to computer use in design and manufacturing. However, complex results can be achieved with intuitive approaches using locally available resources in terms of materials and skills. The use of information as a building resource seems to form the link between digital and intuitive or manual approaches. As shown later, the direct manipulation of matter, structural schemes and spatial solutions allows using a large amount of intrinsically contained information and can thus enhance the communication between different agents involved in the building or transformation process.

The following survey on design examples and experiments has been carried out with the aim of understanding in how far the focus of technological innovation in architecture has shifted from material and technique to information and in how far the weightlessness of this resource can have a positive impact on contexts that have been considered distant from technological innovation so far.

Complex vs. Simple

Among the following examples, some design approaches that are commonly considered at the cutting edge will be cited. Generally they are characterized by a high level of integration between geometric control, consciousness on
material constraints and manufacturing logics. Their requirements in terms of technical equipment are rather high. One of the central questions this ongoing research wants to dig out is how much of the basic concepts and of the virtuous inputs contained in such advanced approaches is actually depending on what we call heavy production systems and how much can be considered weightless and thus transferable to other contexts.

The reference to contexts with less performing productive systems makes the dichotomy between the words complex and simple become a common thread for the analyzed cases. If on one hand complex contexts stimulate complex architectonic answers, on the other, the lack of an advanced technological structure and the impossibility of wasting resources in most parts of the world make it necessary to compensate with concepts such as appropriateness and simplicity. The following examples show that this is not only a constrain but can have useful catalyst effects.

The survey is based mainly on analyses of design experimentations by well known architects and is integrated with own experiments on specific details. Using the mentioned dichotomy, the following categories can be defined:

• complex space – advanced manufacture
  Though based on what can be considered cutting edge technology and therefore inaccessible to most contexts, the possible transferability of basic features and underlying concepts to less performing contexts shall be understood.
• complex space – simplified manufacture
  The efforts made in order to make complex design approaches coherent with the manufacturing logic of conventional productive systems keep the complex questions under the control of designers and translate the information required for manufacture into simple and controllable operations.
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• complex space - simple material
Using simple material for complex spaces is mainly a geometrical problem. Tiling techniques allow to approximate double-curved surfaces with flat components of small dimension. Depending on the tasks of the generated surfaces, this can be obtained by tessellation with overlapping elements or with unitary elements and interstices.

- **complex space – light structure**
  In lightweight structures the whole involved matter has to collaborate to the structural performance; this means that such structures have an intrinsic complexity depending on the natural laws that define there behaviour and form. Besides saving resources, at certain scales, the use of lightweight structures can make design process more intuitive. Shapes and spaces are discovered rather than designed.

- **complex space – adaptable structure**
  Adaptable structures are seen here as a synthesis of the three previous categories. The mentioned intuitive character of certain lightweight structures applied to locally available materials and manufacturing procedures that are calibrated on the specific skills of local productive systems can generate spaces that are highly adaptable both in time and place.

**Complex Spaces and Simple Solutions – A Survey**

**Advanced Manufacture**

Architectures with double-curved surfaces or similar complex features may require a very high number of geometrically different components. The pneumatic cladding realized for Munich’s new soccer stadium (by Herzog & De Meuron) is made of 2816 individual rhomboid cushions (Menges 2006-1). For each of them a related cutting pattern for the ETFE-membrane had to be generated. The German firm Covertex who provided the cladding components decided to use advanced CAD/CAM techniques to control this process. Only in exceptional cases the tessellation of complex geometries succeeds with simple elements. Therefore some levels of diversity must necessarily be accepted during the manufacturing process. Two apparently very similar works like the glass dome realized for a covered swimming pool in southern Germany in 1989 (by Kohlmeier und Bechler with Schlaich Bergermann & Partner) and the Great Court roof for the British Museum (Foster & Partners with Buro Happold) show two basic approaches. What shall keep simple, the composing elements or the node? Schlaich decided for the first, developing a tessellation scheme with struts of constant length and flexible nodes. Foster and Happold opted for the second way keeping the node simple and accepting structural elements of several different geometries. In both cases, the glass
panels have been cut to measure in countless different shapes. It is evident that
the introduction of CNC devices such as laser cutters and automatic labelling
opens new possibilities for complex design solutions.
Besides producing the actual components with CAM technologies, these
methods can also be employed to manufacture support structures such as
CNC-milled moulds for fibre reinforced resin elements or similar
components. As shown later, such approaches can make otherwise too
complicated manufacturing processes viable. The use of advanced CAD/CAM
technologies can allow a conceptual shift from the obligation of rationalisation
in design to rationalisation in production.

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Simplified Manufacture

The use of numeric information that can be managed with modern computers
can make the actual manufacturing process easier or sometimes even possible.
One viable procedure consists in decomposing complex geometries into flat components in order to use planar sheet material. This passage from a three-dimensional spatial result to bi-dimensional elements makes the required equipment and the related working processes more feasible. A cutting table is certainly easier to handle than a 3D-milling machine, both manually or digitally controlled.

In the Son-O-House in the Netherlands (Fig. 1, left) NOX Architects show how a rigorous management of contained information can decompose complex concepts in rather simply manufacturable elements (Spuybroek 2004). All the parts the structure is made of are flat. The three-dimensional geometry is made of intersecting ribs cut out of 1cm thick stainless steel plates. An automatic nesting algorithm made all necessary elements fit into a small number of rectangular plates.

That such articulated geometries can be built with simple materials and techniques is proven by the Emergence and Design Group of the AA in London who realized a differentiated honeycomb structure made of digitally cut cardboard strips (Fig 1, right). The high degree of diversity that is achieved within the assembled structure has considerable performance consequences allowing the system to adapt “to specific structural, environmental and other forces not only within the overall system but locally [...]” as Achim Menges explaines (2006-2).

A didactic workshop involving children of a rural town in north-eastern Brazil gave us the possibility to test the realization of an object with double-curved surface without resorting to CAM devices or any other advanced manufacturing tool. The young participants succeeded in preparing sheets of recycled cardboard by following computer generated outlines and assembling them on place in order to form a blob-shaped bench (Fig.2). The form has been shaped with a solid-modelling tool (software: Maxon Cinema 4D) and
then transferred to a bi-dimensional vector graphic tool (software: Autocad) in order to generate real-scale prints of all 45 cuts that compose the object.

![Fig. 2: Computer generated and manually build cardboard bench.](image)

Small imprecisions due to the manual work done by non-trained operators could easily be absorbed by slightly deforming the cardboard without compromising the overall stability. More durable materials require a higher level of precision, that is difficult to achieve without digital production methods, as the realization of the same bench with medium density fibreboard showed.

As shown, the described approaches make the manufacturing process feasible by dealing consciously with information during the design phase. A strict division between the design and the manufacturing phase is required; this makes interaction during the construction process difficult and restrains related feedback effects.

**Simple Material**

The same can be said about techniques that use simple sheet material and adapt it on complex geometries. Achim Menges (2006-1) describes a manufacturing technique applied by the Dutch firm Exploform to prepare aluminium panels with double-curved geometry. Under the detonation of explosives under water, metal sheets are formed on a mould by means of the water pressure generated during the process. This technique is documented since the end of the 19th century and was used in the aerospace industry for the manufacture of special components with complex geometry, but only the use of CNC-milled polystyrene moulds for the geometrical control, make this process economically feasible. This provides a further example of how an appropriate use of information can make materials and techniques available that have not been considered formerly in the building industry.
In some cases, the three-dimensional deformation of sheet-material can be avoided by tiling; this requires a support structure that provides a geometrical reference. Overlapping tiles can provide a closed surface and the material they are made of can vary considerably as the recycled aluminium caps from sardine cans in the Uruguayan house of Figure 3b show. An alternative is the tessellation with standard elements and interstices that absorb tolerances and irregularities.

![Fig. 3: Tiled surfaces with high tech and low tech realization.](image)

**Lightweight Structure**

The rigorous application of complex structural schemes like gridshells or other double-curved surfaces can make the whole design of a building so light that rather cheap and easily available materials can be employed for the realization. Shigeru Ban’s cardboard tubes, a material that was not thought for the building sector, did a good job in the high-tech context of the Expo 2000 in Germany as well as in the refugee camps of Rwanda (Mc Quaid 2003). Employing less material is per se an environmental improvement as less embedded energy is spent for the realization of the building; this is even truer if the employed materials are renewable or recycled. Beyond this aspect, we found lightweight structures to be more suitable to welcome untrained persons on the building site and benefit from their contribution. The single building components can be lifted and manipulated directly by a few persons without difficult apparatus; in this way also security problems are much easier to manage than on conventional building sites (Pollak 2005).

At a first glance, the rules that characterize the structural and formal behaviour of shells or tensile structures may appear complicated but their intrinsic constraints provide an excellent communication basis for design approaches that metabolize various external inputs such as local conditions, end-users wishes etc.. In other words, they guide the form finding process.
Adaptable Structure

Very light constructions can have formal constraints that make their use less universal. Some structural schemes however, allow ambiguous interpretations without losing performance. Especially gridshells and lattice meshes can easily be extended or readapted in height and shape. Figure 4 shows a grid structure with hexagonal pattern that was derived from an experimental project made by Shigeru Ban together with students at the Rice University in Texas (Mc Quaid 2003). The lattice is built with wooden elements of equal dimension jointed with standard bolts; this makes its manufacture extremely simple. The structural stability is achieved experimentally lifting a small number of nodes and allowing the structural lattice to stabilize in the related shape. The final stiffness depends on the tightening tolerance of each single bolt in the triangular nodes and can be enhanced by introducing tending cables.

Fig. 4: Replicable pattern with adaptable structural behavior.

The introduction of complex and nonlinear issues in the architectonic discussion is challenging the concept of efficiency – a main goal of classical engineering – and is helping to recognize the value concepts like structural ambiguity and redundancy have for architectures that have to interact with a permanently mutating environment. It is not surprising that the classification of natural growing constructions, such as the radiolaria shells or certain foam structures described by Nachtigall (2003), with classical structural schemes is unsatisfactory.

The design of such structures requires a high level of integration between more analytical digital models and more intuitive physical models. All the findings must constantly be verified in both approaches. Moreover, a working environment that enhances random and feedback effects should be built up.
Conclusions

In a time in which it is not possible for single individuals to comprehend the knowledge of mankind as a whole, it is questionable (if not anachronistic) to keep the Vitruvian ideal of architect as a universal genius alive. Processes of environmental transformation are constantly ongoing with or without architects. Understanding more about these processes and about the technological means we have to interact with them makes it possible to take advantage from the already invested energies and base implementation approaches on local resources and available skills.

The activation of stronger contacts between local decision makers and end users on one hand and practitioners and volunteers from abroad on the other, can accelerate the emergence of viable solutions and their spread within specific contexts and among different realities of our world. Digital communication and face-to-face communication must be integrated in order to make maximum use of possible random and feedback effects.

The application of modeling methods, especially when digital and physical models are integrated, widen the range of possible design options and make the use of available but formerly not considered solutions possible. Employed materials and applied techniques can be simple; nonetheless complex spatial results can be achieved.

Image Credits

Fig. 1 left: NOX architects | Fig. 1 right: Emergence and Design Group AA | Fig. 3a: Mike Reid | Fig. 3b: Francesco Jacques-Dias | Fig. 3c: Ric Court | Fig. 4 right: Orlando Giglio

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References


