Industrialized Building Systems: Reproduction before Automation and Robotics

Roger-Bruno RICHARD, Architect and Professor

École d'architecture, Université de Montréal
C.P. 6128, succursale Centre-ville, Montréal (Québec) H3C 3J7 Canada
roger.richard@umontreal.ca

ABSTRACT: Industrialization is the aggregation of a large market to divide into infinitesimal fractions the investment in a technology capable of simplifying the production of complex goods and therefore reducing the costs. Simplification is the goal. Whenever the first four degrees of Industrialization, Prefabrication / Mechanization / Automation / Robotics, transfer the tasks from craftsmen to machines, they merely replace people with machines and duplicate the traditional processes (it is normal: new technologies always go by the traditional patterns first). Things are different with the fifth degree, Reproduction. Reproduction implies innovative processes capable of short-cutting the long sequential operations of craftsmanship nature – i.e. capable of categorically simplifying the production, as notably illustrated by the analogy of Printing / the Printed-Circuit / the Printed Plumbing Core. Using performance criteria, in order to avoid a captive image from the past, one can select promising options through the "Technology Matrix" (where processes interact with materials) and thereafter generate building system aiming at Reproduction.

KEYWORDS: Industrialization, Reproduction, Performance criteria, Technology matrix, Process-Product Interaction.

1. INDUSTRIALIZATION

Even if we live in the post-industrial era, where any product done in a craftsmanship fashion is bound to be luxury, there is still a lot of craftsmanship in the building industry today and the old saying is still true: if a car was produced the way buildings are delivered, very few people would be able to own one; if an electronic calculator was produced the way buildings are delivered, it would cost a fortune.

The advantages of industrialization and post-industrialization are based on quantity: to justify with an important market the investment in a technology capable in return of simplifying the production of complex goods. That is the very nature of industrialization: a large quantity of units will divide the investment into small (eventually infinitesimal) fractions, thereby reducing the production costs of a single unit down to marginal amounts and making (if the economy is transferred to the pricing) the product available to a large audience.

For instance, if you build a chair for yourself, you will buy some wood, glue, paint and, using hand tools, you will probably devote some 10 to 15 hours to do it. If you foresee a large market of 50,000 chairs, then a more sophisticated process will have to be considered, perhaps plastic injection: the mould itself costs a lot, over 50,000$, but it will produce plastic chairs at the rate of one per five minutes: that is one dollar per chair plus material; plus the fee to the manufacturer that has invested in the injection machine hosting your mould.

Therefore, the critical investment in a more productive process, although costly at the outset, is generating a benefit progressing with the number of units produced, once the break-even point is reached. Of course, the injected plastic chair presents a completely different design, visually and aesthetically; but, if the Performance Criteria are governing and if they are clearly spelled out, it can be as solid, as comfortable and as beautiful in its own way.

2. DEGREES OF INDUSTRIALIZATION

Five degrees of industrialization are usually recognized. The first four are Prefabrication, Mechanization, Automation and Robotics: they are usually duplicating the traditional processes, merely transferring the tasks from the craftsman to a very expensive machine.

Whereas the fifth, which we will call “Reproduction”, implies research and development of innovative processes truly capable of simplifying the production (Richard 2002).

2.1 Prefabrication

Pre – fabrication start with “pre” which means “before” and/or “elsewhere”. In the building industry, it generally implies building in a factory components or full modules very similar to the ones done on a traditional construction site, and in most cases using the same processes and the same materials.

Still, for the following reasons, prefabrication can very often bring the construction costs down, as much as 15% in some instances:

- Rationalization of the tasks along a production line;
- Specialized tooling and handling equipment;
- Semi-skilled labour;
- Climatic protection;
- Better quality control.
- Bulk purchasing of raw material due to the single delivery point.

2.2 Mechanization

Relying on mechanized tooling to ease the work of the labour (pneumatic harmer, power tools, etc…). Usually the case whenever there is prefabrication.

2.3 Automation

The tooling is taking over the tasks performed by labour; the foreman is still around, although the engineer and the programmer are the critical people involved. A study about Swedish wood-frame panels assembled by automation indicates an economy up to 27% compared with traditional construction methods.

2.4 Robotics

The same tooling is performing by itself diversified multiple tasks.

2.5 Reproduction

Reproduction is the introduction of an innovative technology capable of simplifying the production of complex goods, of short-cutting long sequential operations. Therefore achieving more substantial economies than mechanizing, automating or robotizing around the traditional construction methods, as it is the case with the automation of wood-frame panels production for instance.

Of course, Reproduction is not necessarily available as a downright option: it is often present together with some of the other degrees industrialization.

3. THE “PRINTING” ANALOGICAL CHAIN

The analogical chain triggered by the Printing process is quite prolific and can illustrate the full meaning of Reproduction: Printing does replace in two movements the long sequential activities of the script, the Printed Circuit produce in two operations all the connections between the components of an electronic device, the Integrated Circuit replace the components with an additional operation, and the Printed Plumbing Core is providing in two operations all the conduits required for the kitchen & bathroom.

3.1 Printing

Instead of hiring a staff of copyists to rewrite “n” copies of the Bible, Gutenberg carved a large amount of wood types. He invested a lot of time in doing that, more time than to rewrite one, two, three even four copies of the Bible. But when the types were available, Gutenberg assembled them to produce a full page, inked them and then made contact with “n” sheets of papers to produce “n” copies of the page. Reassembling the types to produce the other pages, he was thereafter able to produce “n” copies of the Bible a lot faster than the copyists.

Gutenberg has therefore justified quantitatively a process capable of simplifying the production of a complex product. The rotary press that came later went even further by replacing the on-off operations by a continuous production; a knife separates the pages at the end.

3.2 The Printed Circuit

If the electronics industry had replaced by machines the labour welding components to wires in the old wired circuit, they would have moved to Mechanization, Automation or even Robotics. But a “new Gutenberg” had the idea of replacing the time consuming multiple hand-made welding by a simple and almost instant operation: silk-screening a negative of the circuit paths on a plate, and generating a positive conducting network by electro-deposition (see figure 1). The “Printed Circuit” has a completely different configuration than the wired circuit, either man-made or even automated, but it meets the same performance criteria much better (less space, high precision and more solidity). And the product can be modified just by changing the pattern of the silk-screening (Richard 1972).

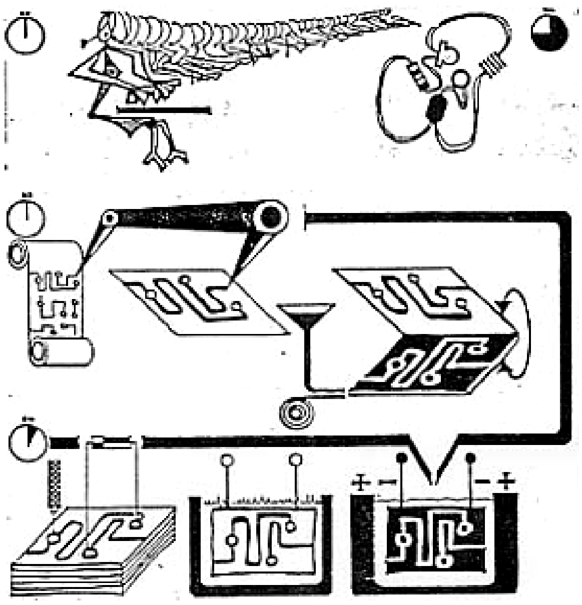

Figure 1. Wired circuit and Printed Circuits

3.3 The Integrated Circuit

The Integrated Circuit went one grand step further: printing the components themselves on the circuit. And this explains the multiple low cost electronic devices available on the market today.

3.4 The Printed Plumbing Core

Let us move from the printed circuit to residential plumbing; as plumbing is also a network connecting components.
Traditionally, the pipes are cut to pieces, attached to couplings / gaskets and connected on the site between themselves and to the fixtures one after another. Years ago, some manufacturers did offer a "Prefabricated Plumbing Core", but the market did not respond.

Heinz Wager (Wager) and others (Biondo & Rognoni) came with a bright proposals, directly related to Reproduction: an innovative “Printed Plumbing Core” formed by two complementary (“left hand – right hand”) pre-moulded sheets (vacuum formed plastic or deep-drawn aluminium) where each sheet has the conducts embossed as half circles (see figure 2).

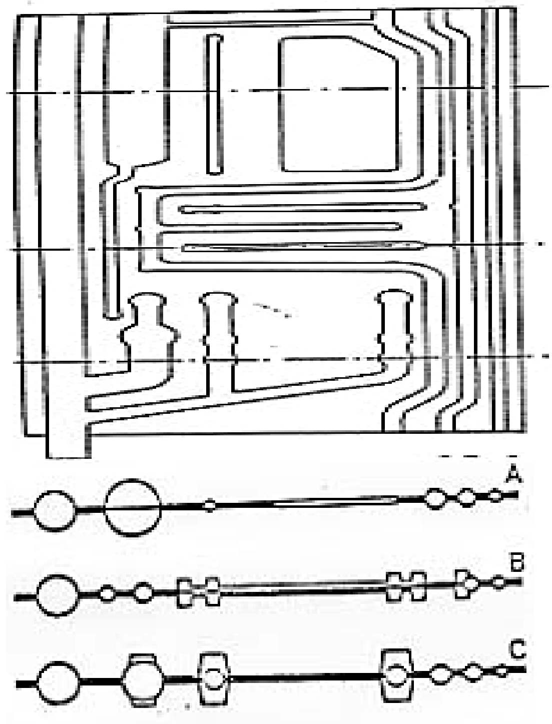

Figure 2. The Printed Plumbing Core

An adhesive applied with a roller covers only the flat parts: when the two sheets are bonded face-to-face, the flat parts become unified and the half circles become open conduits.

4.THE TECHNOLOGY MATRIX

Based on those analogies, we can define as the key to industrialization the development of an innovative process capable of simplifying the answer to a complex set of requirements (Richard 2002) i.e. reaching the Reproduction level.
Once the user's needs are spelled out and the sub-systems identified, the performance criteria are the facilitators when the designer is searching for a new technology: by aiming at the performance rather than the form, the criteria will permit a more open and creative selection of technologies (see figure 3).

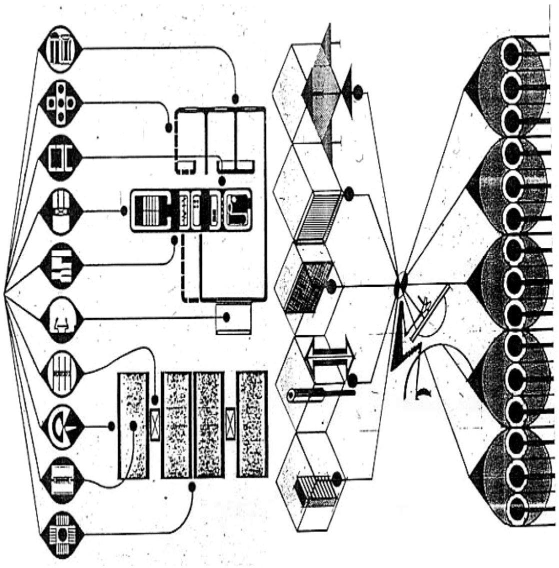

Figure 3. Selection of technologies

That approach means, quite appropriately, a new image of the product, closely related to the process as it was the case with the injected plastic chair and the printed circuit. The results can lead to a production economy up to 50%.

Like the painter who can select form the basic colours spread on the palette, the designer can start with a Matrix of technologies, where processes interact with materials (see figure 4).

		COATING	OVERLAY	CALENDERING	ADHESIVE	LAMINATION	SPRAYING	DRILLING	ELECTRO-DEPOSITION	FOLDING	ROLLING	WINDING	EXTRUSION	PRESSING	DEEP-DRAWING	VACUUM	CASTING	MOULDING	CENTRIFUGATION	INJECTION	Other
Metal:	STEEL																				
	ALUMINIUM														9						
	OTHER																				
Wood:	SOLID																				
	ENGINEERED					1								1							
	COMPOSITE				2	9															
Concrete:	REGULAR												4				1,6			6	
	LIGHTWEIGHT						8							5			3	3,7			
	STABILIZED COMPOUND						8														
Plastics:	TH. FORMING															9					
	TH. SETTING																		9	9	
	COMPOSITE																				
Misc.:	GLASS																				
	PLASTER																				
	OTHER	9												9							

Figure 4. A Matrix of technologies

On such a Matrix, one can locate, for instance:

- the two interactions that led to the PRINTED CIRCUIT: coating (silk-screening) ink (misc.) over lead (other metals) electrodeposited on a plate;
- the two interactions that led to the PLUMBING CORE: deep-drawing an aluminium sheet (or vacuum-forming a resin sheet) and covering with adhesive the flat parts.

Using the Matrix in a similar manner, with the performance criteria as a guideline, a creative designer can combine various processes and materials to generate different technologies for different components or sub-systems of the building industry. The following components are already- on-the-market examples of the type of results that approach can generate:

- HOLLOW CORE SLAB: Extrusion of concrete along a line of pre-stressed cables; rather than building (and dismantling) formwork, installing the reinforcing, delivering and pouring the concrete on the site; the cheapest way to produce a structural slab.

- MULTIFUNCTIONAL LIGHTWEIGH CONCRETE PANELS: Casting or pressing or moulding a monolithic panel integrating thermal & acoustical insulation, air & vapour barrier, structural or bracing capacity, cladding and texture as well as the jointing geometry; then spraying a coating to achieve waterproofing; rather than putting up a stud wall with insulating blankets, air and vapour barrier membranes, exterior sheeting and cladding as well as interior finish. Similar to the Misawa Homes' Pre-cast Autoclave Lightweight Concrete ("PALC").

- SINGLE SHELL BATHROOM & WATER-CLOSET BASE: incorporating all the components (bath/wash-basin/shower/even toilet bowl) and facilitating the maintenance (round corners and no tile joints) in composite, through deep-drawing, covering or even centrifugation; rather than laying & grouting tiles on a waterproof backing. Or producing the same shell in metal through electro-deposition; similar to Buckminster Fuller's bathroom proposal.

5. THE PRINTED SERVICE-CORE

By doing to the Printed Plumbing Wall what the Integrated Circuit did to the Printed Circuit i.e. "printing the components themselves", we can mould or cast in two complementary parts, using lightweight concrete, the box that groups the kitchen/W.C./laundry/mechanical-electrical shaft/ stairs/etc. and integrating at the factory all the plumbing and most of the wiring; rather than installing the elements one by one at the site or prefabricating the plumbing core. We could prospectively produce the full "serving" unit of the building in a single module that can be called the "Printed Service Core" (see figure 5).

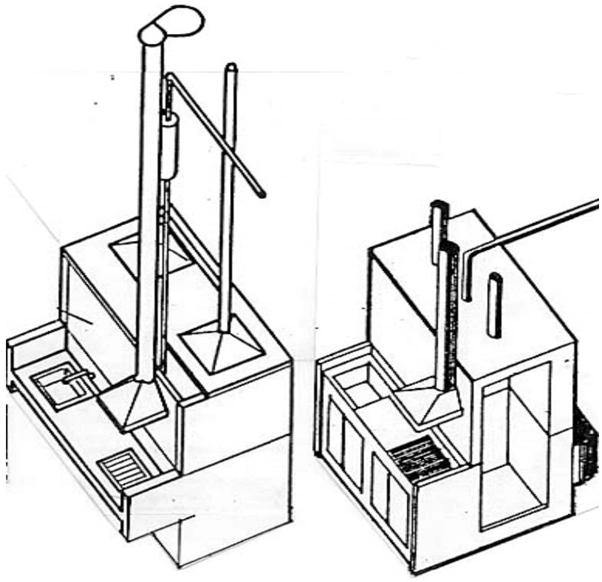

Figure 5. The Printed Service-Core

6. THE PRINTED LOAD-BEARINGSERVICE-CORE

The next step is to make it load-bearing as it could, out of its full 3D module features, support totally or partially the floor of the open spaces around, like the vertical circulation core of an office building. The "Printed Load-Bearing Service Core" will simplify the production of the "serving" area(s) and therefore simplify the production of the complex part of the building = reducing the construction cost.

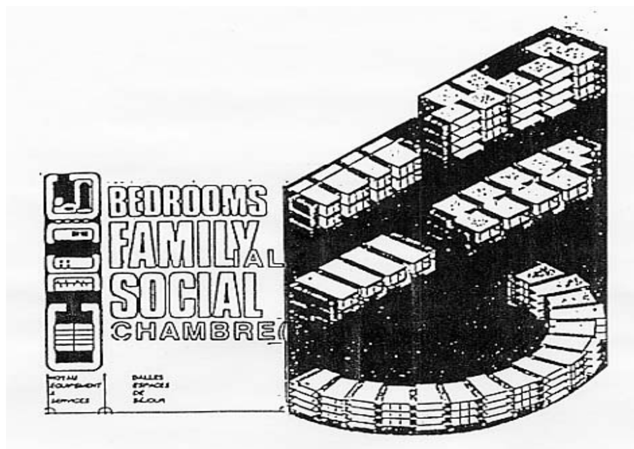

Figure 6. The Printed Load-Bearing Service-Core

The "Printed Load-Bearing Service Core" can reduce the costs due to its Reproduction level manufacturing process, but it also simplifies the site assembly: being a 3D module, it is self supporting and could be figured to structurally support the slabs generating the “served” area (living room, dining room, bedrooms, etc.) , the exterior wall panels and the interior partitions. The job-site requirements are then limited to simple connections.

But, as it is the case with most process based innovations, the image of the product is not conform to the traditional patterns. The “Printed Load-Bearing Service Core” adds a geographical discipline to the planning process, which is not new with office building but very rare in residential building.

A new architectural language can be generated through that discipline if the architects can accept to bypass the freedom of locating the services wherever their concept dictate or the usual logic of grouping the services at the centre of the building.

7. CONCLUSION

There is more to do than was done and there is no limit to the possibilities of the Technology matrix or “palette”: innovation is more promising in the Matrix than in the Mechanization / Automation / Robotics of our traditional craftsmanship methods. Therefore the emerging technologies should be aiming at the simplification of production rather than replacing the human hands with machines: Reproduction rather than Automation or Robotics, and of course Mass Customization rather than Mass Production.

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