ELSEVIER

Automation in Construction 14 (2005) 442–451

AUTOMATION IN CONSTRUCTION

www.elsevier.com/locate/autcon

Industrialised building systems: reproduction before automation and robotics

Roger-Bruno Richard

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

Abstract

To deliver quality architecture to the vast majority of people, the building industry should move to full industrialization. Industrialization is basically the aggregation of a large market to divide into fractions the investment in strategies and technologies capable, in return, of simplifying the production and therefore reducing the costs. Simplification is the goal. Whereas the first four degrees of industrialization (i.e., prefabrication, mechanization, automation, robotics) remain at the level of duplicating the traditional construction processes, the fifth degree, reproduction, seeks innovative processes capable of short-cutting the repetitive linear operations of craftsmanship nature. A methodology can be extrapolated from the analogical model of printing (from the electronic printed circuit to the printed plumbing core). Adopting this methodology implies three steps: (i) generating the geometry of the product from the performance criteria; (ii) selecting a process that can simplify the materialisation; and (iii) designing the product accordingly. The load-bearing service core offers a relevant case study of that methodology: the space is distributed between the served and serving areas, the latter being concentrated into a value-added factory-made module capable of generating diversified building types.

Keywords: Industrialization; Reproduction; Served and serving spaces; Analogical model; Performance criteria; Building Systems; Process–product interaction; Load-bearing service core

1. Industrialising the building industry

Industrialization has demonstrated a high capacity to reduce the costs, improve the quality and get complex products available to the vast majority of people. It is the case for most products offered on the market today, including construction materials and components (roof trusses, prestressed concrete slabs, windows, curtain walls, etc.). But so far, industrialization is not really applied to the building as a whole. Yet, if a car was produced the way a building is delivered, very few people would be able to own one; if a computer was produced the way a building is delivered, it would cost a fortune.

2. Industrialization

Industrialization is based on quantity. An important market can justify the investment in strategies and

E-mail address: roger.richard@umontreal.ca.

0926-5805/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.autcon.2004.09.009

technologies capable, in return, of simplifying the production of complex goods. That is the very nature of industrialization: the production of a large quantity of units divides that investment into small (eventually infinitesimal) fractions, thereby reducing the fixed production costs of a single unit down to marginal amounts and getting the product available to a large audience.

For instance, producing a handicraft chair does not require an important investment in terms of materials and equipment, (wood, glue, paint and some hand tools); but between 20 to 25 h of labour have to be devoted to it, and at $20 per hour, the cost of the chair will be at least over $400. For a large market of 50,000 chairs, a more productive process will have to be considered, perhaps plastic injection: the mould represents an important investment, over $50,000, but it will produce chairs in a single operation at the rate of one per 3 min, that is one dollar per chair+material+1/20 of 1 h of labour. Of course, buying an injection machine is highly expensive, but alternative solutions, such as delegating the production to a subcontractor who operates an injection machine and who amortizes it through various projects, do permit this level of industrialization.

The injected plastic chair can therefore be produced faster and at a much reduced cost than the handicraft chair (and it can be as solid and comfortable). Although the plastic chair presents a completely different image—visually and aesthetically—it can project an interesting image provided the design is imaginative. The situation would have been different if the manufacturer had turned to automation or robotics to replace a craftsperson: the product would still have a handicraft look, but the cost of the tools would probably be more expensive as many operations would be required. Therefore, if a performing chair is the objective, the injection machine can deliver it at a very low cost; if the look of the traditional wood chair is requested, then automation can help but at a higher cost.

The critical investment in a more efficient process, although costly at the outset, can generate a benefit that increases with the number of units produced once the break-even point is reached. However, as explained in the previous example, the investment can be "shared" with others when the work is delegated to a subcontractor.

3. Degrees of industrialization

Five degrees of industrialization can be identified. The first four are prefabrication, mechanization, automation and robotics. They do require an important investment in production facilities, but very often, they duplicate the traditional processes, merely transferring the tasks from the craftsperson to the machine.

The fifth degree, which we will call "reproduction", implies research and development of innovative processes truly capable of simplifying the production [7].

3.1. Prefabrication

Prefabrication starts with "pre," which means "before" and/or "elsewhere." In the building industry, prefabrication generally implies building (in a factory) components or full modules very similar to the ones done on a traditional construction site, very often using the same processes and the same materials. For instance, most modular housing manufacturers are first building wood-framed panels quite similar to the ones done at the site even when they use automated devices.

Still, for the following reasons, prefabrication does bring the construction costs down as much as 15% when the plant is producing at full capacity (i.e., when mass production is obtained):

- climatic protection;
- rationalization of the tasks along a production line;
- specialized tooling and handling equipment;
- semiskilled labour;
- better quality control; and
- bulk purchasing of raw material due to the single delivery point.

3.2. Mechanization

Mechanization comes in whenever machinery is employed to ease the work of the labour (power tools, etc.). Usually, prefabrication will be accompanied by