AN INTRODUCTION TO OPEN BUILDING

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ABSTRACT

This paper aims to connect Open Building to Lean Construction. The concept of Open Building identifies the conflict between the inertia of the building and construction industry and a consumer demand in constant state of flux. It suggests distinguishing different levels of decision making, in order to decouple building parts with different life cycles, controlled by different parties, built by different trades. In order to decouple and yet coordinate, a set of rules for dimensioning, positioning and interfacing was developed. The paper concludes with examples of systems and product development, based on the principles of Open Building. It is an introduction to Open Building for a forum of Lean construction experts. Future discussions will show whether a synergy between the two concepts mentioned is worth exploring.

KEY WORDS

Open Building, Lean Construction, levels of decision making, positional and dimensional coordination.

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INTRODUCTION

The origins of the concept of Open Building is best captured by one of John Habraken's finest quotes: 'We should not to forecast what will happen, but try to make provisions for the unforeseen' (Habraken, 196I). In order to accommodate unknown future change, he suggested to introduce different levels of decision making in the building process: tissue, support and infill, respectively referring to the urban fabric, containing base buildings with their fit-outs.

The *raison d'être* of Open Building can also be expressed in terms of care, responsibility and technology.

People, who care about the environment they live in, will make it a better and safer place. Therefore the built environment must encourage people to take responsibility for their own territory. An environment that clearly distinguishes those spaces and parts of a building for which occupants should take responsibility, will address the user's needs to feel responsible. Therefore a building should be designed and built in such a way that both spaces and parts of the building can be clearly allocated to those parties and individuals that should take responsibility for them.

Buildings, which are designed and built with separate systems, can create conditions for responsibility and care. Therefore the subdivision of the building process needs to reflect the lines of decision making and the definition of responsibilities between the parties. This subdivision can then be translated into specifications for connections between building parts. This in turn creates buildings that can be modified and taken apart again (Cuperus, 1996).

It offers the basis for a well-structured building process with well-defined interfaces. It allows us, to at least partially transfer the construction process from building to manufacturing. It is the key to reducing waste by coordinating dimensions and positions in stead of improvising on site by cutting to size. Applying information instead of energy.

This is an important condition to re-use building parts, thus extending the lifetime of building parts, without the waste of dumping and recycling, coinciding with degradation and the use of energy.

Lean Construction is the building and construction equivalent of lean production, a manufacturing method that aims to reduce 'waste' in the broadest sense of the word.

'The first step in the process of Lean Production is to specify Value', and 'Value is created by the producer'. 'From the customer's standpoint this is why producers exist'. But: 'Value can only be defined by the ultimate customer'. (Womack e.a. 1996).

A superficial comparison of Open Building and Lean Construction suggest that they have much ground in common. They both originate from dissatisfaction with traditional second wave industrial production that was felt at approximately the same time. The principles of lean production were first adopted in the early sixties in Japanese car manufacturing. At the same time discontent with mass housing of the post war-housing boom in The Netherlands resulted in the introduction of different levels of decision making in the housing industry. The base building ('support') and fit-out ('infill') were treated as separate entities, with different life cycles, in order to build an environment that can respond to individual needs of the dweller. Open Building is a multi facetted concept, with technical, organizational and financial solutions for a built environment that can adapt to changing needs. It supports user participation, industrialization and restructuring of the building process. If change is the problem, a layered organization of the building process can provide at least a part of the solution. Positional and dimensional co-ordination of building parts and their interfaces are a tool and a condition for industrialization and probably a leaner construction process.

In order to gain a better understanding of the concept of Open Building relative to Lean Construction, the structuring of decision making and the importance of de-coupling yet coordinating is explained. Rules for dimensions and positions and interfaces of building parts were developed. The above is illustrated with two examples of product/ systems development.

LEVELS OF DECISION MAKING

If the notion of having to make provisions for an unknown future is the intriguing problem of Open Building, the concept of levels gives directions towards the solutions. Three levels of decision making are defined, being tissue, support and infill. They are separated, yet coordinated. The town fabric (tissue level) is of a higher level than the buildings, positioned within the town fabric. Buildings can be altered or replaced, while the town fabric remains the same. The buildings in turn can be divided in base building (support level) and fit-out (infill level).

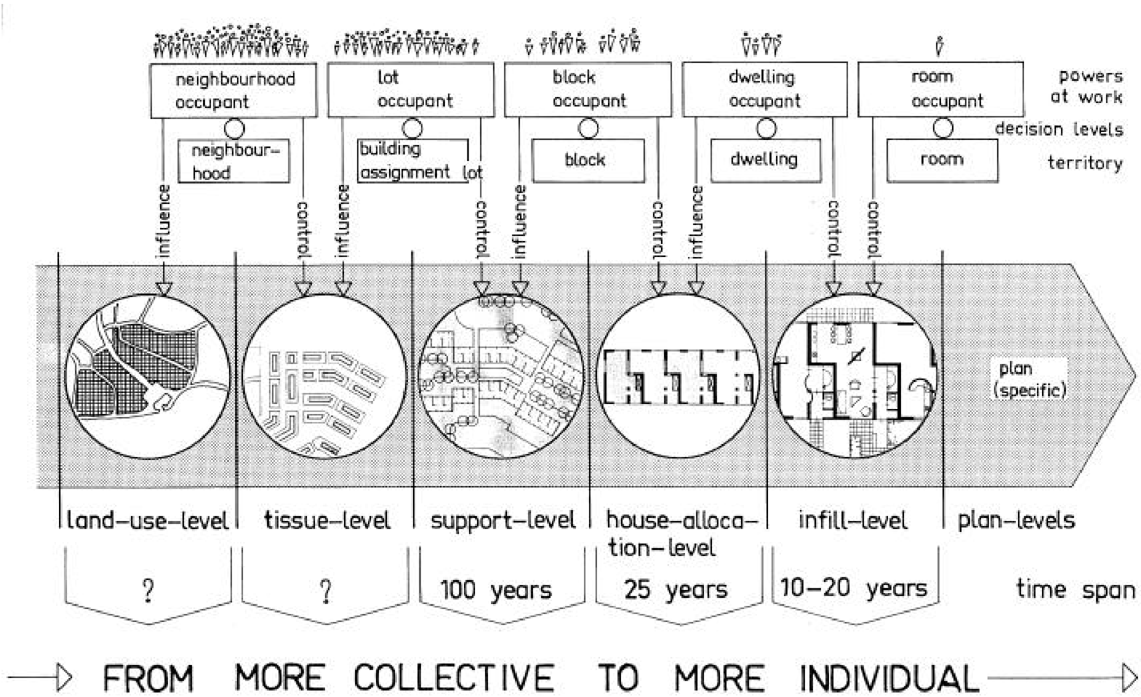

Figure 1: levels of decision making

The higher level (support) accommodates and limits the lower level (infill), which in turn determines its requirements towards the higher. On every level there is an 'ultimate customer': the consumer on the infill level, the housing corporation or developer on the support level, the municipality on the tissue level (Figure 1).

The levels of decision making always refer to decisions about building parts. They connect a decision making party to an object under construction or in transformation. The different levels of decision-making should be disconnected, yet coordinated. The higher level (support) accommodates and limits the lower level (infill), which in turn determines its requirements towards the higher. On every level there is an 'ultimate customer': the consumer on the infill level, the housing corporation or developer on the support level, the municipality on the tissue level.

In addition to the levels of decision-making, the building process is also subdivided along the lines of disciplines and different trades in the construction and building industry. This involves a different kind of coordination and belongs to the field of building management and contracting. Then there is the subdivision in technical subsystems, such as façade, roof, load bearing construction, inner partitioning, HVAC.

Another subdivision can be along the lines of financing, with a long term mortgage on the support and the infill financed with a personal loan. This opens new financing constructions such a rent-buy, with a long term lease on the support and a personally owned infill.

If building parts with a different life cycle or a different environmental impact need to be separated, new subdivisions will be introduced.

Any subdivision serves its own aim. A better understanding of these different subdivisions helps to synchronize their dividing lines, for a more efficient building process.

DIMENSION, POSITION AND INTERFACE

Rules for dimensions, position and interfaces of building parts is a prerequisite for Open Building. This paragraph describes the shift in emphasis from dimensional co-ordination in the seventies to regulating the interface of building parts in the nineties. The co-ordination of position remains equally important.

MODULAR CO-ORDINATION

The development of modular co-ordination in the Netherlands needs to be seen in a historical and a demographic perspective.

At the end of World War II the Netherlands had a population of 9.2 million in 1945, which was to increase to 9.5 million in 1947, 13 million in 1970 and to 15 million in 1990. The number of people per dwelling decreased from 4.3 in 1947, 2.54 in 1970 to 2.51 in 1990 (CBS, 1994,1995).

At the same time the country, like so many other countries was recovering from the physical, mental and economical damage of the World War II. A high volume of houses had to be built in economic lean times.

Coinciding with high activities in the building industry, new ideas about efficiency were introduced in industrial production. There was a strong belief that dimensional rules to manufacture modular parts of all kinds was the key to a better building production at reduced costs. This was reflected in NEN 5700, the first Dutch code on modular co-ordination, a two page document published in 1964, in accordance with international ISO codes on the same subject. This code defined the basic module of 10 cm (NNI, 1954). A direct relation was suggested between dimensional co-ordination and an increased efficiency of the building process and thus between standardization and industrialization (NNI, 1978).

Based on Habraken's book 'Support, an alternative to mass housing' (Habraken 1961) one and a half years later the SAR (foundation for Architectural Research) published SAR '65. This publication advocated industrialization of the house building process as a means to improve the quality of the built environment.

In the opinion of the SAR industrialization had shifted from a goal to a means. In order to create better conditions for industrialization the SAR suggested to introduce two production spheres in house building, being the support and infill construction. Support and infill constructions would be supplied by different industries. The introduction of two production spheres also introduced the need for a positional coordination. Based on the basic module of 10 cm a 'tartan-grid' of 10-20 cm was developed. The distinction between support and infill was a distinction between levels of decision making, having technical implications.

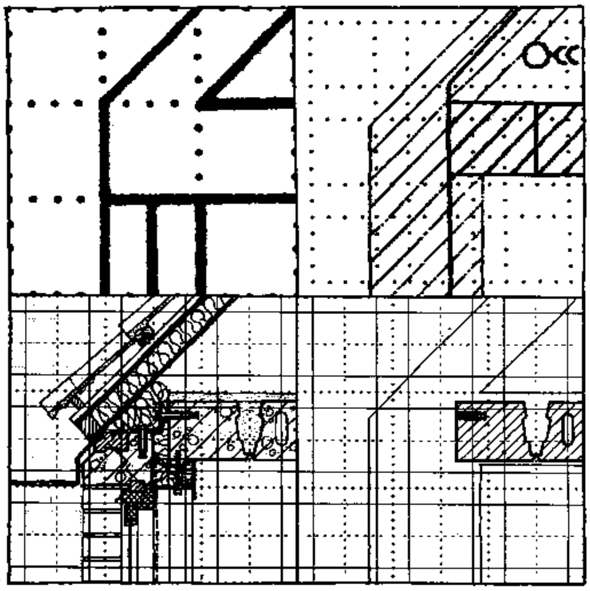

Figure 2: Design sequence of space plan, material plan, construction detail and product design according to the rules of modular co-ordination (NEN 2883).

The central point of industrialization by modular co-ordination had moved from standardization to communication and co-ordination (NNI, 1978). The SAR proposals materialized in an new code NEN 2880 issued in 1975, giving rules to position different 'element groups' on the tartan-grid (NNI, 1977).

NEN 2880 in turn was followed by the draft NEN 2883 in 1981, a modular co-ordination code specially made for dwellings. This was a very well considered and intelligent document, with detailed tartan-grids for very precise co-ordination of dimensions and positions of building parts (Figure 2). (NNI, 1981). This code has never successfully passed the testing period and in retrospect it can be said that its precision and therefore its relative complexity met too much opposition in the building industry to become effective. The general feeling was that a simplified code would make a better chance. NEN 6000 was published in 1986 to replace NEN 2880 and NEN 2883 (NNI, 1986).

BUILDING NODE

Changes in the building process have resulted in an interesting change in thinking about modular co-ordination. The emphasis has shifted from positional and dimensional co-ordination to 'connectional' co-ordination.

The building industry is changing form building on site using basic building materials to an assembly process: complete and complex building parts are made in the factory and assembled on the site into a building. The gradual shift from building to assembling has resulted in a more efficient building process, the building time has reduced and the quality of the parts has increased. However, the overall quality of the building is not only determined by the quality of its consisting parts, but also by the way they were put together. New problems emerged: two prefabricated parts only fit on the building site if their dimensions and connections are well coordinated. If due to a lack of coordination the parts don't fit it is very hard to make them fit and still maintain the same quality level. The industrialized manufacturing processes of building parts have allowed us to get a wider variety of building parts, potentially translating in a unique built environment. In practice we see a continuation of monotonous buildings.

If the building industry could agree on connection conditions for their building parts, they would have more freedom to develop new products, fitting within the agreed constraints of dimension and connection. The Building Node Research Project aims at developing rules to regulate the connection of building parts as a basis for systematic product development. Two elements of the project need a further explanation (Kapteijns, e.a., 1993).

Formal Description

Existing classifications of building materials and building parts did not satisfy the purpose of this research project. They all served a different purpose, either to organize product information in a library or to organize the brief of the building. A new classification named the formal description needed to be developed in order to give every building part in a building a unique label. Its looks were very much determined to be used for computer processing. The label includes two codes, being the abstract description and the product description. The abstract description is a code giving information about the position of the product in the building. The product description is a code giving material/product characteristics in terms of adaptability on the building site. A distinction is made between Material 'M', Shape 'V' and Part 'O'.

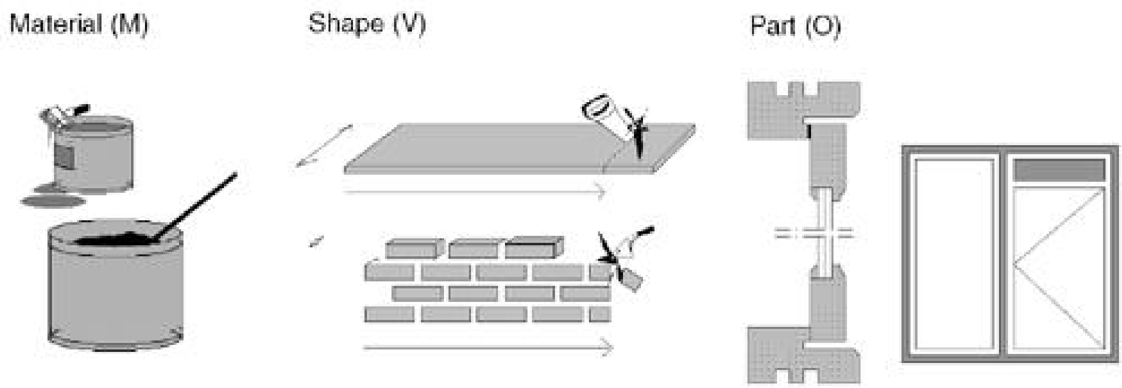

Figure 3: Material (M), Shape (V) and Part (O)

An element labeled 'M' is molded on site. (For example: in situ poured concrete and paint). It is made and delivered in bulk and it has a 'self-fitting' quality.

An element labeled 'V' (shape) has basic predefined dimensions as it is delivered at the site. (For example: bricks, timber, sheet and panel material). It is made in large quantities, independent of its adoption. It can easily be made to fit on the site, by hacking, sawing or cutting.

An element labeled 'O' (part) is prefabricated and cannot be adapted on the site without damaging it. (For example: a pre-cast concrete panel and an aluminum window frame) (Figure 3).

Dependencies

This chapter looks into the relationships and dependencies between building parts. A computer application was developed to illustrate the point. The program can be fed with pairs of building parts, having a dependency relationship. (For example: a door has a dependency relationship with its doorframe). The program then visualizes the relationships showing a dependency diagram. This diagram allows us to recognize clusters of building parts connected to the rest of the diagram with only one or two lines. A small number of connections to a (complex) cluster indicate good conditions for prefabrication. If by a design effort the number of connections can be reduced, the co-ordination problem will be reduced as well (Figure 4).

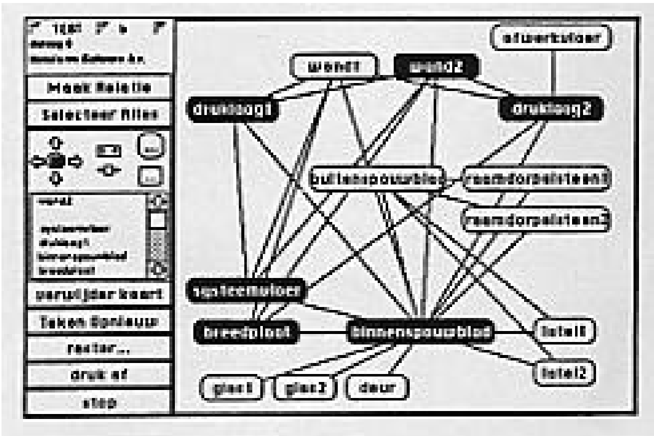

Figure 4: Dependency diagram

SYSTEMS AND SUB-SYSTEMS

If we look at the building a system, subsystems such as roof, façade and fit-out can be recognized. At the same time the building process is subdivided along the lines of disciplines. In order to de-couple, yet co-ordinate the levels mentioned, sub-systems and disciplines, dimensions, positions and interfaces of building parts need to be defined. This is illustrated with two examples of product development of a fit-out subsystem and a roof as a subsystem.

MATURA

One of these systems needs to be mentioned. This is the Matura infill system, developed by Habraken en Van Randen, who have both played an important role in the history of Open Building. Minimizing the interfaces was one of the main aims of the product developers: ‘All technical subsystems, containing conduits ands cables were redistributed in space to assure minimum interfaces among them and maximum freedom for development. Walls were freed of conduits and cables for the same reason. Two new components were introduced to achieve such freedom for deployment and to assure rapid installation. One is the ‘Matrix tile’ and rests on the floor. The other is an L-shaped baseboard channel, which rests on the matrix tile. The two together hold all cables and conduits (…)’ (Figure 5).

Four other principles were:

- to focus on technical systems;
- to use ‘off-the-shelf’ subsystems;
- to make the single dwelling an autonomous unit of on-site production;
  rigorously systemize the positioning of components. (Habraken, 1989) .

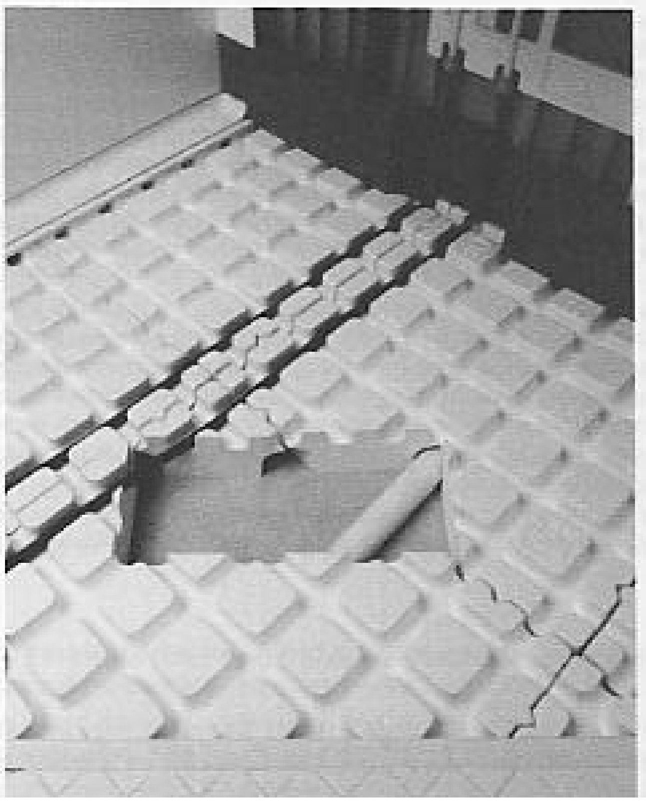

Figure 5: Matura infill system

PASSE- PARTOUT

‘This new Total Roof caters for the individual needs of the consumer as well as the architectural tastes, by using a systems approach that has resulted in a roof frame and a complimentary set of accessories, fitting in a LEGO like fashion by the adoption of a dedicated set of position and dimension rules, called modular co-ordination.’

The LEGO building blocks and the modern kitchen industries have served as inspiring products and processes when this predefinition project was initiated in 1996. The first prototype was presented in December 1997 and a total project was completed in July 1998.

The total roof should not be material dependent. The system should allow a free choice of materials: timber, steel, concrete or new materials for the structural parts, accommodating a free choice of accessories. In order to establish a long lasting relationship with the consumer the total roof need elements that are hard to copy and easy to protect by patents. The only way to satisfy consumer demand is to introduce the roof as a system.

Combined with side panels that hinge at the top and in turn supporting panels that span sideways, a structurally rigid frame work is made to accommodate user selected infills, accessories and finishings (Figure 6).

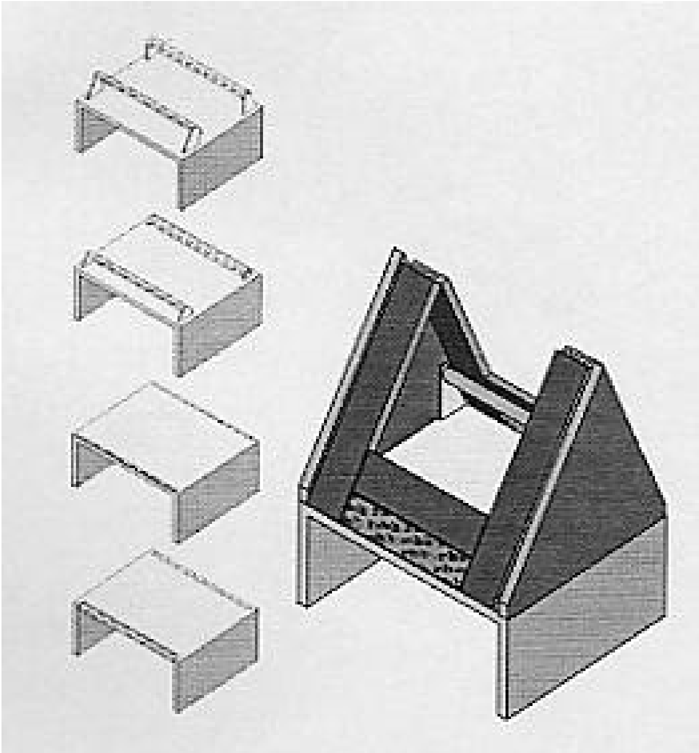

Figure 6: RBB Braas Total Roof

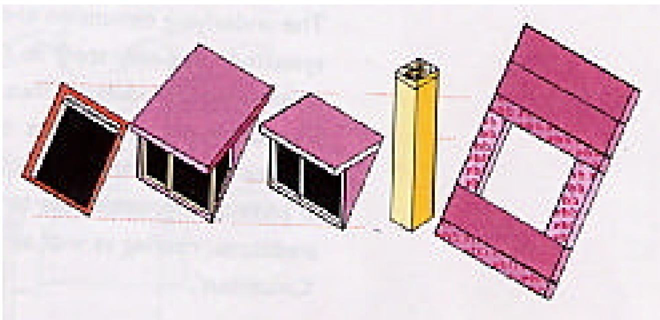

Figure 7: Roof accessories

The Caveletti is part of the systems and can be adopted in existing as well as in newly constructed buildings. It decouples the roof structure from the rest of the building, from the gables as well as the facades, thus making the roof an independent subsystem, that can be developed, produced, sold, constructed, maintained, replaced and taken apart from the rest of the building. The Caveletti roof system allows simple as well as more complex roof shapes to be made. The system parts of the Caveletti roof system can be adapted to the underlying structure of the building. The result is a framework for infill products, a passe-partout for the consumer chosen accessories and finishings (Figure 7)(Cuperus, e.a. 1998).

CONCLUSIONS

Open Building originates from a tradition of user participation in creating a built environment the customer is prepared to take care for, to look after, to maintain, to defend and take responsibility for. It has developed a set of tools to accommodate different levels of decision-making. Lean Construction aims to apply the concept of lean production to the construction industry in order to improve efficiency and quality.

Both Open Building and Lean Construction take the customer seriously. Open Building has been referred to in Lean Construction publications (Koskela, 2000)

Open Building aims to optimize the quality of the built environment, by improving the relationship between the customer and the building industry. Lean Construction aims to optimize building and construction. In this paper the concept of Open Building was explained in order to investigate its relationship with Lean construction.

A synergy between the concepts mentioned is worth exploring and developing.

REFERENCES

CBS (1994) Centraal Bureau voor de Statistiek (The Netherlands Central Bureau of Statistics), 1899 - 1994 vijfenegentig jaren statistiek in tijdreeksen, Voorburg/Heerlen.

CBS, (1995) Centraal Bureau voor de Statistiek, (The Netherlands Central Bureau of Statistics) Statistisch Jaarboek 1995, Voorburg/Heerlen.

Cuperus, Y.J (1996) Housing for the Millions, The challenge ahead, conference papers, Hongkong.

Cuperus, Y.J., Kapteijns, H.J.M., Köhler, C., Randen, A. van (1998); Passe-partout, summary of Komplettdächer für den europäischen Markt. OBOM, Delft.

Habraken, N.J. (1961) Supports an alternative to mass housing, London 1972, Amsterdam 1961 (Dutch version)

Habraken, N.J. (1989) Architectural systems: development of an infill system, Conference proceedings ‘Quality in the built environment’, Newcastle upon Tyne.

Kapteijns, J.H.M. (1993) Het Informatiseren van het Ontwerpen van Bouwknopen, OBOM, Delft.

Koskela, L. (2000) An exploration towards a production theory and its application to construction, VTT, Espoo.

NNI (1954), Nederlands Normalisatie Instituut, NEN 5700 Modulaire coördinatie bij het bouwen. algemene regels (Modular co-ordination in building. General rules). Den Haag.

NNI (1977) Nederlands Normalisatie Instituut, NEN 2880, Modulaire coördinatie bij het bouwen (Modular co-ordination in building), Rijswijk.

NNI (1978) Nederlands Normalisatie Instituut, ontwerp NEN 2883 Modulaire coördinatie bij het bouwen. Woningen (Modular co-ordination in building. Dwellings), Rijswijk, Bijlage A, pp. 11-17.

NNI (1981) Nederlands Normalisatie Instituut, NEN 2883, Regels voor gecontracteerde experimenten met modulaire coördinatie in de woningbouw (Rules for contractually agreed experiments with modular co-ordination in housebuilding), Delft 1981.

NNI (1986) Nederlands Normalisatie Instituut, NEN 6000, Modulaire coördinatie voor gebouwen. Begrippen, algemene bepalingen en regels voor plannen (Modular co-ordination for buildings. Definitions general rules and rules for plans), Delft.

Womack, J.P., Jones, D.T., (1996) Lean Thinking, New York.