SYSTEMATIC APPROACH TO DESIGN OF BUILDING’S TRANSFORMATION

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INTRODUCTION

Traditionally design has concentrated on the construction phase, optimizing construction costs and short-term performance. However new circumstances such as changing economies, customization of building industry and environmental consciousness are asking for different design approaches and application of new building methods. In order to stimulate the development of new innovative ideas that will help to bridge the gap between traditional and new building concept the Dutch government has started the project called “IFD” (industrial, flexible and dismantled buildings). This concept should stimulate further industrialization of building process by systematization of building; extend the life cycle of building by adding the aspects of flexibility and extend the life cycle of building components by dismantling building components. IFD concept is basic for this research project which is focused on D (dismantling). Disassembly is precondition for easy transformation on building level and exchangeability, reuse, repair and recycling on product and material level. Dismantling is not related only to the longer life of the building and waste reduction but further more it has to do with: simplified and faster construction and reconstruction processes; reduction of noise and dust; less use of raw materials, easier quality control; and finally less use of energy which leads to lower greenhouse effect.

PRESENTATION

State of the art
Environmental conciseness
Building operation and construction consume large quantities of materials and energy and contributes significant solid liquid and gaseous emissions to the local and global environment. In Brundtland Report it was stated that the building industry is the greatest consumer of worlds natural resources and energy as well as the greatest waste producer [DIOC96]. For example 50% of material resources taken from nature are building related; over 50% of national waste production comes from the building sector; 40% of the energy consumption in Europe is building related [Anink96]
In dens populated country, as the Netherlands the yearly waste production of 14 million tones is no option any more. Therefor in order to improve the efficiency of the building industry the way we will construct and transform our buildings in the future has to be fundamentally different focusing on material saving, energy saving and clean construction and reconstruction process.
Market requirements
In the past decades the technical and functional service life of buildings was approximately 50 years. Today it happens that buildings with an age of 15 years are demolished to give way to new construction while most of their components still have technical life cycle of 50-75 years. This has to do with market-oriented economy, life stile changes and changing businesses. For that reason average functional service life is becoming shorter and forces a return-on-investments to come quicker. Within this context the reduction of the technical service life is no option, because this would in fact be destruction of capital investment.

Design
In order to keep buildings and their components in their life cycle as long as possible, we must consider how we can access and replace parts of existing building systems, and accordingly how we can design and integrate building systems in order to be able to replace them later on. This is asking for more systematic approach to the design (the first phase of building life cycle) where the greatest potential exist to influence the building properties in all life cycle phases. Such development provides a framework for the multidisciplinary teamwork (concurrent engineering) that can influence the building design for cost effective and high performance buildings.

Strategies for design of transformable structures
Dismantle building can be a good strategy to bring the technical, functional and economic life span of building in line. Such buildings could be efficiently exploited and remain a high standard of quality for use, which in return contributes to the quality of the built environment.(figure 1 left). Moreover such buildings stimulate conscious handling of raw materials, which is an important element of sustainable development in the building industry.

Figure 1: “A+markt” IFD building project in Amsterdam (left), shearing levels of change within the building (right)

When designing a dynamic structure whose parts could be dismantled back into components than the aspects which are related to the process of making and use of building materials have to be integrated from the beginning of design process. In table below the key aspects of sustainable design are defined per life cycle phase.(figure 2). Design for disassembly is considered to be
successful integral design concept which aims at optimization of building properties in each of its life cycle phases for longer life of building and its components.

<table>
<thead>
<tr>
<th>Life cycle phase</th>
<th>Strategy per L.C. phase</th>
<th>Relevance</th>
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</thead>
<tbody>
<tr>
<td>Design</td>
<td>• Development of scenarios for building use</td>
<td>Flexible building</td>
</tr>
<tr>
<td></td>
<td>• Optimization of the building in each of its life cycle phases</td>
<td>Environmental burdens</td>
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<td></td>
<td>• Concurrent engineering</td>
<td>Timely and correct decision making</td>
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<td></td>
<td>• Use of material saving process</td>
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<td></td>
<td>• Use of recyclable or reusable materials</td>
<td>Energy use</td>
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<td></td>
<td>• Use of low weight materials</td>
<td>Environmental burdens</td>
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<td></td>
<td>• Use of less energy intensive materials</td>
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<td>Transport</td>
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<td>Assembly</td>
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<td>• Parallel assembly</td>
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<td></td>
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<td>Environmental burdens</td>
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<td></td>
<td>• Design for maintenance/long life</td>
<td>Resource depletion</td>
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<tr>
<td>Dismantling</td>
<td>• Design for disassembly</td>
<td>Resource depletion</td>
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Figure 2: aspects of sustainable design per life cycle phase

The major obstacles in design for disassembly are “shearing layers of change” (Stewart Brand) that create constant temporal tension in building. Design Life of modern building is 75 years, yet their service life is unpredictable because their major parts were out at different rates complicating replacement and repair schedules. Faster cycling components such as Space Plan elements are in conflict with slower elements such as structure and site (Kibert00). When considering the potential for closed loop materials cycle for the built environment it becomes clear that the main problem lays in dependent integration of components with different lifetime and functional expectances at connections. Therefor the first step towards managing the temporal tension in building is through decoupling of slow (fixed) and fast (changeable) components (Kibert00).

In relation to that the design strategy should be focused on defining the hierarchical order which is suitable for maintenance and replaceability of changeable components and accordingly on design of dismantlebel interfaces to insure reuse and recycling. Such design strategy should be applied on all three levels: building level, product level and material level. Dismantling on building level would provide transformable building structure which can be easily adopted to the new requirements, dismantling on product level would provides reuse of components, elements and half products, while dismantling on material level would provide material recycling.

In accordance with that some design principles are listed bellow:

• Provide separation between the fixed and the flexible parts of the building
• Create separation between the elements within different functional and life time expectances by using separate construction systems
• Provide accessibility to the elements with shorter life cycle
• Use open in stand of closed systems to allow easy alteration in the future
• Design building connections optimizing the type of material, its performance, life cycle and assembly sequence
• Use a minimal number of connections to allow easy disassembly
• Keep all components separated avoiding the penetration into another components or systems
• Dry jointing technique should be used in construction.
• Parallel assembly should replace sequential assembly in order to allow disassembly of single part without disruption to other parts.

Case study in the Netherlands

Recently built family “smart houses” in the Netherlands could be used as example where above-mentioned principles were applied. Dutch government has subsidized this project as one of IFD projects.

Strategy - flexibility
The load bearing structure of the “Smarthouse” is made of steel scelet. Façade, roof, floor and separation walls are sequentially assembled into structure and each system could be replaced without interference to others. Installations are distributed through the hollow floor what makes functional flexibility possible.

According to above-mentioned principles smart house has following flexibility aspects: exchangeability of façade, roof, partitioning walls, installations, extendibility of the structure, and spatial flexibility.

Dismantling
The weight of Smart house is 25.000 kg including the weight of load bearing structure (5000-8000kg). This is one fifth of one conventional house.(Winkel99) Having in mind that the components are made in factories and than transported to the assembly sites, it would be possible to transport whole building at once since its weight does not reach the maximal weight that could be transported on one truck ( max. weight is 35.000 kg.). All parts of the smart house could be dismantled to the single component.(figure 3) The possibility of bringing the components back into production and building process is being considered.

Figure 3: Smart house – dismantleble connection(left), one of the building types(right)
**Recycling**

Most of the steel components could be easily brought back into the building process as a half product. Comparing with the material recycling half product reuse saves much more energy. The partitioning walls are constructed with gypsum boards that are made of old papers and rest products. All boards will be brought back to the production process.

**CONCLUSIONS AND RECOMMENDATIONS**

Modern buildings are not designed to be dismantled, building products are not designed for disassembly and the materials comprising building products are often composites that makes recycling extremity difficult. Buildings can experience different phases in building use and they frequently undergo renovations and modernization. In each case the inability to easily remove and replace components results in significant energy inputs to building systems and larger quantities of waste. The aim of this research is to provide a Decision Support Model (DSM) for design for disassembly. The DSM will provide a recommendation for design and application of building systems being a part of dynamic building structures. Therefore the research addresses the interaction between various building components, considering various determinants such as functionality, durability and demountability. The aim of this project is to develop a decision support model which will help to make a balanced considerations when designing a building that can be easily transformed and whose parts could be reused or recycled.

**REFERENCES**


Kibert00- Construction ecology and metabolism. Conference proceedings “Integrated life cycle design” Helsinki 2000

Winkel99- Project description “Smart House” the Netherlands 1999

IFD00- IFD Bouwen demonstratieprojecten, Rotterdam 2000

Hendriks99- Industrieel flexibel en Demontabel Bouwen – Ontwerpen op veranderbaarheid, Eindhoven 1999