TIMELESS FLEXIBLE BUILDING
Matching demand and supply in flexible housing

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Abstract
The concepts of Open Building and Lean Construction suggest strategies for designing, building and operating the built environment. These concepts create value and take into account all present and future stakeholders who are in control during construction and use. It gives guidelines on how to manage a construction process to create a built environment that is sustainable. At the same time we can see that in practice the concept is less flexible than the value it hopes to create. The starting point of this research project was the assumption that there is a major mismatch between consumers’ demands for flexibility on the one hand, and the flexibility that is actually supplied. This paper reports on this research project, which finally provides easily understandable guidelines to manage housing during the different stages of the life cycle.

The questions this paper will attempt to answer include the following: which flexibility initiatives were promised and actually adopted by the developers and landlords of the houses; how did the users actually make use of all the offered flexibility during the use phase; and is it possible to optimize the demand and supply for future flexibility based on the principles of lean construction?

A description of long-term value is provided, based on user interviews and case studies have been conducted in order to identify obstacles on the way to long-time flexibility. References are made to the Netherlands IFD (Industrial, Flexible, Demountable) Governmental initiative that ran from 1999 to 2006. Five experimental projects from this initiative are used as case studies in this research project.

This study builds on the assumption that a foolproof product will add to the adaptability of a building, thus extending its life cycle, preventing waste and contributing to the sustainability of the built environment. In the final analysis the conclusion is drawn that among other things, house manuals should be compulsory and that a house that is easy to understand and “read” would only require a short manual. Such a manual would guarantee a natural hand over of IFD responsibilities to the next generations.

Keywords: Open Building, Lean Construction, user-participation, IFD, Continuous Customization

INTRODUCTION

Many people in the Netherlands are unable to live in the type of home they would like. The quality and quantity of housing stocks often fail to meet the ever-changing demands of users since too few suitable homes are available. As a result, first-time buyers in particular face difficulties finding a home. In addition, many people choose to remain in their existing home for too long until they are successful in finding a suitable home that matches their specific individual wishes. This is leading to a blockage in Dutch housing stocks (Boelhouwer, 2009). When it comes to their home, people's needs are also constantly changing. Market supply is failing to respond rapidly enough to changes in demand, leading to stagnation in the housing ladder. In the last decade, the housing market in the Netherlands has changed from being supply-led to demand-led. This means that users need no longer select from a specific and
limited supply, but that the supply must more effectively meet the specific and individual demand of these users. Flexible construction is one way of providing a better response to individual demand. A flexible home is designed and built in such a way that it can be adapted to suit the changing requirements of its users. This is also referred to as consumer-focused building (Zijgers, 2008). First of all, an explanation will be provided of IDF construction.

**INDUSTRIAL FLEXIBLE DEMOUNTABLE CONSTRUCTION**

In the period 1999-2006, the Dutch Ministries of Housing, Spatial Planning and the Environment (VROM) and Economic Affairs (EZ) instituted an experimental programme: Industrial Flexible Demountable Construction (*Industrieel Flexibel Demontabel* or IFD in Dutch). Construction companies and developers were attracted to take part in the experiment by subsidies awarded for the development of innovative construction products and methods. The IFD programme was a response to a demand-led market. The residents were involved in the development of these homes from as early as the design phase. The homes can not only be adapted to suit changing requirements during the design phase (process flexibility), but also in the user phase after construction (product flexibility). During the course of the IFD programme, a total of 91 projects were realised, including 34 residential construction projects (Sev, 2007).

**Consumer-focused construction**

In consumer-focused construction, the building’s occupant plays a central role. The home is designed especially for them and built in accordance with their individual wishes (Cuperus, 2002). It is therefore very important to evaluate the results of the IFD programme. What is the ultimate experience of the occupants of these homes? Which flexibility elements are now being used in practice and which are not? The answers to these questions may prove very important for development companies if they wish to build flexible and adaptable homes in the future. In other words, which measures would companies be advised to invest in and which not?

**Industrial construction**

Industrial construction is a building method in which construction components are system-built in a uniform manner under controlled conditions. These components are then assembled on the building site to create larger components or complete buildings. Industrial construction often involves the manufacture of large series of components that are not intended for any specific project, but this is not a necessary precondition. Mass customisation enables these components to be assembled in a range of individual combinations and variations despite the fact that they are manufactured in large standardised series. Industrial construction is one way of improving the speed and manageability of construction and enhancing product quality (Thillart, 2002). Mass customisation involves the following: the consumer purchases a product or part of one that ultimately results in a customised solution but is actually made from standard components that are mass produced (Stienstra, 2004:16).

**Flexible construction**

Flexibility is a characteristic of a building or construction components that enables adaptations to be made in response to the changing demands and wishes of users (Gunst 2008). Flexibility can be divided into process flexibility and product flexibility. Process flexibility offers possibilities for adaptations during the design and construction process and provides extensive freedom of choice for the first generation of occupants in particular. Product flexibility makes it possible to make adaptations when the home is actually in use in order to meet the changing living requirements of the occupants (Geraedts, 2000).
Demountable construction
Demountable construction involves constructing buildings in such a way that the building components can be easily removed or relocated and removed at a later date. This aspect is extremely important in terms of enabling buildings to be modified or extended. For example, part of a facade can be literally dismantled, removed and then re-used after the building has been extended. This reuse also means that demountable construction helps to reduce environmental pollution caused by the construction process by preventing waste.

OPEN BUILDING AND LEAN CONSTRUCTION

Open Building and Lean Construction are complementary strategies that can work in synergy (Cuperus, 2001). In order to grasp their full potential, some elaboration may be helpful.
In 1961 John Habraken observed: ‘We should not try to forecast what will happen, but try to make provision for what cannot be foreseen’ (Habraken, 1999). He proposed a built environment layered along lines of control. The urban fabric comprises base building (support), and fit-out (infill). This understanding is intended to structure the way buildings are designed, constructed, and operated. Open Building gives guidelines for structuring the product and to a lesser degree the construction process.
Lean Construction is the construction equivalent of Lean Production, which in turn is a westernized interpretation of the Japanese TPS, the Toyota Production System (Womack et al., 1990). The lean mantra is: ‘Create value, banish waste’. The construction industry’s output is the built environment; it needs to create value for its end users, in the same way as Toyota serves its clients. But what is value and who is the value for? In this respect lean production differs from lean construction. This is an ongoing debate which still has a long way to go.
Banishing waste from the construction process is easier. Observing the Toyota process enabled seven types of waste to be identified (Ohno, 1988). Waiting and re-work are two of the most notorious wastes in the construction industry. One strategy to prevent re-work, in other words to do things right the first time, is by fool-proofing the process. For example: a USB connector is foolproof, it does not need any explanation on how to plug it in. A bank card with magnetic strip is not: it can be swiped in four different ways of which only one is correct; and the different swipe machines and a sticker with explaining texts and graphics only complicate things.
Lean Construction gives guidelines to structure the construction process and to a lesser degree the value of the built environment it is supposed to accommodate. A deeper understanding of Open Building in relation to Lean Construction is instrumental in undertaking the case studies that will be described next.

PROBLEM STATEMENT AND RESEARCH QUESTIONS

Seven years of IFD has left us with the unsatisfactory notion that its products have never been thoroughly evaluated. This is understandable, since it takes time to measure the effects. The longer the time lapse, the more valuable the data become. This chapter describes the need to evaluate in the light of consumer oriented building.

Problem
A superficial evaluation of IFD housing construction projects suggests that many home occupants are not living as they would wish and are actually unaware that their home can easily be adapted to suit their requirements. If this is indeed the case, there is an unnecessary mismatch between how people would like to live and their home. If IFD had been effectively
evaluated, this problem would have been revealed and potential improvements could have been identified.

**Approach and objective**

Five of the 34 IFD housing construction projects were investigated to explore the mismatch hypothesis. Data was collected by means of a document survey, project visits and interviews with the key stakeholders, in other words the residents and commissioning parties. Lean Construction and Open Building provided conceptual frameworks for questions and answers that can reveal solutions. For Lean: ‘Does the home offer the optimum value that its occupant would like? If not, where is the waste and what is the remedy to prevent this?’ For Open Building: ‘Is the domain of the occupant clearly defined and delimited? If not, how can residents be made to understand the dividing line between the base building and those sections that can be modified?’

**RESEARCH METHOD**

This study focuses on 34 housing projects realised in the period 1999 - 2006 as part of the experimental IFD programme in the Netherlands. In order to obtain a good impression of the actual use of the flexibility measures, only those housing projects completed at least five years before the start of the study (2010) were selected. Ultimately, five housing projects were singled out for further study:

1. De Kersentuin
2. Multiple Choice
3. Ecoflex
4. La Fenetre
5. Terbregse.nl

By means of a literature and document review along with interviews with the project developers, the original initiatives to achieve flexibility were compared with the actual flexibility achieved after completion of the housing. Surveys were conducted among residents in the relevant projects in order to investigate the actual use of flexibility once the home was in use, the aim being to get answers to the following questions:

- Are the residents aware of the flexibility and adaptability of the homes?
- Were these actually utilised in the development phase?
- Are the homes already being occupied by a second generation of users and, if so, have they adapted the home to suit their specific living requirements?
- Did the occupants receive documentation to inform them of the possibilities for adaptation?
- Do the occupants wish to make adaptations to specific elements in their home that are not currently included in the possibilities?
- Which options for flexibility that were initiated and realised are being utilised the most?

**FINDINGS**

Analysis of the literature and documents revealed that, with the exception of the initiatives on the basis of which the residential construction projects were awarded experimental status (SEV, 2007), there has been no documentation of what happened to the projects concerned during the design, construction and user phase. The results of the survey are therefore an important source of the findings in this study.

**De Kersentuin case**

For the IFD project De Kersentuin, the brief was to realise a sustainable and ecological project with a great deal of freedom of choice, but it was not specifically focused on innovative or industrial construction methods. The project comprises a mixture of 94 apartments and terraced houses and was completed in 2003. The homes were built using a timber frame construction and are 6 m in width in order to provide sufficient flexibility and freedom in terms of layout.
Almost all types can be extended. Only 10% of residents opted for a standard basic home, with the rest choosing individual detailing.

**Figure 1: De Kersentuin case with 94 homes**

The occupants of De Kersentuin were given a lot of freedom to arrange the layout of their home to suit their personal requirements. There were three different possible positions for the staircase (see Figure 2).

**Figure 2: three possible positions for the staircase in the floor plan and the possibilities for extension on the garden side by means of demountable facade components and additional strip foundation.**

The volume of the homes in De Kersentuin can also be modified after completion when the home is in use. This is made possible because additional strip foundation was installed for future extensions and the facades are partly demountable and can be re-used after the home has been extended. The interior of the homes can also be adapted by relocating the movable lightweight partition walls. The equipment and finishing can also be adapted for subsequent occupants. The survey revealed that the occupants were well aware of the developments and possibilities for adaptation in their home and most had actually made use of these (42%). This is because most occupants attended meetings of the De Kersentuin residents’ association from the outset, which played an important role in the development of the project right from the start. The occupants had also adapted the layout and volume of their home after completion. Interestingly, as many as 60% of occupants questioned had not received a manual for their home after completion.
**Figure 3: the volume extension realised in a home in De Kersentuin.**

In one of the extensions completed later in order to increase the volume of the home, the existing facade was not re-used despite the initial built-in flexibility and the additional investment aimed at making the facade demountable. In order to make it possible to continue to live in the house during the modifications, the original demountable facade was not relocated and re-used after the modification. Only after completion of the rebuilding work was it removed (see Figure 3).

**Conclusions for De Kersentuin case**

This study reveals that flexibility primarily takes the form of greater freedom of choice for the first generation of occupants since they are directly involved in and have an influence on the design and realisation process. The long-term adaptability of the homes is currently limited by the fact that many are still occupied by the first generation of occupants. Several occupants have however made use of the possibilities to adapt the home while in use, including expanding the bedroom or the hallway. One of the problems identified relates to a lack of information. In particular, occupants who would like to change or adapt something after completion do not know whom to contact. For this reason, most occupants made modifications to their home on their own, largely applying traditional methods and therefore not taking full advantage of the flexible and demountable facilities invested in the home for this purpose.

**Multiple Choice Case**

The Multiple Choice project is a flexible construction concept comprising 18 detached homes with a steel frame construction. This project differs from all the other projects because the occupants did not have to choose between a range of different design variants, since the homes were developed and constructed on the basis of what are known as envelopes. An envelope is the maximum contour or built volume within which the house can be built. When the homes are in use, occupants are free to extend them up to the maximum limits of this envelope. One of the key characteristics of the Multiple Choice project is its high level of industrialisation. The size of the home is variable within the set envelope. The width sizes vary from 4.80 m to 8.40 m, with increments of 1.20 m. The depth template varies from 2.70 m to 3.60 m, making the home extendable from 5.40 m by modules of 0.90 m. The customer does not have to choose between different extension modules, but chooses within the maximum construction size, gradually working down to smaller levels of scale.
The buyers received an interactive CD-ROM which they could use to determine the budget, the position of the garage, the direction of the garden and spatial features such as additional rooms and loggias. They could then choose from variants that matched their chosen profile. Residents could choose from a total of 159 variants. Multiple choice questions were used to make an assessment of which homes most effectively matched the requirements of the residents (see Figure 5).

In order to enable future extensions to the homes while in use, additional driven foundation piles were included and the facade components were made demountable. The layout of the home can be easily modified as a result of the use of easily demountable partition walls. The pipes in the upper floor are accessible to enable future adaptations. As a result, wet rooms on the first floor can also be modified when the home is in use.

**Conclusions for Multiple Choice case**

The residents of the Multiple Choice project have so far made little use of the flexibility options offered. This flexibility was primarily focused on the first occupants during the development process. For example, they were able to choose between different staircase positions. The first generation of occupants had no reason to modify their home after completion because it had already been designed in line with their individual wishes. One second-generation occupant did modify his home while in use by changing the location of the

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Figure 4: Multiple Choice case with 18 detached homes.

Figure 5: multiple choice questions were used to make an assessment of which homes most effectively matched the requirements of the residents.
kitchen. Because of a lack of information in the form of a manual, he was not aware of the fact that it was a flexibly adaptable home.

**Ecoflex Case**
The brief for the Ecoflex project was to develop a sustainable housing concept in which the 14 homes have flexible layout, can be extended and can be used for several purposes. A wide freedom of choice was achieved within a normal price category for terraced homes. The fact that the homes can be extended also makes them attractive to buyers. Ten buyers extended their homes immediately. It would appear that residents initially tend to opt for many additional cubic metres. The variants selected do not differ to a great extent in terms of layout, but primarily in terms of size.

*Figure 6: Ecoflex case with 14 detached homes and the possibilities for extension of the homes around the fixed core.*

This project is an example of partitionable base building. Residents had the choice of five different basic variants and a list of possible additions. The final result is that all 14 homes have a different layout and fittings. The homes can only be extended at the rear thanks to the additional 1.50 m of strip foundation and because the rear facade is made up of demountable and re-usable timber frame components and window frames. This also makes it possible to have different facade layouts. The only thing that cannot be modified is the core of the house. Residents are free to arrange the layout of the house around this core as they wish. The house can be extended by a total of around 50 m2 (see Figure 6). The home layout can be adapted for the second generation of users, with the exception of the staircase and the vertical pipes.

*Conclusions for Ecoflex case*
The survey revealed that none of the second-generation occupants took advantage of the options for flexibility. It also emerged that the occupants had no idea whom they should contact if they wished to modify their home. This is partly because no manual is available for residents providing information about possible modifications. The research also revealed a problem directly related to the industrial flooring system used and the fact that the homes used a partitionable base building system. In the detailing and finishing work, insufficient account was taken of possible noise nuisance relating to the desired flexibility of the demountable construction components. Many residents complained about contact noise: "when the children are playing upstairs, it sounds like a cupboard crashing to the ground”, said one resident.

**La Fenêtre Case**
La Fenêtre is the largest housing complex within the experimental IFD programme. It is one of the first residential buildings with a complete steel construction and also one of the largest
projects to include industrial infrastructure and flooring. The aim was to achieve permanent adaptability.

Figure 7: La Fenêtre case with 115 homes spread across 16 floors

The layout of the homes can be modified. In principle, future generations of residents also have the freedom to arrange the layout of the apartment as they wish. The interior walls are easy to remove. Thanks to the floor system used, the pipes are easily accessible and can be modified, enabling changes to be made to the wet rooms in the future.

Conclusions for La Fenêtre case
The survey results revealed that no one had taken advantage of the flexibility options offered. This is because the landlord does not allow residents to make modifications to the homes, having opted for a fixed standard layout. In addition, it emerged that no one was aware of the fact that the homes have a flexible design and can be adapted to suit changing individual living requirements.

Terbregse.nl Case
The Terbregse.nl project, featuring 41 homes, is an example of collective private commissioning. The aim of the project was to offer a high level of freedom of choice for individual purchasers.

Figure 8: Terbregse.nl case with 41 homes.

The focus was on a flexible construction process that enabled individual choices for future users. The homes are three storeys high and the layout can be freely determined. In addition to the opportunity to freely determine the number of rooms and change the position of the kitchen, toilet and bathroom, the homes can also be extended upwards and at the front and back
(see Figure 9). This has been made possible by the use of additional strip foundation. The facade is demountable and the window frame can be re-used in an extension.

Figure 9: options for extension upwards, at the front and rear, with demountable and re-usable facade components.

Conclusions for Terbregse.nl case
The residents all took advantage of the flexibility options to arrange the layout of their home to suit their individual wishes, primarily during the initiative phase. As a result, most of them have so far had no need to make further adaptations. Three residents have subsequently taken advantage of the possibility to adapt their home, ranging from changes to the layout to the relocation of the kitchen. It emerged that none of them were aware of whom they should contact to arrange possible modifications.

CONCLUSIONS AND RECOMMENDATIONS

No wide-ranging IFD evaluation has been conducted to date. Studying five of the 34 IFD housing construction projects has revealed that the second-generation of residents have made little or no use of the options for flexibility, the F in IFD. In the current demand-led market, people moving house prefer to find a suitable home within the available budget and in the desired area that does not need modification. Seen from that perspective, the need for flexible homes would appear to be lower in a demand-led market than in a supply-led market. Some of the second-generation residents have made modifications to their home using traditional methods, being unaware of the integrated flexibility. According to lean terminology, this unawareness is a source of waste that can be avoided by making the home fool-proof. This would require the flexibility of the home being obvious at a glance or announced in some other way, for example by means of a laminated manual that cannot be removed from the meter cabinet, or an app for a smart phone. The Open Building concept provides indications of which part of the home belongs to the infill level, the user’s domain, and which belong to the base building or support level, the section that cannot be changed by the user. By making the boundaries of flexibility easily identifiable, owners can be encouraged to increase the value of homes by means of improvements, while preventing waste caused by the use of inappropriate techniques.

These conclusions are based on the study of five IFD housing construction projects, all of which have what appears to be hidden flexibility. The next challenge will be to identify these hidden secrets in existing buildings, name them and make them visible or otherwise announce them. This will ensure that value is created with minimum effort and waste is prevented.
REFERENCES


