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IMPLEMENTATION OF INNOVATION: THE INERTIA OF IMPLEMENTING THE OPEN BUILDING CONCEPT IN PRACTICE

JOHANNES A.W.H. VAN OORSCHOT
Twente University
Engineering Technology, Construction Management & Engineering
j.a.w.h.vanoorschot@utwente.nl

ELMA DURMISEVIC
Twente University
e.durmisevic@utwente.nl

JOHANNES I.M. HALMAN
Twente University
j.i.m.halman@utwente.nl

Abstract

The Open Building concept has been developed half a century ago. Despite the relative potential advantages to society, this concept of Open Building has not been widely implemented in the construction industry. Consequently, it did not lead to a general new approach of designing structures. Why does the construction industry use the Open building concept so rarely among their projects? Using in-depth semi-structured interviews with the 'founding fathers' of Open Building in combination with literature, the inertia which obstructs the implementation of Open building in the construction industry are identified. The study shows that inertia on adopting the principles of Open Building are primarily related to the type of collaboration between firms on construction projects. Only few impediments are of technical nature.

Keywords: Innovation in Construction, Open Building, Implementation of Innovation, Inertia

Introduction

In order to answer the housing problem after turbulent periods in the 20th century, mass production of dwellings offers accommodation to many citizens [Habraken, 1999]. Furthermore, mass production has long been recognized as an effective means of reducing a product's unit cost. The organizational structure and work processes in most construction firms have their roots in these mass production principles [Halman et al, 2008]. However, static mass housing is not capable to adapt easily to changing customer demands, to accommodate more than one program of functions over time. Static building structures causes an increasingly inefficient utilized building stock [Habraken, 1999; Kendall and Teicher, 2000; Thillard, 2004].

To overcome the identified problems with static building structures, the Dutch architect John Habraken proposed the open building system in 1961. In this system, the 'base-building' and its interior are separated, the so-called 'support/infill' approach. Open Building has been of interest for many scholars and has been adopted in the last few decades in countries like Japan, UK and USA. In general, the design customization options include interior and exterior design components, as well as the spatial arrangements that determine the total area of a home [Hofman, 2010].

In the past fifty years many pilot projects have been applied successfully at a small scale. However, it remains a challenge to achieve them at a broad scale. In this paper we will explore for possible reasons why the concept of Open Building has not been widely adopted in the building industry. To this end we first interviewed the founding fathers of Open Building and asked them to reflect upon the development of the concept and the resistance in the building industry to adopt the design principles of this concept. This reflection helped us to identify some important inertia. Based on the insights from the adoption theory of innovation we searched for possible solutions to overcome these inertia. These will be discussed in the discussion section of this paper.
The rest of this paper is structured as follows; in the next section the research method that has been used is presented. The section is followed by a section in which the theory of Open Building is discussed and a section in which the results of the interviews are presented. In the last part of the paper the results of the interviews and limitations and implication for further research are discussed.

Research method

The goal of this study is to identify the inertia on Open Building. To better understand the implications of this specific context a literature study was conducted on Open Building. First, the work of Habraken, the founding father of Open Building, was studied. Secondly more work was studied of the scientific working group 'Open Building Implementation' of the International Council for Research and Innovation in Building and Construction (CIB) and the journal 'Open House International'. Also the work of other scholars in this field in the Netherlands were studied by making use of backward and forward reviewing on the key words 'industrialization', 'flexibility' and 'sustainability' [Webster and Watson, 2002; Short, 2009; Cropanzano, 2010].
From literature was derived that the potential respondents in the Netherlands were (and some still are) associated to Eindhoven University of Technology and Delft University of Technology. With respect to many others who made contributions to Open Building, the following five early promoters of Open Building were interviewed in the autumn 2010: John Habraken, Age van Randen, Ype Cuperus, Jos Lichtenberg and Jouke Post.

Data collected by in-depth interviews were used to explain and explore the inertia of implementation of Open Building in practice. Analysis of the interview data increased the understanding of factors that impede Open Building and what compensation mechanisms are available to mitigate these impediments. The interviews took between one and three hours and with permission the interviews were taped and transcribed within 24-hours after the interview.
Each interview began with explaining the research goal and the role of the researcher. Each respondent was asked to answer a set of structured, open ended questions. These questions where supplemented with questions that came up during the interview.
The interview data were analyzed as follows. First the recurring words and important issues and stories where highlighted in the interview transcripts. These words and issues where clustered for each transcript and the clusters where compared across transcripts. Finally the clusters where labeled.

Literature

The basics of Open Building
The founding father of Open Building is the Dutch architect John Habraken. Already in 1961 he published his book '*De dragers en de mensen*' (Supports: an alternative to mass housing). In his book Habraken argued that mass housing disrupts the age-old 'natural relation' between human being and their built environment. He stated that people will lose interest in things which could not be influenced by them as with mass housing. Furthermore dwellings cannot be understood as products or manufactured objects. Thus, dwelling is a fundamentally human process. Therefore, residents needed to be able to make autonomous decisions on their own behalf concerning their dwelling. Concluding, dwellings provided by units of housing accordingly to mass-housing are inconsistent with the human process [Habraken, 1999].
According to Habraken, Open Building implies a strategy consisting of twofold complementary perspectives. First there is the social perspective that seeks to respond to user's preferences by offering flexibility needed for adaptation of individual units over time. Second there is the technical perspective which seeks ways of building where sub-systems can be installed or changed or removed with a minimum of interface problems [Habraken, 2003]. Furthermore, Open Building comprises the following ideas:

- "There are distinct levels of intervention in the built environment;
- Users (inhabitants) may make design decisions as well as professionals;
- Designing is a process with multiple participants, including different kinds of professionals;
- The interface between technical systems allows the replacement of one system with another performing the same function;
- The built environment is in constant transformation and change must be recognized and understood;
- The built environment is the product of an ongoing, never ending design process, in which environment transforms part by part" [Habraken, 1999].

Habraken distinct basically three levels of decision making: the tissue level (urban planning), the support level (architecture of the base building) and the infill level (design of the interior). Based on Habrakens' 'theory of levels' several other scholars defined more layers based on the differences between the technical and functional life cycle of building systems [Brand, 1995; Duffy, 1998]. However, the theory of levels by Brand and Duffy are based on subdivisions of Habrakens' support and infill level:

- Support level. The base building or the support of a building is the permanent construction with a life span up to 200 years. The support provides service space for

occupancy, the infill. The type, number and size of the individual infill units are primarily not determined by the support, compared with more traditional buildings. Part of the support are all the elements belonging to the public routing (stairs and elevators, corridors and galleries, et cetera) and common used utilities (like foyers, community rooms, et cetera).

The support itself could contain several lots. The lots within the support structure must be connected separately to the services which could be found in the public space of the structure. Based on the thoughts of Habraken, the support should accommodate the infill in an adaptable way. This means that the support determines the capacity of change, based on diverse and changing demands, of the infill leaving the support unaffected. [Habraken, 1999; Kendall and Teicher, 2000]

- Infill level. The infill system consists of many systems and subsystems which could be subdivided in many elements and components. In contradiction to more traditional construction projects the elements are not brought to the site to be processed by its own subcontractor in the building based on the site conditions. The infill is a far more integrated set of products which are basically custom prefabricated off-side for an infill unit. Therefore the infill must be installed as a whole. The infill system constructs a unit (dwelling, office space, et cetera) within the support structure [Habraken, 1999; Kendall and Teicher, 2000].

The main goal of Open Building is to achieve independency between building parts, so buildings can be created that are able to adapt to new user requirements. Despite this clear vision, applying the Open Building principles in practice is challenging. The application of Open Building is still prominent in the Netherlands but also the United States and Japan are known for their efforts.

Research findings

Early promoters of Open Building in The Netherlands, John Habraken, Age van Randen, Ype Cuperus, Jos Lichtenberg and Jouke Post, were asked to describe on their past experience the impeding and stimulating factors towards Open Building as well as the opportunities and threats of further development.

Inertia on Open Building
According to Habraken, the conventional way of designing dwellings can best be characterized as a continued process of "re-inventing the wheel", which hampers Open Building (OB). Van Randen mentioned the uniqueness and one-off characteristics of projects; thinking something new for every project.
Moreover, the traditional project organization itself is the most important impediment of Open building. Lichtenberg explains that innovations, especially Open Building Systems, are implemented in the market through projects. Typically the market consists of projects through which OB must be communicated with the market. Habraken, Van Randen and Lichtenberg mentioned that during the process many firms and actors are involved based on a fragmented and scattered division of roles, responsibilities and decision-making. All the actors need to be convinced of OB and OB innovations before it will be adopted and implemented in the project. And also Post experiences the building process of OB projects as difficult, due to the many layers in the process through which OB must be communicated.
According to Lichtenberg, firms feel very uncomfortable to change towards OB (relationships) because they are programmed for a specific task. When firms are confronted with other tasks, they consider those tasks as risky because they are not adjusted to these new tasks.
Besides the riskiness of financial loss, Habraken and Cuperus mentioned that construction firms are reluctant to relinquish former attainments. For example, architects have to design structures with predetermined Open Building Systems and contractors only erect the support system (and thus not the infill) based on different decision-making levels.
Thus as Lichtenberg generalizes, in construction, a project-based industry, there is a long organizational chain between the innovator and the beneficiary, which impedes diffusion. The challenging task of the innovator consists of convincing all the stakeholders of the advantages of Open Building (or any other innovation).

Habraken explains that conventional projects rely on floor plans. Firms, like financiers, contractors, engineers and architects base their work on floor plans. The involvement of many actors complicates the composition of the floor plan and the complexity increases when the end-users will be involved accordingly to OB. With limited influence of end-users there arises a mismatch between the floor plan and end-users demands. Therefore the 'system' should be reshaped around end-users as suggested by OB.
However, why should construction firms change the system, to which they are used to, when they still make money with conventional floor plan? In addition, Post observed that OB projects, where buildings are assembled in an intelligent user-friendly way, are not of interest of the industry as long as construction firms earn money with conventional projects. Also Lichtenberg came to this conclusion. The willingness of organizations to accept Open Building depends on organizations' attitude towards change. As Lichtenberg mentioned; 'to innovate, organizations need to accept something new, but above all give way old routines'.
Furthermore Post remarked that OB only could be successful when supply and demand are complementary to each other. However, without a client demand about flexibility, the construction industry will not likely invest in the development of interdependent interfaces.

Market demand concerning flexibility failed to occur because adaptability of building structures is esteemed by the market as a hidden quality. Moreover, accordance Habraken organizations need to adapt their collaboration on projects in accordance with the developed system; otherwise the building system has no market potential (because it could not be a competitive alternative). Furthermore, when organizations adapt to the system it will stimulate new developments.

Van Randen mentioned legislation as an impediment of Open Building. However, Habraken en Post both mentioned legislation as an incentive of Open Building. From the interviews with the founding fathers it is concluded that some types of prescriptive based legislation could be inertia on OB like the municipal zoning pan, while some types of performance based legislation could be incentives towards OB.

Other inertia on OB mentioned by the early promoters are:

- The small percentage of total investment in Research and Development;
- Dwelling have a high intensity of installation per square meter and this complicates the development of Open Building in house-building;
- The (inter)dependencies of components hampers the implementation of OB in practice. The interfaces between prefabricated parts are not well developed accordance Van Randen. In addition, Lichtenberg mentioned that interfaces between components within systems require (de)mountability to be flexible or adaptable. However, interfaces are complex due to the many actors involved to realize a particular interface.

Opportunities for Open Building

Habraken claims that the discrepancy of customization between cars, clothing, et cetera versus dwellings will result in a breakthrough of OB. However, programs like IFD-building could not be seen as an initiative which stimulates a breakthrough. Furthermore, these initiatives must be seen as a search for a possible directive of development.

The balance between price and quality was mentioned by the founding fathers as an incentive to OB. Habraken explains that the harmonization between the functional lice-cycle and the technical life-cycle (up to 200 years), means the optimal use of capital. This prevents unnecessary demolishing of building components which could last for many years. In contrast, Post suggests constructing buildings for a limited period of time (20 years), because for short periods reasonable estimations could be made of user demands. After 20 years user demands change dramatically and therefore small changes are not sufficient to meet these demands. Constructing for a period of 200 years is very expensive and the estimation of how the building will be used in this period are hard to make.

Labor could be another incentive accordance Lichtenberg and Post. Lichtenberg explains that increasing labor costs on the construction site stimulates industrialization. In addition, Post remarks that higher quality demands and the ambition to realize buildings in a shorter period of time stimulates industrializations and thus could stimulate dry (de)mountable interfaces. Thus, changing labor circumstances could offer new opportunities to OB. This is clearly described by Van Randen; the objective to create as few as possible (inter)dependencies between systems, so that short-term systems could be replaced without any alterations to the long-term systems. Therefore consciousness is required about the need to consider future use of building structures during the design stage, this life-cycle approach stimulates flexibility accordance Post.

Compensating mechanism

First, Habraken suggests formalizing an infill industry (contracts, norms, recognition, et cetera). Secondly, Habraken proposes single point responsibility, or more specific; make firms responsible for the process, logistics and organization of OB projects. Habraken referred to Sekisui, Japan, as an example of a successful innovative open building system for the home-building industry. The concept is based on a stale framework to which standard components from the market are added to construct a fully customized dwelling. The organizational set up is based on a single point responsibility for a more efficient construction process and to simplify the project organization, especially for the customer.

Also in the Netherlands there are initiatives to simplify the project organization and lower the number of contact points in the construction process. Lichtenberg referred to an initiative called Industrial Building 2015 (IB2015), which aims for an Open Systems Building approach with a central role for the industry. The program focuses at five main principles: 1) decoupling of building components, 2) conceptual solutions, 3) industrial connections (interfaces), 4) Building Information Modeling (BIM) and 5) full-service. The current discussion involves the division of roles; who should coordinate and/or fulfill the pioneering role.

Accordance to Habraken and Post, legislation could be an important incentive to OB when designed properly. The Japanese long-term-housing act, an example to which Habraken referred, stimulates sustainable innovation, the act balances between prescriptive and performance based legislation. The end-user could achieve a considerable fiscal advantage when a constructed building as a whole lasts for 200 years. This stimulates market demand for sustainable buildings which subsequently results in pressure on the construction industry to develop sustainable buildings.

Both Van Randen and Lichtenberg explained that the complexity of interfaces results from the many involved actors which affect the interface design. Van Randen suggests an interface specialist; however another actor in an already fragmented industry could result in a diminished coherence within the interface. Lichtenberg defined an interface as a set of design rules, the virtual interface. However, the interface could also be a physical connection. Anyway, it is the task of actors to agree upon design rules and when there is no agreement among actors an adaptor or intermediary-interface could be a solution.

Market demand could also be an important compensating mechanism to overcome inertia on OB accordance to Lichtenberg and Post. Post claims that no OB developments in the industry will take place when there is no clear client demand. Profit oriented construction firms could be stimulated in developing OB solution by holding out the prospect of future sales or projects, accordance Lichtenberg.

Table 1: Inertia on Open Building

	Respondents				
	John Habraken	**Age van Randen**	**Ype Cuperus**	**Jos Lichtenberg**	**Jouke Post**
Impediments	-It is re-inventing the wheel for every project, a characterization of project-based production that impedes the development of Open Building. -Dwellings has a high intensity of installation per square meter this complicates the development of Open Building in house-building. Construction firms still try to optimize conventional construction methods and believe that Open Building is too complex; the introduction of Open Building means restructuring the division of roles and responsibilities around projects. -The conventional construction process relies on floor plans; financiers, contractors, engineers, architects base their work on floor plans. The involvement of many actors complicates the composition of the floor plan and the complexity increases when the end-users will be involved. Therefore the system should reshape the way towards client involvement. However, why should construction firms change the system, to which they are used to, when they still make money with conventional building? -Construction firms fear the unknown and the risk of losing revenues. -Construction firms are reluctant to relinquish former attainments.	-Construction projects are characterized by improvisation; thinking of something new for every project. -Legislation hampers the development of Open Building. -The complexity of working together with many actors restrains Open Building. -The (inter)dependencies of components hampers the implementation of Open Building in practice. The interfaces between prefabricated parts are not well developed.	-Modular Coordination (MC) (design rules for size and place to formalize Open Building in design) has never been implemented, because: (1) the opposition of architects based on the argument that MC restricts freedom of design, (2) MC focused on industrialization which in that days was open to negative publicity, (3) some firms could apply the design rules with only small adaptations while other had to change / invest heavily, (4) some firms tend to lose the competition because products of competitors where easier applicable, and (5) the design rules where too complex.	-During the building process many firms are involved. The construction process is programmed around fragmented disciplines. Due to this fragmentation alternative organization forms are hard to achieve. - All construction firms involved in a project must be convinced of OB. - Interfaces between components within systems require (de)mountability to be adaptable. However, interfaces are complex due to the many actors involved to realize a particular interface. -Firms are programmed to perform a specific task. When firms are confronted with other tasks, firms consider these tasks as risky. - The innovation inertia: OB is accepting something new, but above all overcoming old routines. - Only a very small part of total investments in construction is spend on research and development. - There are no organizations in the industry with enough importance (like Apple, Toyota) that could, top-down, stimulates OB. There are many small to medium-sized enterprises (SME) which have to collaborate in OB projects (and thus stimulating OB bottom-up).	-The building process of Open Building projects goes very slowly with many difficulties, due to the many layers in the process through which Open Building must be communicated. -Open Building could only by successful when supply and demand are complementary to each other. Therefore it is necessary that construction firms change the way they operate in projects towards Open Building. -The market describes flexibility as a hidden quality; only few demands flexibility in projects. Therefore, legislation could formalize flexibility with respect to sustainability. - Open Building projects, where buildings are assembled in a intelligent and user-friendly way, are not of interest of the industry as long as construction firms earn money with conventional projects.

Table 2: Opportunities for Open Building

	Respondents				
	John Habraken	**Age van Randen**	**Ype Cuperus**	**Jos Lichtenberg**	**Jouke Post**
Opportunities	-The discrepancy between customized options for cars, clothing and suchlike, and the few customized options for dwellings stimulates a breakthrough of Open Building. -Programs like Industrial, Flexible and Demountable (IFD) building could not be seen as body of thoughts which stimulates a breakthrough. However, these programs could be seen as a search for a possible directive of development. -The harmonization between the functional life-cycle and the technical life-cycle (up to 200 years) means the optimal use of capital. This prevents unnecessary demolishing of building components which could last for many years.	-The objective is to create as few as possible dependencies between systems, so that short-term systems could be replaced without any alterations to the long-term system.		-Increasing labor costs on the construction site stimulates industrialization.	-Consciously about the need to consider future use of building structures during the design stage stimulates flexibility (life-cycle approach). -Higher quality demands and ambition to realize buildings in a shorter period of time stimulates industrialization in construction, and thus could stimulate dry (de)mountable interfaces. -Buildings should be constructed for a limited period of time (20 years), because for short periods reasonable estimations could be made of user demands. After 20 years user demands changed dramatically and therefore small changes are not sufficient to meet these demands. Constructing for a period of 200 years is very expensive and the estimation of how the building will be used in this period are hard to make.

Table 3: Compensating mechanisms inertia on Open Building

	Respondents				
	John Habraken	**Age van Randen**	**Ype Cuperus**	**Jos Lichtenberg**	**Jouke Post**
Compensating mechanisms	-Formalization (collaborations, contracts, norms, recognition et cetera) of an infill industry. -Balance between price and quality. -Introduction of 'single point responsibility' like Sekisui (Japan) and Tokoman (Finland). Firms are responsible for the process and they arrange the logistics and organization. -Legislation and governmental policy could stimulates OB: the Japanese long-term housing act, which requires building structures to last 200 years, in combination with fiscal benefits stimulates market demand.	-The many involved actors influence the interface design. An interface specialist could be the solution; however a new role is created in an already fragmented industry. As a result the coherence diminishes.		-The complexity of interface results from the many involved actors. An interface could be a design rule; the virtual interface. The interface could also be a physical connection. It is primarily the task of actors to agree upon design rules. Without this agreement, an adapter or intermediary-interface could be a solution. -The innovation program 'Industrial Building 2015' (IB2015) tries to diminish the number of firms to maximum 4-6 main firms. This is a bottom-up approach of projects towards a more efficient and convenient construction process. -The market consists of a certain collection of projects. And for every project many firms need to be convinced of Open Building. Therefore, a certain sale of Open Building projects, introduced by clients, stimulates Open Building.	

Discussion

Open Building, despite its 50th birthday, is still not applied at a broad scale. However, today there are new opportunities for Open Building. First of all, consumers are more demanding than ever. They want to have a say in the design of their future house and have clear demands about what it is they want. Second, sustainability has become much more important, which in the philosophy of Open Building is a key role. Third, the building process nowadays is expensive due to an increased number of parties involved in the process, resulting in communication problems and higher failure costs that are for the expense of the customer and are calculated in and higher price of the building. Therefore, nowadays more importance is given to the extension of the lifecycle of buildings to be able to spread out the costs over a longer period of time. Fourth, there is an ongoing development of increased willingness of companies to cooperate and develop products and systems together, in which Open Platforms plays an important role.
Conventional buildings are developed in a form of closed (static) systems, due to the fixed integration of technical systems into functional building systems. Due to this high level of functional and material integration, it is usually impossible to remove components in order to replace or exchange them. This is the reason why closed building systems are not suitable for easy transformation and cannot adapt to changes in user requirements. Therefore, to achieve adaptability of buildings, an open system is needed. The main difference between a closed and an open system is the separation and decoupling of sub-assemblies that have different functional and life cycle expectancies [Durmisevic, 2006]. To achieve this, a carefully designed systematization of building components into independent subsystems in a hierarchical order is needed. For such systematization, the design of common interfaces that allow independency between components is required. If this can be achieved, a building can consist of different modules that can be independently upgraded, reconfigured, replaced or added. The different modules together can then form a category of components that can be assembled with standardized interfaces. Open Systems Building (OSB) is a framework to achieve this and can be seen as a realization of Open Building.

According to Gann and Salter, construction should be viewed as a process rather than an industry: ‘it includes designing, maintaining and adapting the built environment, involving many organizations from a range of industrial sectors, temporarily working together on project-specific task’ [Gann and Salter, 2000]. Reasoning for this definition could be the following characteristics of construction: ‘the physical substance of a house is a pile of materials assembled from widely scattered sources. They undergo different kinds and degrees of processing in large numbers of places, require many types of handling over periods that vary greatly in length, and use the services of a multitude of people organized into many different sorts of business entity’[Cox and Goodman, 1956]. Gann and Salter’s definition is emphasized by Habraken’s distinction between support and infill. Besides a physically separation of building systems also a distinction between decision-making units and responsibilities, this clear the way, as Habraken puts it, for a support and infill industry.

Construction projects are a gathering of complex product systems, characterized by (1) many interconnected and customized elements organized in a hierarchical way, (2) nonlinear and continuously emerging properties where small changes to one element of the system can lead to large changes elsewhere in the system and (3) a high degree of user involvement in the innovation process [Winch, 1998]. Dubois and Gadde divided complexity in construction in two main categories [Dubois and Gadde, 2002]. The first category encompasses the uncertainty in the undertaking of individual activities which has four causes, (1) management

is unfamiliar with local resources and the local environment, (2) lack of complete specification for the activities at the construction site, (3) lack of uniformity of materials, work, and teams with regard to place and time (every project is unique), and (4) unpredictability of the environment. As a result, centralized decision-making is difficult to apply and this leads to decentralization of authority. The second category is associated with three factors of operational interdependence in construction [Gidado, 1996], (1) the number of technologies and the interdependence among them, (2) the rigidity of sequence between the various main operations, and (3) the overlap of stages or elements of construction. Furthermore, complex product systems need to be adjusted at the construction site, because of (1) the lack of complete specification, (2) lack of uniformity and (3) an unpredictable environment [Dubois and Gadde, 2002]. This supports the research findings of the interview with the founding fathers of Open Building. It describes in general the inertia on Open Building mentioned by Van Randen, Lichtenberg and Post.

Project-based firms in the construction process are focused on individual projects. The realization of projects is based on combining technical expertise from other organizations [Gann and Salter, 2000; Dubois and Gadde, 2002]. Furthermore, the role of an individual firm is very different among projects; because the division of labor among the actors varies greatly form project to project [Dubois and Gadde, 2000]. As mentioned by Habraken and found by Gann and Salter [Gann and Salter, 2000] it is re-inventing the wheel that characterize project-based production. Gann and Salter found that there are limited links across business units and individual projects. Therefore, the rate of organizational learning of Open Building projects is very low.

According to Gann and Salter firms need to integrate the experiences of projects into their continuous business processes in order to ensure the coherence of the organization, especially according to Open Building projects.

Furthermore, adoption decisions by firms concerning Open Building have to be implemented in projects. As mentioned, projects are collaborative engagements with other firms and as a result Open Building has to be negotiated within the project coalition. A firms' ability to do this, the role of the champion, will be strongly influenced by its role in the coalition [Winch, 1998]. This was also literal mentioned by Lichtenberg.

Open Building needs a champion [Schilling, 2000; Rogers, 2003]. According to Rogers, a champion is 'a charismatic individual who throws his or her weight behind an innovation, thus overcoming indifference or resistance that the new idea may provoke in an organization' [Rogers, 2003]. In construction, the champion can come from every part of the industry. Pries and Janszen and Lichtenberg found that champions typically come from component suppliers [Pries and Janszen, 1995; Lichtenberg, 2002]. This was also suggested by Lichtenberg and Post.

A compensating mechanism for the inertia on Open Building could be *the broker* [Winch, 1998; Rogers, 2004; Winch and Courtney, 2007]. According to Winch and Courtney, a broker is a distinctive type of actor in networks or actor that links other actors in the network [Winch and Courtney, 2007]. However, who should take the broker-role regarding Open Building? As mentioned by the founding fathers as well as several scholars [Dubois and Gadde, 2002; Hofman, 2010] construction firms should look for ways to reconfigure their short-term vision based organizations and project coalitions to long-term setup to encounter the challenges of future construction.

Traditionally, the principal architect or engineer and the principal contractor act as systems integrators, a broker-role between clients, regulators, professional institutions, trade contractors (specialized suppliers), specialized consultants and components suppliers [Winch,

1998; Miller et al., 1995]. The latter three could act as Open Building champions as mentioned before. Typically, construction has two separate system integrators, due to the distinction between the design stage and the construction stage. Therefore, the role is shared by the architect/engineer and contractor. As a result the systems integrator role is less effective. In addition, architects displays competence in regulatory frameworks and clients requirements, but are not equipped to integrate all technical systems into a building. Also the contractor's integration capabilities are typically restricted to the managerial rather than technical level [Winch, 1998]. Thus, the Open Building systems integrator has three functions (1) the skills to integrate interdependent components into a coherent whole, (2) detailed knowledge of client requirements, and (3) knowledge of the rules and regulations governing the industry [Miller, et al.; 1995]. Therefore, and as found in the research date, it is questionable or the architect and/or contractor should fulfill the broker role. However, Nam and Tatum demonstrated that the role of the architect and contractor is decisive in the success of Open Building. The systems integrator, although still questionable or this not could be a specialized supplier for example, must be convinced of the merits otherwise implementation will be slow [Nam and Tatum, 1997].
Winch and Courtney suggests that independent and objective organizations should take the liaison role between firms that are otherwise not connected. They could add value to the development of Open Building by validating new ideas, act as auditor. They could also act as an intermediary between supply and demand site by shaping the definitions of research problems and shaping the practice of implementation. However, almost every discipline is separately represented by a professional body. This weakens their ability to act as a broker of Open Building as they typically threaten the interest of only a particularly set of actors [Winch, 1998]. Thus, until know the Open Building broker did not come forward yet.

Rogers' defined five perceived attributes of innovations, (1) relative advantage perceived by individuals, (2) compatibility with the values and norms of a social system, (3) complexity, (4) trialability, and (5) observability or the visibility of the results of an innovation [Rogers, 2003]. To be adopted Open Building needs a relative advantage regarding conventional building as mentioned by the respondents and several scholars. For example, it solves technical difficulties or meet social requirements better than traditional solutions [Ling et al., 2007; Hartman et al., 2006; Hartmann et al., 2008]. Firms who make efforts to implement Open Building should stress the problem-solving rather than the performance-improvement aspects of Open Building [Ling et al. 2007]. Most importantly, clients' sponsorship is essential for the successful implementation of Open Building [Nam and Tatum, 1997]. In general, without an adequate incentive structure than it is unlikely that Open Building take place. In the case of Open Building Systems it is necessary to develop a long-term gain sharing approach. This means a shift form competitive tendering toward partnering. It is assumed that competitive tendering explains the use of standardized building parts used in conventional buildings.
Therefore, competitive tendering hampers customized solutions [Winch, 1998; Dubois and Gadde, 2002]. However, despite the opportunities for high-involvement relationships, taking the step to strategic partnerships would require modification of some of the basic construction norms, like the current focus on the efficiency of individual projects and competitive tendering [Dubois and Gadde, 2000; Gadde and Dubois, 2010]. Thus, as several scholars indicated project organizations are loosely coupled [Brusoni et al., 2001; Dubois and Gadde, 2002; Hofman, 2010]. In contrary with loose coupling, the development of Open Building requires tight organizational coupling [Brusoni et al., 2001; Hofman, 2010].
The founding fathers believed that legislation could stimulate Open Building. Like the Japanese long-term-housing act, so called performance standards, maybe be an appropriate

form for encouraging systemic technological change. Performance standards specifies minimum building requirements, however they does not prescribe the means or components [Gann et al., 1998].
In addition, compared to manufacturing firms of other industries, traditional construction firms are less open to the external environment, they are less market oriented. The nature of the market strongly influences the potential of Open Building; local markets can often mean undemanding customers. Furthermore, firms do not need to change to Open Building to remain successful or viable at all as long as they meet local needs, responding to regulation and adopt new technologies form their suppliers and customers [Reichstein et al, 2005].

Limitations and implications for further research

Only few interviews (5) were conducted in one country (the Netherlands). No interviews were conducted among scholars and practitioners who are making contributions to Open Building today. Perhaps it is more important to speak with (professional) clients, especially housing corporation, who rejects and/or rejected Open Building in the past. Therefore, a broad survey among stakeholders could gain more complete insight into the inertia on Open Building and its possible compensating mechanisms.
Although the limited interview data was verified in literature, there is no guarantee that the data is complete and unbiased. There is also no insight in the interrelation between impeding factors as well as compensating mechanism. The innovation behavior of construction firms have been subject of several scholars. Only few scholars paid attention to the adoption and implementation of Open Building, where Open Building Systems are hold as systemic innovations. A review of literature around 'innovation behavior of construction firms' and 'adoption and implementation of systemic innovation in construction' could provide more insight in the state of the art concerning the implementation of Open Building Systems and other innovations in practice. Furthermore, only few contributions have been made to formulate 'design rules' for Open Building Systems and its adoption and implementation process and in addition applying and testing those design rules.

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