Collaborative Mass Housing Design Practice with Smart Models

Tian Tian LO[1], Marc Aurel SCHNABEL[2] and Yan GAO[3]

[1,2]*The Chinese University of Hong Kong,* [3]*University of Hong Kong*

[1]*http://www.arch.cuhk.edu.hk,* [2]*http://aurel.tk/,* [3]*http://fac.arch.hku.hk/staff/gao-yan/*

[1]*skyduo@gmail.com,* [2]*marcaurel@cuhk.edu.hk,* [3]*yangao@hku.hk*

Abstract. Mass housing, due to its repetitive patterns, provides great opportunities for the rule-based parametric design. Design rules and logics can be formulated to generate various design solutions, also known as rule-based design process. In addition, mass housing design ought to be a complex process that involves not only the architects, developers and contractors, but also ideally, includes the users. In reality, however, the users are always excluded during the design process as there is no such a system that provides simple, effective and feasible design communication mechanisms. This meta-paper aims to collates and presents all possible parameters that are affiliated with mass housing. It will explore into various levels of scales from urban to building-units to map out the interconnected relationships. The outcomes open up new possibilities to apply parametric modeling in mass housing design practice.

Keywords. Mass housing; open building; rule-based parametric; open-source architecture; collaborative design system

Introduction

At present, the increasing population of city dwellers has resulted in an increase of densities and limitations of urban land resources. This has led to a higher demand of high-rise residential buildings, yet did not respond to affordability – a pertinent social problem. In response, governments of cities are veering towards mass social housing schemes which have become a commonality of populated cities like Singapore, Hong Kong and many other Asian cities.

Those schemes were very successful in providing housing for the people. However, as most mass social housing designs are carried out by the governments who value economy and cost more than anything else, the design of the social-housing often shrinks to the most basic fitness. This is particular true in large-scale projects for tenants with lower incomes when in actuality. With the abundance of powerful computer aided design tools, such buildings have as much potential as commercial buildings for more humanistic designs. 'Stellar' designs can be granted to all, and not just for the selected few.

Open Building and Collaborative Design

Open Building is an approach for building design that was recognized internationally during the sixties to represent a new wave in the architectural field [1]. John Habraken (1961) commented that housing must always recognize two domains of actions - the action of the community and that of the inhabitants. Without the individual inhabitant, the result is usually uniform and brutal, which we can see in most mass housing projects nowadays. On the other hand, without the design control, the spontaneous result will be chaotic and disturbing [2]. The coherent balance between the individual participation and the top-down design manipulation is challenging as it involves all parties during the building process, which ideally led by the building maters - the architects.

Three levels of decision making need to be spelled out, namely the *Tissue,* the *Support* and the *Infill.* They are separated, yet dependent. 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 consistent. The buildings in turn can be divided into the base building (support level) and the fit-out (infill level). The higher level (support) accommodates and limits the lower level (infill), which in turn determines its requirements towards the higher (Cuperus, 2001). 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).

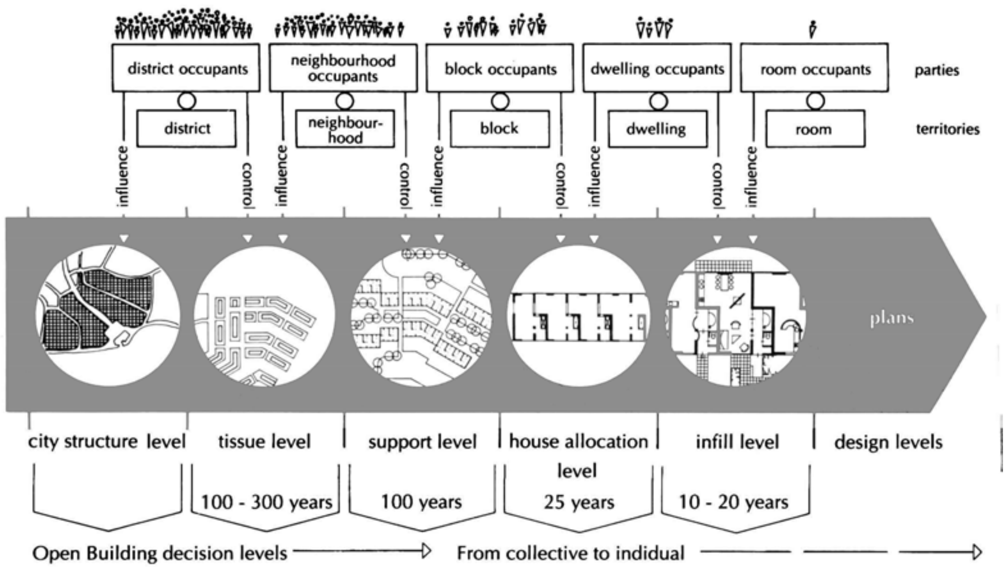

Figure 1
Levels of decision making (Kendall, Teicher,2010).

The focus of this paper is at the infill level where it involves the group of occupants which constantly change every 10-20 years. In mass housing, especially in the high-rise context, the changes are usually limited by the fixed floor layout. The new occupants usually have to accustom themselves to the design instead of the other way round. With the use of current design technologies and techniques, such as the modular fabricated units, and the parametric systems, the big question is how do we keep the modularity yet allow individuality. This paper aims to propose a design system that allows building prototypes for series and to promote dynamism in housing.

Two main issues are to be discussed. Firstly, the collaboration with the individual occupants in the design process to achieve uniqueness; next, how to accommodate its occupants, who seems inevitably subjected to constant changes. In order to understand its advantages, let's have a quick look at some built precedents.

Ökohaus, Berlin, Germany

The *Ökohaus* project (Eco-home), is a project conducted by Frei Otto and Herman Kendell in 1988 for *the Internationale Bau Ausstellung* (IBA) exhibition. It is a collective housing which exercises user participation and open design. Frei Otto sees this as an opportunity to consider new ways of living in high-density urban context. Every occupant participates in the design with the help of the architects just like they are building a detached house individually. This is made possible with the structure raised independently to frame each unique unit design. Construction of each housing unit was also done individually.

The whole collaboration process was conducted manually (Figure 2, left) and the participatory process itself took two years. However, the result was an attractive yet unusual collage of living molecules that represent each occupant's best demands. The building coexists in harmony, generating an urban ecosystem filled with richness and diversity [4]. In addition, the self-management nature of the process has created a very strong sense of community with personal satisfaction and the sense of belonging for each tenant.

Next21, Osaka, Japan

Next21 (Figure 2, right) is an experimental multi-family housing project demonstrating the new concept of multi-family housing units that incorporates sustainable design methods and advanced technologies which are expected to be used in the near future. The building consists of 18 individual housing units, which were designed by 13 different architects. For this project, the focus is more on the building system itself instead of the collaboration process as compared to the previous example (Kim et al, 1993). Specific design strategies are generated from the framework of two principal concepts, the system building and the two-stage building.

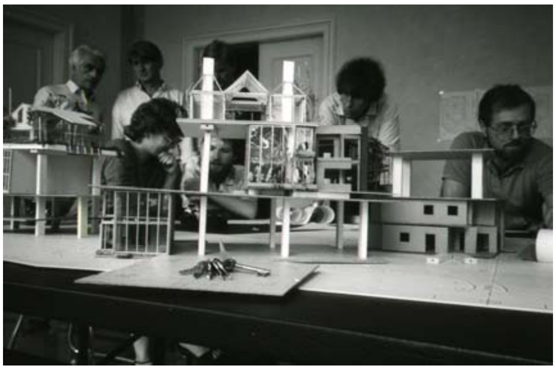

Figure 2
Manual collaboration and self-management design process (left). (Photo courtesy of Jorge Giménez Arias).
NEXT21 with its distinct infrastructure and infill (right) [5].

The INO Hospital Project, Bern, Switzerland(Kendall, 2005)

The *INO Hospital* is the most recent project to adopt the open building strategy. It is a 50,000-square-meter expansion to a large university hospital campus in Bern. In this example, the building is broken down into 3 systems, each lasting a certain period of time. As this is a hospital typology, the primary system is the base building infrastructure aiming to accommodate the secondary system of changing departmental sizes and changing zoning layout such as emergency, imaging, surgery and pharmacy departments. These two systems are intended to last 100 and 20 years respectively. The last tertiary system in includes the equipment, finishes and furnishing which were intended to last only 5-10 years (Kendall, 2005).

The uniqueness of this project is the design process. Three competitions were set up for the selection of architects for each system. The architect of the first had to design a plan without the secondary system, i.e. detailed programmatic information, by another architect team (Figure 3), who subsequently designed a flexible infill layout for the future changes. Lastly the tertiary design filled in the remaining blank area. Although each system tried to incorporate with each other, the independent multi-system system reduced the organizational problem in coordination of the future uncertainties.

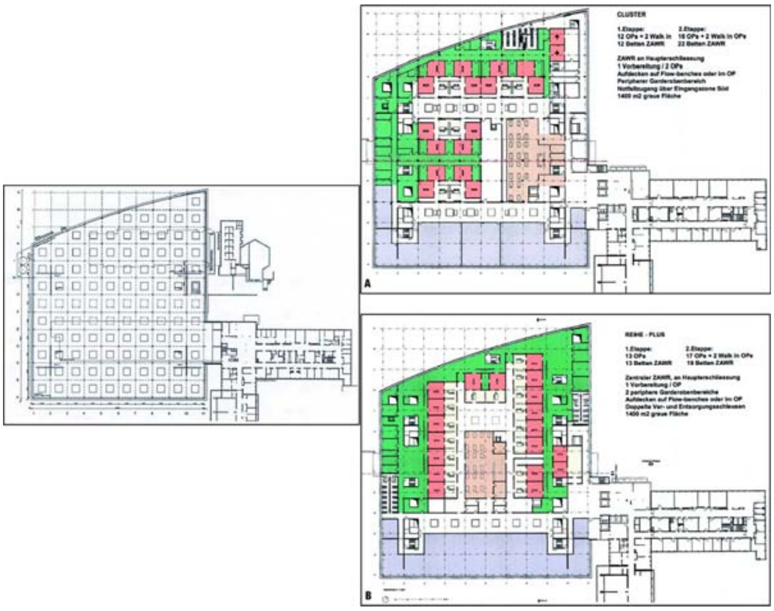

Figure 3
Base Building plan (left) and two infill layout proposals (right) [6].

Existing Technology for Collaborative Design

From the three examples above, communication with the occupants is done manually. It is still manageable as the project scale is either small or the clients are only a small group of people. Despite the use of some technology in generating design, such as in the INO project, the collaboration process is still very primitive.

In the context of mass-housing, which usually involve medium to high rise buildings, manual communication and management is impossible for collaboration purposes. There is a need for a better communication system to encourage more collaborative and participation in design process.

Building Information Modeling (BIM) was introduced as a system that generates and represents architecture elements as objects instead of lines and planes. Coupled with its collaborative flexibility and easy information exchange among professions, it advocates convenient collaboration that saves time and cost for building construction. More resources can therefore be spent in bringing more community involvement into the design process.

The community can participate in a Virtual environment (VE). VE is a useful platform for architects to communicate with the community. In accordance to the likes of social network systems, VE, with its added support in visualization and engagement, can be used by architects to generate and develop design while maintaining close communication with the community. Furthermore, VE provides simulation results that are more intuitive for interpretation, hence facilitating discussion among the various groups.

Designs can then be customized in mass for the community using parametric design techniques. These complex visuals can be articulated when surfaces are defined digitally with algorithms. The easy manipulation of the virtual 3D-design is able to generate a wide variety of design options in the VE at a significant low cost, which provide an incentive for more architects to adopt this system.

Indeed, there are numerous Computer-Aided Design (CAD) software which offer design freedom to architects. However, many are simply too sophisticated for non-professionals. Unless one has prior experience in the design field, it is likely that he will find it inconvenient to use. On the contrary, open source code is useful tool to be utilized in computer software, as that would provide a means to create a simplified interface for a layman user.

The involvement of the community in the design process could greatly change the position of the architects. Instead of taking full control of the design, they will manage the ideas generated to create a more community-based architecture – replacing rigid geometrical forms with dynamic and participatory processes, networks, and systems. This paper will investigate such possibilities. This open system might also give transparency to the design decisions, hence justifying clearly why some designs are much preferred over others.

Building Parameters and Algorithms

Apart from the design technology advancement, building design methodology in terms of ideas and construction methods have also progressed to a great extend providing greater opportunities in creating building systems for design collaboration.

Starting from Le Corbusier's 5 points of architecture (Bech, 1996), his free plan and free façade incorporating the pilotis (foundation posts/columns) have already contributed to the possibilities of flexible and dynamic planning outcomes. The continuous string of the windows provides view of the exterior and introduces daylight into the interior. Together with the last point, the roof garden, they provide good building quality to the occupants. With a flexible housing system, occupants could dictate how the windows and greenery are laid out in their unit design.

Parameterizing design in line with BIM is being explored and experimented by many architects and students. Frank Genry and Zaha Hadid for example are using parametric design instruments to generate specific design outcomes which were almost impossible to realize a few decades earlier. Digital tools such as '*Grasshopper*' with *Rhino3D*™ or *Generative Components*™ have simplified the parameterizing of model such that designers can now use a network of nodes to generate buildings.

By breaking down housing units into sophisticated parameters, to the extent that every wall, windows, furniture, equipment and doors become digital components, it allows great flexibility in generating a different type of floor plans with the click of buttons (Figure 4). By employing specific algorithms or methodologies such as *Shape Grammar* or *Space Syntax* one can generate as much possibilities in terms of geometric forms and layout possibilities with the help of computers (Benros et al, 2007). Hereby defined constraints are introduced in such a way that design solutions are diverging to one that suits the users and fits the overall context of the building.

Module systems can be scripted into design manuals to overcome the problems of mismatching, to optimize product structures, and to coordinate among the involved parties. Hereby the alignment of a design process with the actual product-management allows for innovation to happen that keeps intact a given multi-modular building system. This is facilitated through accessible data, and digital technologies (Gao et al, 2012).

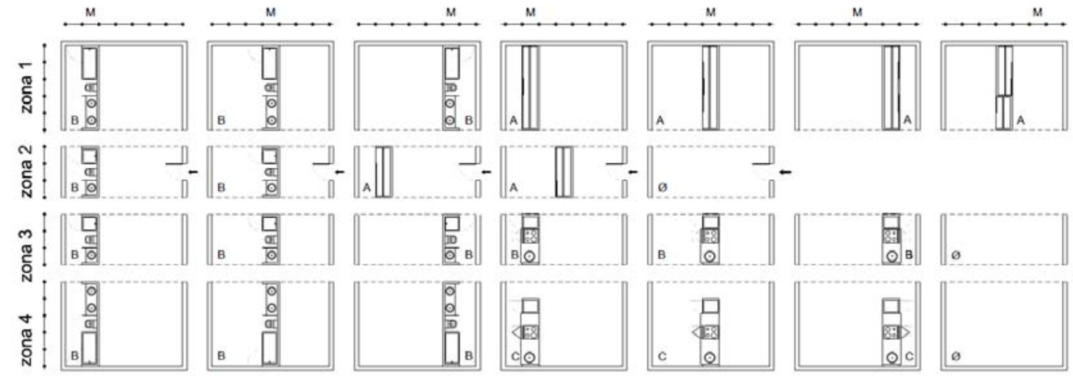

Figure 4
Flexible plan layout (Benros et al, 2007).

With so much parameters and constrains at hand, the method has advanced to a stage where human mind is incapable of keeping track of each design solutions. Optimization becomes the next strategy in helping designers filter through all the solutions generated. User preferences are input into the computer with the help of certain formulas to let the computer generate optimized solutions.

The design technologies and methodologies described provide great opportunities in creating a system that allows users' participation in design processes. Especially in the context of mass housing, with a strong and flexible framework structure, there is only a need to look through all the available design systems and tools to look at which one or few is suitable to be integrated for a system that allows mass participation to generate a mass customized residential building.

Barcode Housing

Most of the tools created at present target housing units or single floor plans. The closest form of participatory design system recently developed is the "Barcode Housing System" (Madrazo et al, 2009), which allows the prospective occupants to adjust their plan layout according to their needs (Figure 5). The architects will then collate all the designs, stack them up respectively and design a façade that will make the housing building look as a whole.

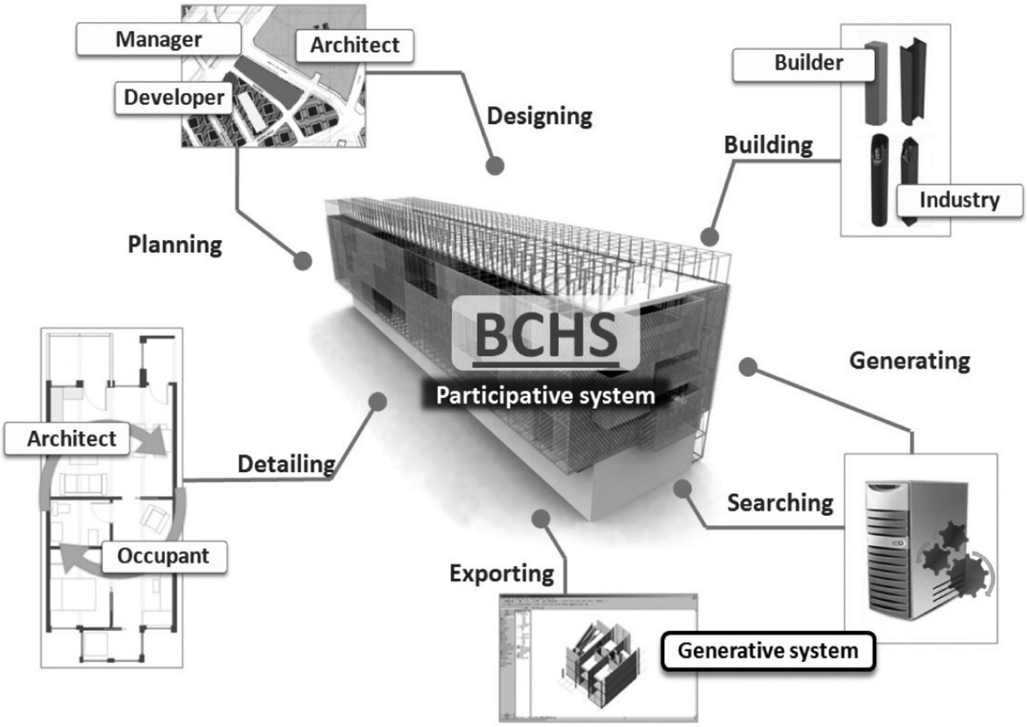

Figure 5
Actors and actions taking place in the environment (Madrazo et al, 2009).

However, this system though successful within a certain extent, has no platform for collective communication and discussion as compared to method used for the Ökohaus. Moreover, the users are only able to adjust their floor plan layout but not the overall location of their units. Constrains of the design are still very inflexible and don't offer dynamic design solutions. The system also does not consider future changes by employing a flexible spatial layout.

A Proposed User-Participatory System

Open-source architecture (OsA) is a new system initiated by the Open-source Council. [3]. It recognizes the layperson as decision-making agents instead of being just consumers A building, its design, context and relationship is generated using BIM and parametric models. Hence is appears easy to use the exiting data-models of a building and apply it in the process of creating mass housing. However, only a few have attempted to use the relevant models go beyond the formal production of the building.

Buildings are still designed autonomously by architects, giving tenants limited sense of ownership (Figure 6) until they purchased the unit. Moreover, though the architects design ideologies are well-intentioned, the lack of community's active involvement during the delivery process can result in a largely biased and sometimes inappropriate design judgment. Thirdly, there is also an important issue to accommodate many different needs of the residents in a mass social housing; this is not withstanding the common inefficiency of mass discussion, which may just as easily deter the architect from giving up his autonomous design role.

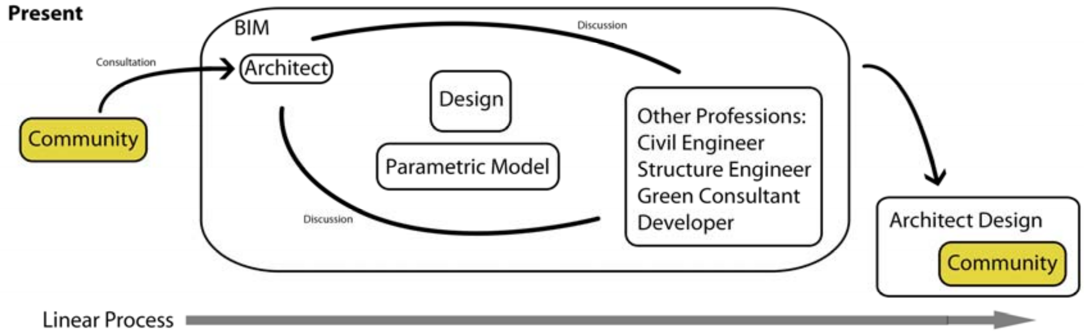

Figure 6
The community being excluded throughout the building process.

Such challenges demand one to relook into an existing culture and suggest striking a balance between collaboration with the community and the project team. If so, a system such as an OsA, with reference to the Open Building by John Habraken (1961), could be a method to address these challenges, while a well-functioning interface within the system may just provide solutions to a prevalent design problem (Figure 7).

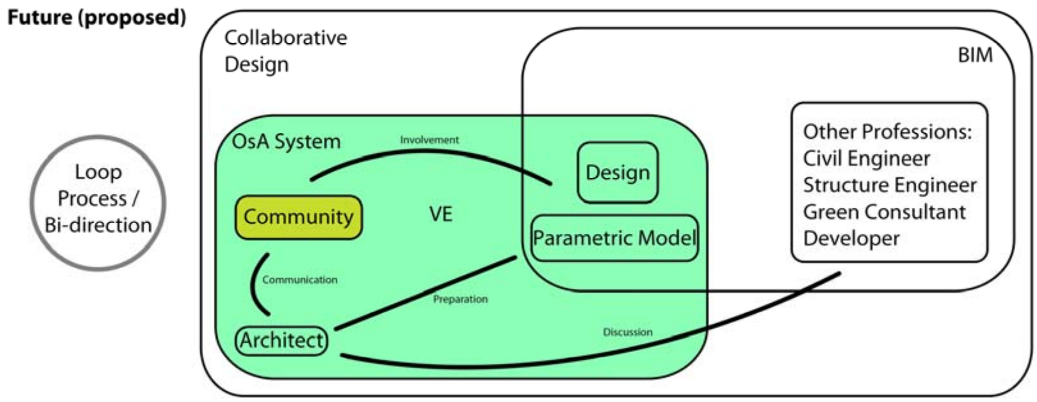

Figure 7
Involvement of community and interaction with the architect with the proposed system.

The potential of OsA recognizes the basic role of each individual user at every stage of the building process, from developers to communities, architects to occupants. An open source article headed by Carlo Ratti (2011) meaningfully describes OsA as being able to harness powerful network effects to scale systems effectively. It is typically democratic, enshrining principles of open access and participation, through political variations range from stealth authoritarianism to communitarian 'concensualism' (Ratti, 2011).

This provides the opportunity to build an interface that allows design collaboration using mass social housing as the design vehicle. In common practice, architects take full control and responsibility in proposing design ideas. They take in the desires and needs of the community and assume that their design will be a matching solution. However, in many cases the design satisfies only a portion of the community. OsA incorporates advanced building information technology and BIM to introduce an alternate workflow system that is both a top-down and a bottom-up design approach. This scheme will allow the community to actively participate during the design process giving them a greater sense of ownership; while at the same time it influences positively the paradigm of an architect's role.

Conclusion and concurrent research

This paper presented a few built examples of collaborative design processes and planning for future unpredictable changes with free plan building designs. The problems in the collaborative design processes of the past can be addressed by the novel potentials of BIM-technologies and complex parametric design methodologies.

With an integrated system that employs the benefits that BIM offers to the production and life-cycle of buildings, structured design parameters and user participation can be included and monitored more efficiently. Communication between prospective occupants, architects and various stakeholders can be executed and carried out easily. With this, communication becomes a feedback loop system instead of a one-way direct flow of instructions.

To further this research, a housing prototype system will be created with the referencing available tools, based upon a full participatory design system that allow real time communication both within the design team and with the users. Various design parameters and strategies will also be examined to develop a more flexible housing design system that will not only create new possibilities in mass housing design practice but also strengthen the interconnected relationships between people and their built environment.

References

Kendall, S. H., & Teicher, J. 2010. *Residential Open Building*, Taylor & Francis.

Proveniers, A., & Fassbinder, H. 1992. *New wave in building: a flexible way of design, construction and real estate management*, Van Gorcum.

Bech-Danielsen, C 1996, 'De-signed ecology'. i T Oksala & GE Lasker (red), *Acta polytechnica scandinavica. Design. Evolution, cognition. Selected and edited papers from DEcon '94 symposium: Civil engineering and building construction series no. 105.* Helsinki, s. 3-11.

Benrós, D., Duarte, J. P., & Branco, F. 2007. A System for Providing Customized Housing. *Proceedings of the 12th International Conference on Computer Aided Architectural Design Futures*, Sydney, Australia, 11–13 July 2007, pp. 153-166.

Cuperus, Y. 2001 'An introduction to open building', *Proceedings of the 9th Annual Conference of the International Group for Lean Construction*, Singapore.

Kim, J., Brouwer, R., & Kearney, J. 1993. NEXT 21: A Prototype Multi-Family Housing Complex. *Ann Arbor*, Michigan: University of Michigan, College of Architecture and Urban Planning.

Kendall, S. 2005. Managing Change: the application of Open Building in the INO Bern Hospital. *In Design & Health Congress*. Retrieved 29 September, 2009, www.designandhealth.com/Media - Publishing/Papers.aspx.

Kendall, S. 2005. Open Building: An Architectural management paradigm for Hospital Architecture. Paper presented at the *CIB W096 Architectural Management*.

Madrazo, L., Sicilia, Á., González, M., & Cojo, A. M. 2009. Barcode housing system: Integrating floor plan layout generation processes within an open and collaborative system to design and build customized housing. T. Tidafi and T. Dorta (eds) *Annual Joining Languages, Cultures and Visions: CAADFutures,* PUM, 2009, pp. 656- 670.

Narahara, T., Terzidis, K. 2006. Multiple-constraint Genetic Algorithm in Housing Design. *Proceedings of the 25th Conference of the Association for Computer-Aided Design in Architecture World* pp. 418-425.

Sasakura, H. 2005. Varible Infill System Rearrangement Experiment for Residence 405 at Osaka Gas Experimental Housing. *The 2005 World Sustainable Building Conference*, Rotterdam, Netherlands.

Schnabel, M A. 2012. Learning parametric designing. *Computational Design Methods and Technologies: Applications in CAD, CAM & CAE Education*. N Gu & X Wang (eds) 56-70. Hershey, IGI Global

Schnabel Marc Aurel. Architectural Education in the BIM-Age. *New Architecture* vol.2012 no.01, pp.25-27. Wuhan, China: New Architecture Magazine Publication, 2012.02.01

Schnabel, M. A., Ham, J. J. 2012. Virtual design studio within a social network, ITcon Vol. 17, *Special Issue eLearning 2.0: Web 2.0-based social learning in built environment*, pg. 397-415, http://www.itcon.org/2012/27

Willis, B. R., Hemsath, T. L., & Hardy, S. 2012. A Parametric Multi-Criterion Housing Typology. *Proceedings of the 32nd Annual Conference of the Association for Computer Aided Design in Architecture (ACADIA)* San Francisco 18-21 October, pp. 501-510.

Yan Gao and Yunsheng Su, 2012 Computational Design Research For High Density Social Housing in China, JET Vol.2 No.1., *Global Science and Technology Forum Journal of Engineering Technology*, ISSN 2251-3701.

[1] http://open-building.org/ob/concepts.html.

[2] http://en.wikipedia.org/wiki/Open_building.

[3] www.domusweb.it/en/op-ed/2011/06/15/open-source-architecture-osarc-.html.

[4] http://www.laciudadviva.org/blogs/?p=14164

[5] http://pkan.info/5233.html

[6] www.healthcaredesignmagazine.com/article/open-building-systematic-approach-designing-change-ready-hospitals?page=2

[7] http://vimeo.com/26638743