Integrated Open Source Design for Architecture In High Density Housing Practice

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Abstract: Housing is a collection of individual units based on negotiation between global standardization by the designers and local customization by the users after occupation. Due to the economic, industrial and time constrains, it is impossible to reflect users' different needs in the design stage for high density housing. In response to this challenge, this research paper argues that the high density housing design can adopt the individual customization by the users in the design stage without paying significantly extra cost, hence the design process could be an open-ended evolutionary and transparent process rather than deterministic execution. To overcome the deficiency in addressing the future uncertainty by different users and the one-off development without the interactive mechanism for users' feedback in the sub-sequential housing design and procurement, This essay proposes Integrated Open Source Design for Architecture (IOSDA) for housing design practice based on collective data and parametric connectivity between the end users and the designers, discussing how to integrate top-down mechanism with designer's empirical inputs and the bottom-up ecosystems with users' participation in high density housing design. IOSDA reflects a different attitude to design the future, which shifts from heroic prediction of the future to engaging the present grassroots, from board proactive reaction to the capacities for new possibilities.

Keywords: Open Source Arch itecture, High Density, Urban Transformation, Parametric Connectivity, Plug-in Infrastructural, Smart BIM, Real Time Monitoring, Iterative Design, Parametric Crowd, Network Thinking, Social Ecology

In product development, open source as a philosophy promotes a universal access via free license to a product's design or blueprint, and universal redistribution, including subsequent improvements to it by anyone (Gerber, A; Molefo O, Van der Merwe, A. 2010). Opening the source code enabled a diversified customization to further develop the original products to break through the limitation of the initial owners of the source codes, i.e. collective intelligence for innovation and development. Open source has been nurturing the IT industry for developing programs. Consequently form different virtual communities according to the particular source codes.

Open Source Architectural (OSA) is an emerging paradigm describing new procedures for the design, construction and operation of buildings, infrastructure and spaces. Drawing from references as diverse as open-source culture, avant-garde architectural theory, science fiction, language theory, and others, it describes an inclusive approach to spatial design, a collaborative use of design software and the transparent operation throughout the course of a building and city's life cycle (Open Source Architecture, Domus 948, 2011).

In the architectural field, the ideas and the approaches of Open Source Design have been borrowed for years. But it couldn't be applied to any architectural practice due to the complexity of the architectural industry including but not limit to design, procurement, construction and many other intertwined issues. The recent Wiki-house could only deal with the simplest house solutions without really exploiting the power of collective design with participation of the end users for high density housing, the type of architecture that need negotiation between multiple users, as well as the designers and the stake holders.

The essential objective of this research paper is to establish the theoretical framework for Integrated Open Source Design for Architecture (IOSDA) for a new form of housing design practice based on collective data and parametric connectivity.

CHAPTER 1: ISSUES AND PROBLEMS IN THE CURRENT HOUSING DESIGN PRACTICE

Architectural design is always the derivative work of other's sources to some extent. Drawings and blueprints are the primary source codes for architects to copy others' work. Different –isms are somehow alike different program languages, e.g. VB, Java, C#, that each has its own syntax and vocabulary. Equally they all create its own community which shares the published source code and customizes them according to specific context such as the users' needs and the environment. Today, the architectural source code has gone beyond architects to both end users and stake holders. Open source architecture lifts up the necessity of architects in some house design chain.

Nevertheless, we as architects don’t have to worry. Building is significantly different from computer program. There is still a long way before autonomous architectural design solely by users’ customization of the published source code of architectural design. For housing design, there must be a balance between the top-down synthetic control and the bottom-up systematic customization. To control the un-controllable is the art of IOSDA.

Issue 1: Financial risks in traditional housing supply chain

In the conventional housing supply chain, the investors always take the risks of building the housing products based on their prediction according to the market analysis of the past. Architects are employed to visualize and materialize the client’s investment for profitable and cost-effective housing. However, the prediction is often frustrated a delayed reaction to the unpredictable market. The housing products might already be undervalued during the construction period. Risks will be higher if the housing takes longer to be built. This is why many developers in China are always rushing for the rapid completion.

Issue 2: Lost of individuality in the duplicated living environment

In the conventional housing market, users can only choose from what have been pre-defined by developers or governments. The development of digital technologies should allow a more humanistic design approach for individual expression. The current housing procurement model is still based on the old-fashioned top-down planning methodologies, in which the developer is the ultimate decision makers to determine what your home would look like; the users have to “happily” pick one "cage" as their own home. The quality of vernacular housing, i.e. the collective harmony of differentiation with the individual expression, through the particular process of making their own houses according to the established recipes for daily buildings, has been completely lost in the dense urban environment, because of the vacuum of individual participation of the building process.

Issue 3: The stringent statutory building code

The important merit of vernacular architecture is its collective beauty of individual customization based on generic tectonic and material principles. Whereas in high-rise housing design, the statutory building codes are always regarded as counter-productive design constrains, suppressing creative opportunities. Effective building codes ensure efficiency and fitness of housing products, meanwhile, it also discourages risk takers for new design possibilities. Building code are often presented as fixed facts. The philosophy of making statutory building codes perhaps needs to be rethought. Defining the codes for the statutory codes should liberate architects in the housing sector from efficient productivity and technical decoration to productive creativity, focusing more on relationships rather than objects, the order between parts rather than the composition of building elements.

The building codes for housing in Hong Kong is probably the most sophisticated building codes in the world. They are written in such a way that you cannot fully interpret them unless you have practiced in Hong Kong for years. Considering the fact that even the professionals cannot easily handle the current building codes, the verification of individual design customization in OSA will therefore an impossible task, unless the building code checking process can be automated with some computational codes, so that the time-consuming repetitive checking of every different units within a range of possibilities can be done with a CLICK!

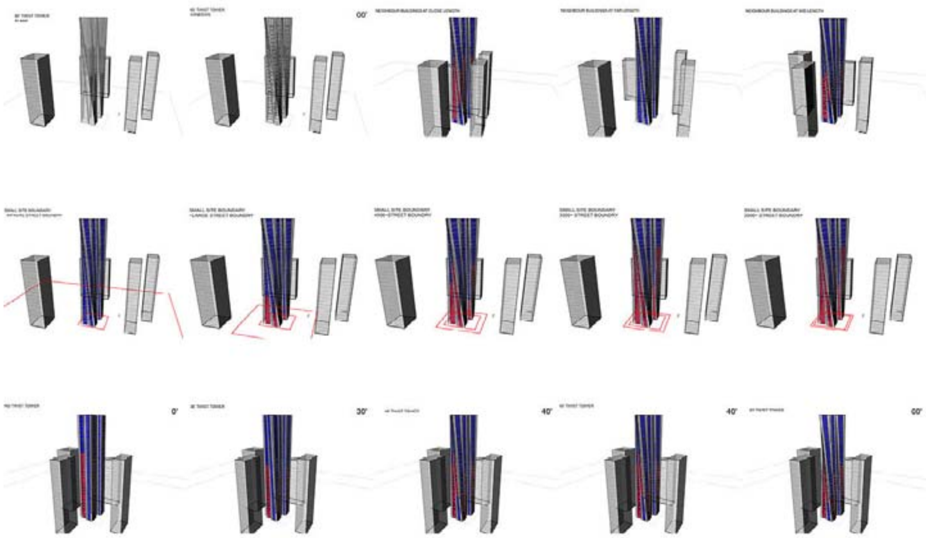

Fig1 Parametric Simulation of the Hong Kong Housing Building Code for Prescribed Windows through Dynamic Context and Building Conditions

Fig1 shows the parametric checking of the Prescribed Windows defined by the statutory building code[1] with changing conditions. It proved that the statutory building codes can be simulated as dynamic references allowing a

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[1] According to the building code issued by Hong Kong Housing Department, Prescribe windows are
o Faces street not less than 4.5m
o Faces uncovered and unobstructed area above a rectangular horizontal plane
o if another rectangular plane, the base whereof is equal to and common with the base of the rectangular horizontal plane, is inclined, above the rectangular horizontal plane, at an angle of 71 1/2 degrees from the horizontal where the window is in a room used for habitation or 76 degrees from the horizontal where the window is in a room used for the purposes of an office or as a kitchen, no part of the building, or of any other building within the site on which such building is erected, protrudes above such plane
o where such window opens on to an area bounded on the side opposite the window by a boundary of the site on which the building is erected, such window is so placed that, if the rectangular horizontal plane *Cap 123F - Building (Planning) Regulations* 12 is projected to such boundary and, from the position at which it first intersects the boundary, another rectangular plane, the base whereof is parallel and level with the sill of the window and has a length equal to the length of the base of the rectangular horizontal plane, is projected, towards the site and above the rectangular horizontal plane, at an angle of 80 1/2 degrees from the horizontal where the window is in a room used for habitation or 83 degrees where the window is in a room used for the purposes of an office or as a kitchen, no part of the building, or of any other building within such site, protrudes above such inclined plane
o Provided that, where there is a service lane or street less than 4.5 m wide adjacent to and parallel with such boundary, the boundary shall, for the purposes of this sub-paragraph be deemed to be at a position 1.5 m beyond such boundary

big number of varieties, instead of the large homogeneous housing products everywhere nowadays in Hong Kong.

Issue 4: The problems of one-off planning methodologies for conventional housing design in addressing future uncertainties

The problems of top-down one-off design methodologies in conventional architectural design have been widely criticized by many scholars (Liane Lefaivre, Top Down Meets Bottom-up, Spontaneous Interventions: design actions for the common good, the August Issue of Architect Magazine, 2012) due to the cost to adapt to the future changes, powerless to address every individual needs. In reality it still dominates the architectural practice, especially in the housing sector. Both the missing theories and the lack of operable design imperators are the main hurdles.

Issue 5: Main problems of bottom-up design approaches

Bottom-up or self-organized systems are becoming more fashionable in architectural design when the younger generations grasp the parametric modelling tools. No doubt that they have challenged the established top-down design approaches; however the new problems arise. First of all, the bottom-up approach is meant to maximize the satisfaction of individual needs (Nikos A. Salingaros, Design Methods, Emergence, and Collective Intelligence, New Science, New Urbanism, New Architecture? Towards a New 21st Century Architecture, Katarxis No. 3, 2004, London) due to its power to process mass data, whereas it has become the seductive tools for architects to realize their own formal obsessions on visual complexity for the sake of complexity. Secondly, many outcomes based on the bottom-up approaches are lack of synthesis of real complex issues and the design intelligence. Such phenomena actually creates the equivalent sameness as the modernism pronounced the international styles. No matter how surprising the form may be, it always repeats the over-familiar complex geometries, such as continuous differentiations on three dimensional surface.

The design owner in the bottom-up design process is still the individual architect. Although we recognize the team collaboration in contemporary architectural practice, how to encourage the diversity and the new possibilities based on multiple independent design team members in the hierarchical design practice is yet to be thoroughly investigated. Only by then we can achieve the collective intelligence for adaptive design, balancing the top-down vision and the bottom-up needs.

Issue 6: High-rise housing evolution upon feedback of the occupants

In China, architects’ mission often terminates when a professional photographer takes shining photos before users’ occupation. The investors wrap up with their profit and handover to another maintenance and service company. The end users are the last one who arrive at the party when most hosts have left. The process is so market driven that the design success is primarily evaluated by the sale record. The design re-iterates itself with little timely feedback from the end users. The current design mechanism of housing procurement in China isn’t able to incorporate users’ feedback for design improvement and adjustment. There are also no practical design mechanisms for absorbing and interpreting the feedback data as part of the design input for the successive design products. Significant price has to be paid to learn lessons from the realities if we don't integrate users' feedback for the next housing design project.

CHAPTER 2: OPEN SOURCE DESIGN AS A NEW OPPORTUNITY

Open source architecture has been talked about for many years but few have realized any built projects, especially in the field of collective housing. The Next 21 project in Japan is a rare case in applying open source design to the collective housing projects.

Precedent Project: Next21, Osaka, Japan (Kim, Brouwer, Kearney, 1993)

Next21 (Fig 2) 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. Specific design strategies are generated from the framework of two principal concepts, the system building and the two-stage building.

Fig2 Next 21 Project

The system building is an integration systems assembled from a series of multiple independent subsystems. This approach allows each building elements to be produced independently and incorporate into the building without disrupting the integrity of the other subsystems. The prefabricated components can also be replaced easily and economically during a building occupancy and use. This could also enhance the ability of building disassembly for short life buildings. These four main subsystems in NEXT21 are namely structure, cladding, infill and plumbing.

The two-stage building strategies follow deeply with the first by classifying the building into two groups: infrastructure which refers to shared elements including structure, cladding and plumbing, and infill which has individual properties including partitions, fitting, interior finishes. The design process in this example is broken into two parts as well; one group conducted interviews to identify the needs and desires of the prospective occupants in the collective housing, while the others were responsible for designing the building structure that accommodated various unit cluster design and changes in time.

Next 21 is one of the most comprehensive buildings that demonstrate and experiments sustainable design methods in the process of design. In 1996, they did an experimental remodeling of one unit with the participation of its residents and it was a great success (Sasakura, 2005). This provides precedence for the possibility of a participation/collaboration design method and also flexible building system for collective housing.

Topic 1: Why is IOSDA for Collective Housing significant?

1. The IOSDA will provide a new housing supply model

One of the implications of IOSDA in China is its alternative funding sources from concentred investment to crowd-funding strategies, in which the end users will participate the design decision process by paying for building their own home in a collective manner, instead of buying a built home in the developers' visions. Architects will also not be in their own opaque design sphere which often wastes resources on predicting the future market.

2. To integrate the top-down mechanism (designer’s stylistic inputs) and the bottom-up systems (users’ customization) in high-rise housing design

As long as architectural profession exists, it is inevitable to embody the designer’s own stylistic preferences. The bottom-up customization in housing design cannot succeed without global design management. Otherwise it will generate global chaos as housing products are not like fashion products, which can be customized as isolated entities. Housing is the collection of individual units based on negotiations between associative customizations and global setups.

3. High-rise housing design becomes on-going and transparent evolutionary process rather than minority controlled and profit driven goods.

Based on parametric connectivity and computational automation, IOSDA will be an iterative process based on real time feedback, which generates more desirable housing products based upon different individual needs. IOSDA will create open ended housing design systems which integrate users’ feedback after occupation, so that the housing systems can be improved in the immediate next project, which will significantly shorten the responding period from the lessons learned to better solutions.

4. Computational and parametric design will finally benefit the ordinary majority instead of realizing extremely expensive and fashionable architecture by star architects.

Computational and parametric design has been used excessively for extremely expensive signature architecture. However, when we lay back and think about the ordinary people, especially in the current economic climate, how much do they really benefit from the high end architecture? Open-source design should support the collaboration between designers and users for building the users' own dwellings, not to continue promoting the employment relationship between the clients and the design elite.

Instead of reproducing another version of so-called parametric towers without examining the living qualities, economic and regulatory constraints, IOSDA should substantiate computational and parametric design tools for designing ordinary high-rise housing towers.

5. IOSDA will substantiate the idea of mass customization in high-rise housing in China into applicable design methodologies and tool sets.

Mass customization in housing design, instead of being abused relentlessly when the essential interest remains in the superficial formal expression which do not address the users' need, nor engage with the intricate constrains in reality. The utopian dream of mass customization for highly differentiated building parts is the result of ignoring the reality. This research project will address the culture of manufacture, marketing and business in China along the exploration of the applicable methodologies and techniques for mass customization in high-rise housing.

Topic 2: What is it all about IOSDA in Collective Housing?

IOSDA is slightly different from Open Design (OD), the former integrates the distribution of the design source code to both the end users and the multiple designers, each of whom will contribute to the overall design under the general framework set by one design leader, whereas the latter primarily refers to the participation of the end users and parities other than the designers to the design process. IOSDA and OD overlaps in the contribution of the collective design intelligence from multiple sources beyond the chief designer's heuristic decisions. IOSDA is a big project. In order to fully grasp the scope of IOSDA, we will have to address the following basic topics:

1. What are the source codes in IOSDA?

The source code of architectural design can be understood in many levels. In the most common level, it can be to the technical drawings that reveal the covered details about how the building was put together from the design information to the material assemblies. At this level, architectural design has always been open source. In fact, all the published architectural technical information contributes to the others' work in one way or another.

The level of IOSDA that we are investigating here is on the individual project, i.e. the source code that is strategically designed for sharing and coordinating collective design inputs for the same project, which is similar to the relationship between the planning control and the architectural design in individual plot. Such building infrastructure could be the standard connecting interface between the global framework and the independent designer's local input, the overall rules that govern the individual design decisions, the tools and techniques that are customized to automate some time-consuming processes, and the universal component database including both geometric and non-geometric information.

2. The interactive interface

Open the source code to whom? If it is for the end users' participation, to what extent the end users will participate the design process? If it is open to the multiple designers or organizations, how to encode and decode the design ideas with standard design descriptions? (Mushon Zer-Aviv, The Case For Open-Source Design: Can Design By Committee Work? Smashing Magazine, 2010) The key translator to communicate between human and the design descriptions is computer, which will only process data with the way that it understands the instructions with the right syntax and expressions. The design interface is crucial as it acts as the transition between the human intention and the data processing at the back stage. It drives how feasible and efficient the communication is between the multiple input data and the collective formal outputs.

In addition to the openness and the user-friendly characteristics, the design interface must allow design leadership, sometimes even accept design arbitration, otherwise the design practice will be stuck in an anarchy state. It is necessary for the design leader to design and manipulate the rules that sort input data and organize them into some design orders, so that the housing project can be eventually delivered efficiently.

3. The funding model

If we cannot convince the developers or the government to take the risks in applying IOSDA, we will have try different funding methods, such as crowdfunding. Having a live interactive interface will enable the project manager to visualize the changing results so effectively that it could attract the potential crowd for purchasing the on-going design products during the development process. Financial incentives must be given to the first crowd who are willing to take the risks, e.g. mainly time than anything else. Such new funding model will completely change the current relationships between clients, designers and users, positioning the users from the end to the frontier. The procurement of housing will enter a new era when housing projects can be initiated by professional fund raisers without a developer, which is not impossible as long as this idea has no jurisdictional obstacles against the land purchase with crowdfunding. Certainly there will be many other issues, such as liabilities, IP protection, Donor exhaustion and financial guarantees and so on (Crowdfunding in a Canadian Context, Exploring the Potential of Crowdfunding in the Creative Content Industries, 2012, P24, www.cmf-fmc.ca). But these are all solvable to establish the crowdfunding model for IOSDA.

4. The universal, modular and open-ended architectural sub-systems

The freedom of customization based on open source can only come true in practice when the architecture is described as a number of sub-systems with multiple standard parts, so that the systems can change its composition over time. The branch of contemporary design that promotes highly specific differentiation is the opposite direction and cannot be implemented in IOSDA.

5. The low-tech construction along with intelligent design solutions

If the goal is to substantiate the theory of IOSDA to design practice, the design products must aim at ordinary construction means, unlike the Japanese metabolism which resulted in extremely expensive buildings and never changed despite its initial concept. The feasibility of IOSDA in design practice is either to avoid the physical changes to provoke any complicated neighbouring consultations, or to promote a dynamic process which allows for changing input data, such as users' needs, material costs, environmental data, while the eventual product will still be a static building last for more than 50 years.

6. Parametric modelling

Since IOSDA needs to respond to unpredictable input data from both the end users and the multiple designers, the digital model must be parametrically constructed to allow collective re-configuration at the building scale. Relationships between the complicated network of different parameters and formal outputs are the essential focus than the shape itself. Not only the particular parameters, but also the input data must be carefully designed as part of the parametric modelling process. In the interest of individual design preferences, the graphic input must be possible in addition to numeric input.

7. Smart BIM

BIM model is the bridge connecting design visualization to building information, eventually grounding dynamic open source models to the construction documents without consuming extra resources compared to using the static model, but this is only in theory upon the fact that all BIM models are parametrically built. In practice the parametric changeability of BIM model is actually quite limited, due to the intricate real-time links of hundreds of thousands of objects and parameters in the building scale.

Smart BIM emphasises the ability of parametric reconfiguration of the control geometries which will lead to smooth update of all the subsequent parts and elements in the BIM model, all the way through to the production information drawings, spreadsheet and illustrations, etc.. This is the challenge for the BIM designer rather than for the software capabilities. The key intellectual property rests in how practical the BIM model can respond to radically different input data, e.g. the overall shape or dimensions. In practice, such Smart BIM modelling process will probably involve multiple software and rely on smooth communication between different software. For instance the communication between Rhino Grasshopper, which is powerful in design manipulation, and Revit, which can produce the construction documentation out of the information models. The two have to work together to integrate the flexible design with the instant and validated information output in practice, i.e. the Smart BIM. We have achieved the preliminary stage of Smart BIM for a singular house as showed in Fig 3-5. Working on collective housing will be far more complicated in making the BIM model work parametrically.

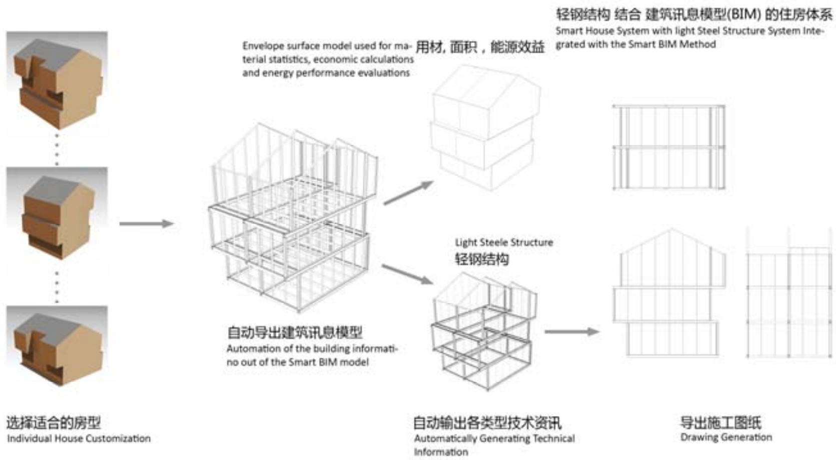

Fig3 Smart BIM Process Diagram in the Single House Test

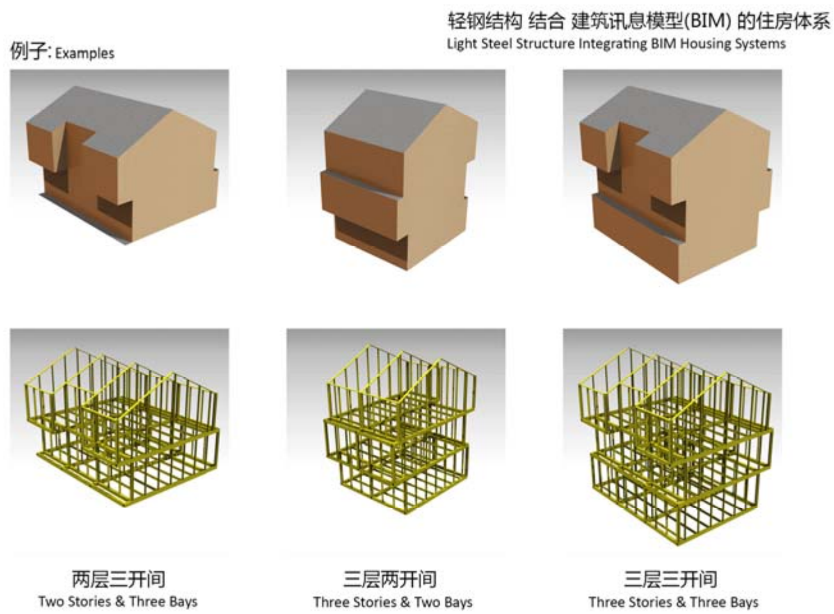

Fig4 Smart BIM Test with Different Surface Model Input

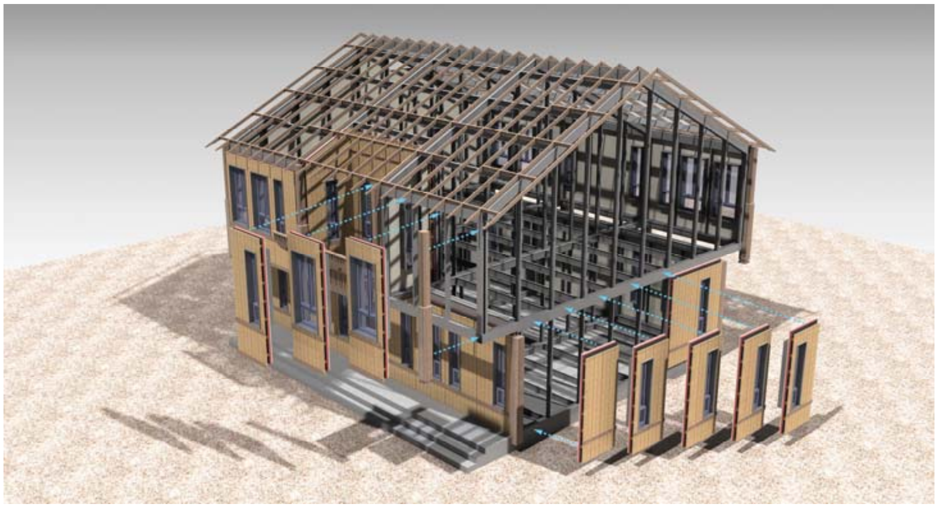

Fig5 Composition Model of the Smart BIM Test

8. Database of the components

As mentioned in item 1, the database of the building components is part of the shared open source code. IOSDA will encourage the industry to build a model library with the participation of the industry suppliers, on the condition that rules of the modelling code are spelled out, for instance the universal connecting interface in terms of alignment and dimensions, the standard parameter sets, the format of the models.

9. Instant 3D viewers

Since IOSDA involves general users in addition to professional designers, the design communication must be carried out with the understandable means of design visualization in real time. Current BIM software has embedded free BIM model viewers (such as Catia with 3D XML format readable in word files) for the end users to open up the entire information model for better communication amongst different parties. The traditional 2D technical drawings are only appropriate for professionally trained experts.

10. The feedback mechanism

In the end, IOSDA should be open ended, allowing for uploading users' feedback from the current product version to improve the next project version in a quantifiable way. Such capability will maintain the robustness of the IOSDA model to avoid discrepancies caused by users' false input, because the model system can decide its formal response by comparing the newly input data with the existing database and only change its configuration when the new data value reach the threshold. Otherwise the IOSDA model will become a reactive model without the ability of "thinking". The IOSDA aims at a more enduring product series within which the next version always learns from the previous version through processing the user feedback.

Topic 3: How to build Information Model in IOSDA?

The success of implementing IOSDA needs a new way to categorize the collective housing for building a more dynamic digital model. According to the project that we have tried to implement the theory of IOSDA (Fig 6-10), we broke down the building systems into:

Fig6 Main View of the OSAD Test

1. Spatial Driver

It refers to the master control geometries, which are often the surface models, to initiate the generative computational process based on various input information. (Fig 7)

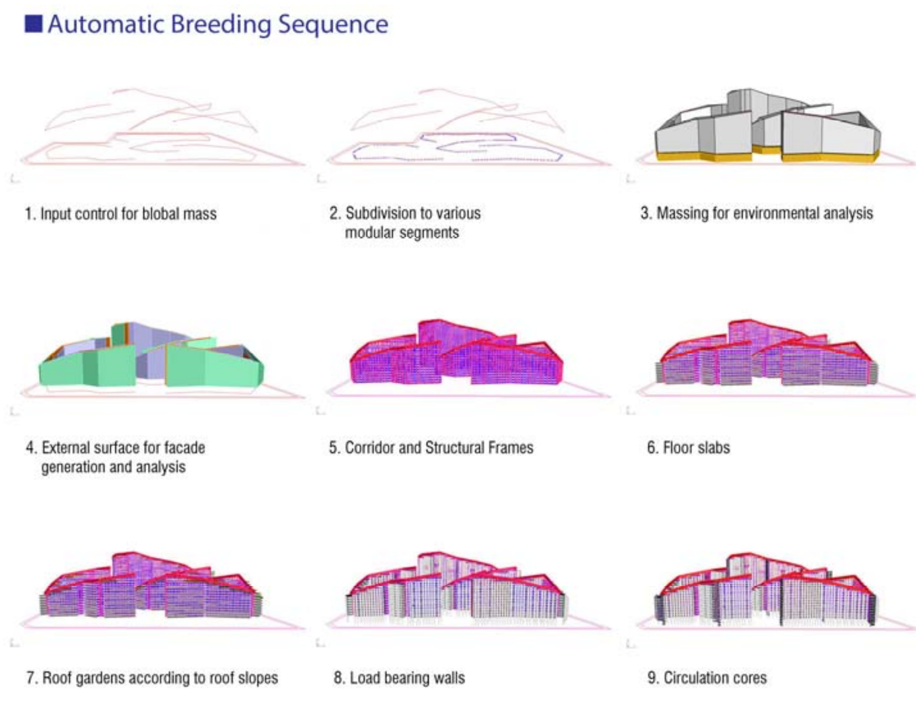

Fig7 The Master Control Surface Model and the Generative Articulation Process

2. Structural Frame

The permanent structural framework with mixed steel and prefabricated concrete as the host for accommodating different infill parts. (Fig 8)

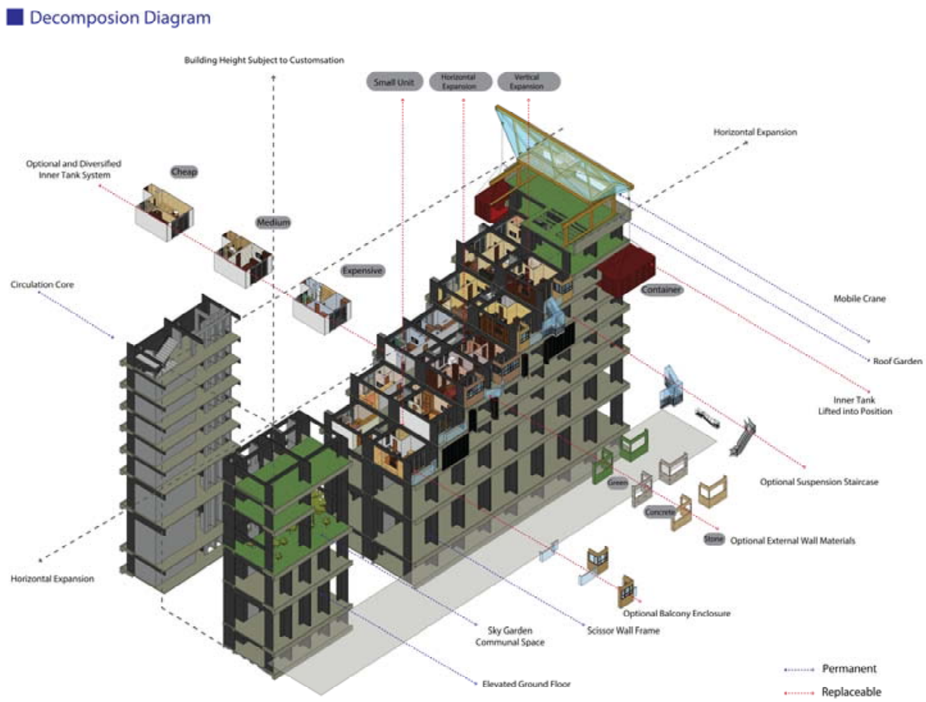

Fig8 System Composition

3. Skin Modules

Since the standard modules of the enclosure units have been regulated into the open source code, the adaptable façade customization will be capable for upgrading by the residents over time. (Fig 9)

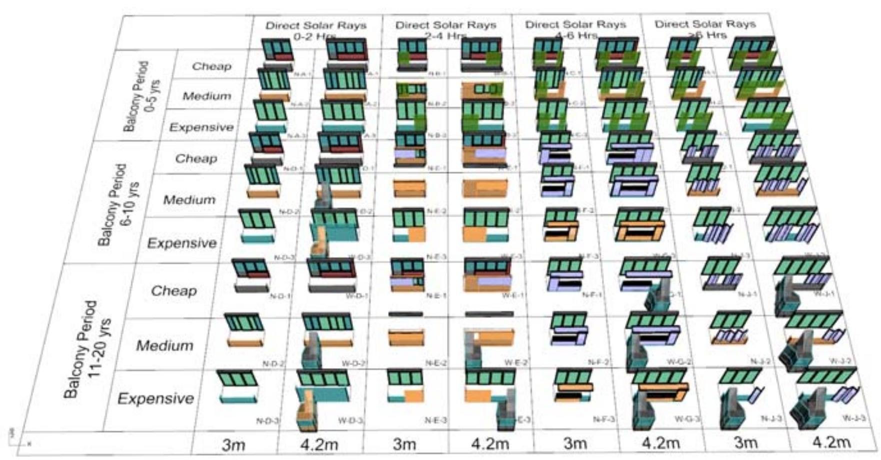

Fig9 Facade Infill Unit Library

4. The Inner Partition System

The spatial layout, i.e. both the plan and the sectional division, will have to allow for flexible rearrangement according to the unpredictable users' needs and preferences. (Fig 10)

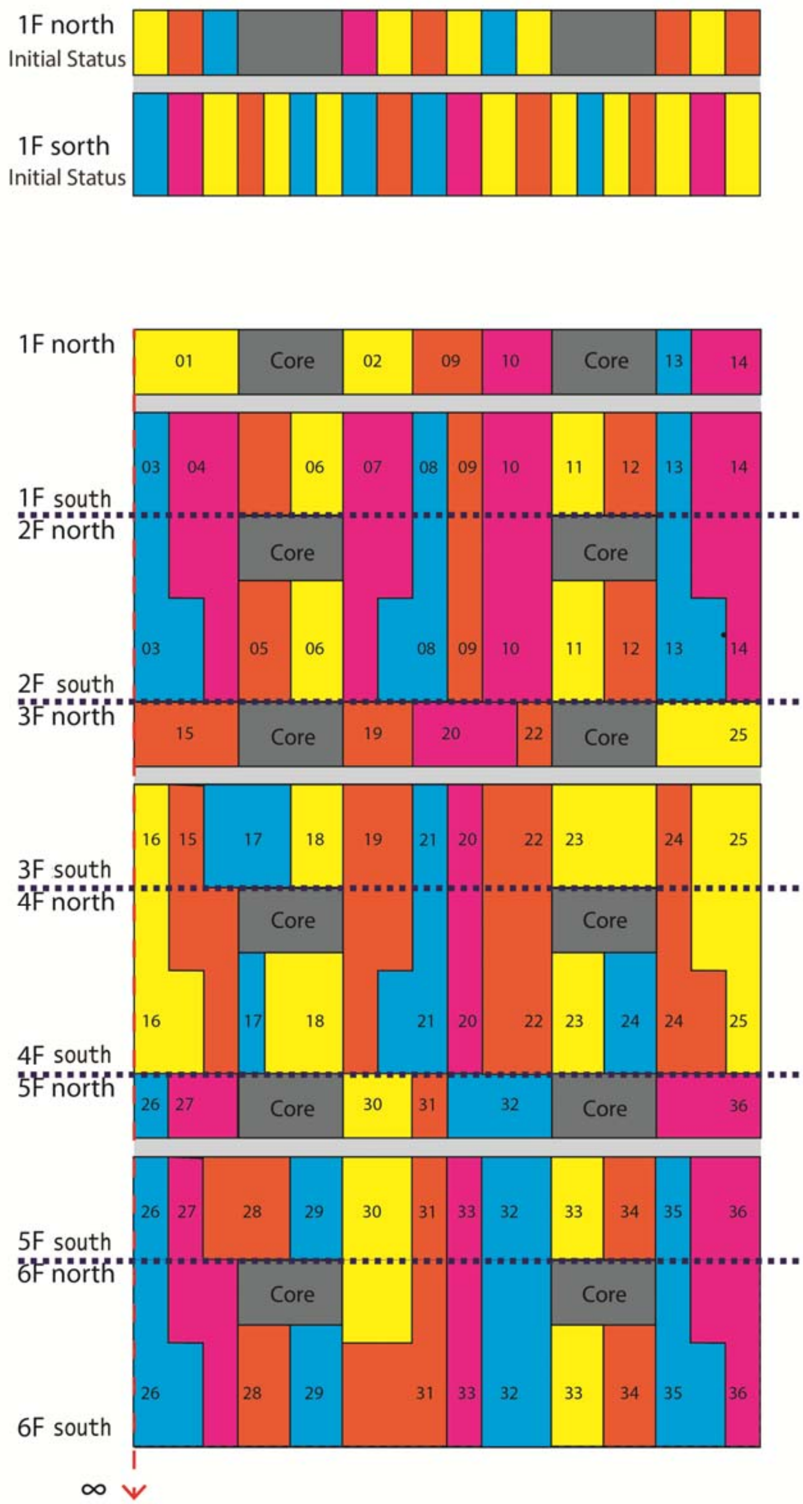

Fig 10 The Combinatory Possibilities based on Modular Plan Layout with Moveable Partition Walls

5. The Utility System Kit

The building service including power, gas, water supply and discharge systems needs to be compact into a utility kit to maximize the possibilities of supporting different spatial layout based on the open source code.

CONCLUSION

Fig 11 summaries the relationship network of IOSDA which engages multiple architectural designers and other parties including the end users through the digital means, i.e. the Web interface for communication, the parametric design for the dynamic modelling of housing systems, the BIM process for streamlining the collective design customization with standard building components, the physical building products which contain the product information for maintenance and operations over the whole life span of the building. Besides, a new party will involve in the design process, i.e. computer engineers, who will provide programming service to link the UI with the parametric model database.

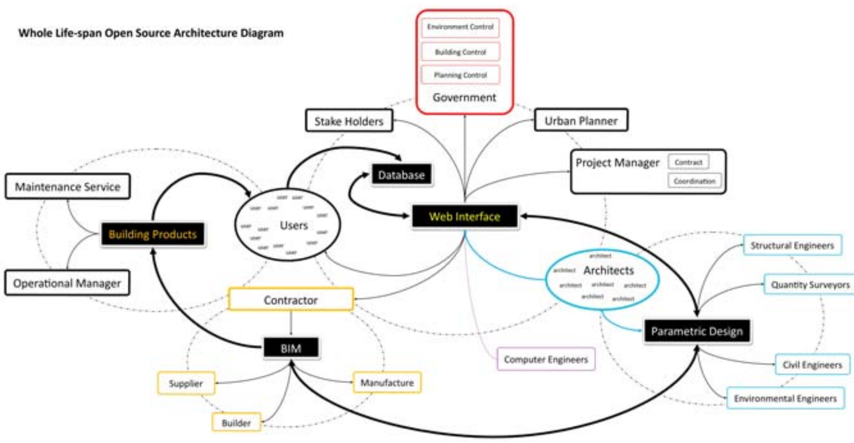

Fig 11 Open Source Architecture Overall System Diagram

IOSDA reflects a different attitude towards the future, which shifts from predicting the future to engaging the present, from the proactive changing to the capacities of new possibilities, because no matter how lucky we might predict the future based on the knowledge from the past, the future uncertainties always persist. The fundamental puzzle for architects is the mission of materializing the future with inhabitable structures. The design process is often frustrated by the creative limitation and the aesthetic inertia of the individual designers. IOSDA offers the alternative trajectory to tackle the future uncertainties. But, it still needs time to overcome many hurdles in real practice, such as the difficulty in attract end users to take part in the data contribution. How many actually will bother to make the effort to participate the design process? A counter example is Vanke, the biggest real estate developer in China, as well as in the world, has recently packed up a new housing product series through optimizing the foreseeable possibilities of the housing unit layout to only four types based upon the research on their dwellers' feedback about the everyday needs. It is yet to be tested during the current turmoil of the housing market in China, which might provide discouraging evidence that IOSDA would remain as a utopian idea in the architectural history. Nevertheless, we need to continue the experimental practice with the necessary theories, methodologies and technologies for applying IOSDA in some real housing projects in China. Hopefully it won't take too long to build the first housing project with IOSDA.

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