MSc Wood Based Building Design for Sustainable Urban Development

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Lifecycle Building Challenge Emphasizing Social Sustainability:

Prototype Timber Building for Future School

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 09.02.2010

Affidavit

I, **IKUE NOMURA**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Lifecycle Building Challenge Emphasizing Social Sustainability: Prototype Timber Building for Future Schoo", 79 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and

2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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Lifecycle Building Challenge Emphasizing Social Sustainability:
Prototype Timber Building for Future School

Abstract:

What does sustainable architecture really mean?? We begin by focusing on our problems occurring in our environment and we must rethink our solutions for them. We must evaluate what we have and what we can do to maintain our environment in a global sense. Green architecture is not just about new inventions which most times create conflict between building technology and economic feasibility. We need to look at building as a process. Sustainable architecture is about merging ecology, economy, and beauty while remaining highly sensitive to a site to create one simple harmonious building that can be maintained through various systems to last years.

This writing demonstrates the idea that sustainable buildings can only be realized through affordable means – feasibility of techniques and cost of materials that are applied to the building. They should be able to be evaluated, constructed and properly maintained within the community and its market force. This paper sets to establish sustainable design ideas pertaining to building technology, social integration and building's full life-cycle management plan. By following the principle of Design for Deconstruction/Dissembling, my study will embody social sustainability through construction planning. The outcome of this study will discuss integration and the potential of timber structures used for public communal programs, such as an educational facility, in order to maintain good relationships between the market order, social involvement, and ecological contribution. As an appropriate technology, this paper analyzes the Open Building/Support & Infill System that is a structural concept wrapped into one to maximize flexibility and the life span of structural components. As a result, my design prototype for a timber modular school will explore sustainable planning from assembling to disassembling. It is through this method that total sustainable management can be achieved.

Acknowledgements

First and foremost, I offer my sincerest gratitude to my supervisor, Dr. Yoshiaki Amino at Vienna University of Technology. He has supported me throughout my thesis with his patience and knowledge while allowing me room to work in my own way. I attribute the level of my Masters degree to his encouragement and effort and without him this thesis, too, would not have been completed or written.

Second, I would like to express my deepest appreciation to my committee members, Prof. Wolfgang Winter, Vienna University of Technology, members of the Urban Wood Program, Prof. Peer Haller, Dresden University of Technology, and Prof. Clara Bertolini Cestari, Politecnico di Torino, for continually and convincingly conveying a spirit of adventure in regard to research and an excitement in regard to teaching.

Lastly, I offer my regards and blessings to all friends and program staffs who supported me through the program in any respect during the completion of my study.

Contents

1

INTRODUCTION

1. Introduction

Architecture is inherently related to and encompasses social factors since the act of building involves the collaboration of designers, engineers, traders, manufactures and industries, and after all it impacts our environment and resources globally. Housing and civil buildings have profound meaning on the site, similar to craft objects, embodying shelter and comfort that respectively fit into its cultural context. Therefore, any attempt to consider sustainability in the use of building within the society must consider the management of all resource flow in the full life-cycle of the buildings from extraction, to manufacturing, to design, to construction, to operation, to renovation, to environmental impact. In addition, sustainable architecture should address not only ecological and economic factors, but also social factors and accentuate the specific qualities of a place, such as craftsmanship, regionalism, and education to support cultural values as well as be at equilibrium with the natural surroundings.

In today's architecture, sustainable buildings are highly technology driven depending on high-end materials and fabrication. New buildings tend to require expertise and limit flexibility in maintaining energy efficiency. Generalization of technology has become critical to social factors and it leads loss of craft skills and labors that is special and symbolic to its place.

I would like to open the discussion by pointing out below problems with current sustainable development:

1) Trends are heading away from organic materials which are renewable and safe for biodegradation. High-end sustainable buildings tend to use composite and engineered products which are difficult to recycle or reuse because of their chemical complexity.

2) Increased practice of using "wet" construction methods such as onsite-cast concrete, or use of connection technique such as pneumatic nails, staples, and adhesives that are difficult to separate or "undo."

3) The highly speculative nature of many buildings, places lowest priority on full life-cycle management plan during the design phase because of low demands for long-term ownership. Therefore, adaptation, renovation, and demolition costs will not be reasonable against new construction.

4) The perceptions behind buildings that are deconstruct-able or modular tend to be seen as short-live or temporary constructions which results in reduced values and depreciation.

Hypothesis:

1) Contribution towards sustainable design should happen in the planning phase rather than actual construction and service phase.
2) Open Building System (OBS) is a building method which is accessible to everyone because of its non-hierarchical organization and incorporation of local materials; therefore, OBS can be an “appropriate technology” to achieve social sustainability.
3) Advantages for using method of Design for Disassembling/Deconstruction is economically and technologically valuable for sustainable architecture practice
4) Wood as an ideal material for lifecycle building challenge

Target Group:

This thesis is intended for owners, architects, designers and builders, and I hope it will help facilitate investigations and incorporation of this important aspect of sustainable design and building.

Limitation:

The topic on sustainability in general is very broad and can be approached from many directions. Various efforts toward achieving sustainability have been carried out by individuals and the collaborative, and their resulting theories tend to have conflicting goals and practices, in fact, becoming very complex. In this paper, I would like to open my discussion of sustainability by following “six competing logics of sustainable architecture[1],” that have been defined by Simon Guy and Francis Farmer to describe the diversity of theories on sustainable architecture. Their classifications includes: eco-technic, eco-centric, eco-aesthetic, eco-cultural, eco-medical, and eco-social logics[2]. For this paper, I am focusing on the fields of eco-technic, eco-cultural, and eco-social logic to pursue my point.

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[1] Simon Guy and Francis Farmer, “Reinterpreting Sustainable Architecture: The Place of Technology,” Journal of Architectural Education, vol. 54, no. 3 (Feb. 2001): p. 141

[2] Simon Guy and Farmer, p. 141

In addition, a number of possible "social" factors in sustainable development are also defined by Simon Guy and Francis Farmer. My intention for the discussion on social sustainability is mainly to deal with 3 factors: 1) Numbers of people with jobs 2) Opportunities for education and training 3) Housing provisions and quality[3].

1.1 Project objective

I would like to re-discuss the essence of sustainability by focusing on “eco-social” architecture instead of “eco-technic” architecture. Social sustainability incorporates environmental concerns along with maintaining cultural diversity and traditional values. In this view, sustainability is important not only as a mean of preserving global ecosystems but also social system and values.

Yet, this “eco-social” logic does not translate directly to architecture. The aim of my study is to embody this logic to actual forms for realization.

1.2 Methodology

This paper will first raise important questions about the relationship between the market order, social integration, and ecological sustainability in architecture by exploring eco-social logic compared to eco-tech logic.

As one of the directions to sustainable development, this paper will examine methods such as Design for Deconstruction (DfD) and the Open Building System (OBS) through literature reviews, cultural precedents, architectural discourse, and architectural exemplars. This careful examination will help guide the design of the timber structure. The goal of my research is to summarize life spans of building functions, systems, and components and analyze them in a design project by planning its lifecycle management strategy.

As a result, I will discuss the potentials and technological significance from the outcome. The conclusions will be asserted as the importance of social integration in sustainable development as well as potential for wood building for communal facility.

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[3] Guy and Farmer, p. 144-145

2

SOCIAL SUSTAINABILITY

2. Social Sustainability

To date, when we refer to sustainable architecture, we talk about solar panels, gray water reuse, eco-valued products…and so on, basically listing technology and various systems. Around the world, there are a few green building rating systems. Although most of those accreditation systems are great tools to evaluate energy and cost efficiency, or reduction of hazardous waste, they lack the social impactions of the projects on neighborhoods. Furthermore, planner's effort in designing credited green building requires more time and money, which takes away from the real meaning behind sustainable planning. Sustainability is about making a building or community beautiful and livable where people would want to maintain. The greenest way of building is to build something that doesn't have to be replaced or demolished. Sustainable buildings can only be achieved with the involvement of social factors such as occupants, owners, and local authority. Even if we have green buildings where no one cares about maintaining it or we keep adding more and more green technologies, in the end the two will create the same situation. However, with the inclusion of social responsibility a building can be maintained over time achieving the principle of sustainable architecture.

I have come up with the word "social sustainability" to explore the importance of social impact on the built environment. My study focuses on the idea that people, who care about the place they live in, are the most influential to the sustainability of their place. The effort people will put to make their own place better and safer eventually leads to maximizing the life time of the built object. Therefore, I rethink sustainable development emphasizing eco-social factors rather than eco-tech to achieve better affordability and feasibility for people.

2.1 Social sustainability and its reciprocal impact on technological development

In today's sustainable architecture, buildings seem to be technology driven depending on high-end materials and fabrication. New buildings tend to require high expertise and limit flexibility to just maintain the performance of energy efficiency. All this eco-tech development and high-tech materials prevents the consumers and local construction business from evolving and adapting to local factors. If analyzed, opportunities can be discovered in areas covering the cost of transportation of materials, relinquishing the high dependency on custom machinery, and even the basic high cost of materials themselves.

Furthermore, development in such prefabrication and pre-cut technology on the one hand is greatly contributing to the reduction of energy and waste material, however, it blurs the conventional way projects are delivered. Project owners, architects, carpenters, and contractors have lost clearly defined roles and responsibilities. Thus, I perceive today's environmental technology as the critical junction between the future success of sustainable architecture and social implications.

Later, my study focuses on the idea of emphasizing sustainable design in architecture in the planning phase rather than the construction and service phase. Planning essentially involves making decisions whether it's about the kind of materials to be used in the building or including the key players such as the various industries and people involved in construction and maintenance. I believe that true sustainability will be achieved when environmentally conscious design is available and permeates through the lives of everyone in the community and not just the wealthy.

2.2 "Sustainable architecture" determined as building lifecycle

Conventional practice of sustainability relies on utilizing as many high performing materials to get the most energy efficient value. For instance, exterior walls are constructed with layers of thermal insulation, air control film, and plasterboard, and so forth, to achieve desirable overall heat transfer coefficient (known as U-value.) Also, all insulation materials are rated for R value: performance in thermal resistance which is the reciprocal of U-value. For multi-layered insulation, R value is simply calculated by summing coefficients of all the material in the given wall section - the higher the R value, the greater the insulating effect[4]. For example, thermal resistance of the typical brick wall is calculated as:

$$\text{R value}_{(\text{total})} = \text{R-value}_{(\text{outside air film})} + \text{R-value}_{(\text{brick})} + \text{R-value}_{(\text{sheathing})} + \text{R-value}_{(\text{fibreglass batt})} + \text{R-value}_{(\text{plasterboard})} + \text{R-value}_{(\text{inside air film})} .$$

Figure1 shows one of the typical brick cladding external wall. There are numbers of different materials layered to construct the wall. As described in above calculation,

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4 2009 ASHRAE Handbook - Fundamentals (I-P Edition). (pp: 38.1). American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc

you can even add more materials to achieve higher thermal resistance. However, as you do so, you are also increasing the amount of waste that goes to the landfill when the building is demolished or renovated. In addition, all materials, building components and their connectors has different service life. Therefore, if the connection between two building components cannot be easily separated from each other, one component that has longer service life has to be also removed in order to replace the other component that has shorter life service life. As a result, you might save energy cost by utilizing as many as high energy performing components into your wall, but you might end up wasting materials and pay more to maintain its performance.

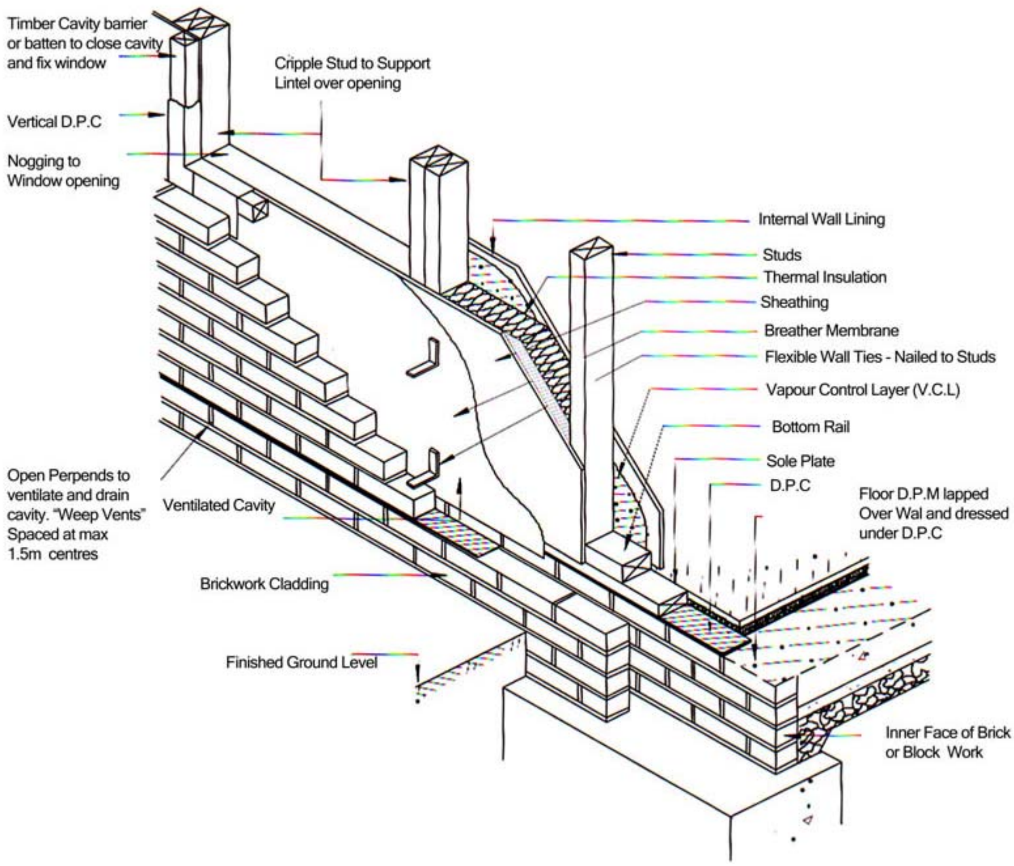

Figure 1 Typical externally sheathed wall with brick cladding

Thus, evaluating sustainable design cannot just be dependent on its energy performance while the building is in use. It has to include management of material consumption and recycle during renovation or demolition. Next chapter will lead to the idea of Design for Deconstruction or Disassembling which is a design guideline focusing on the management of end-of-life building materials.

3

DESIGN FOR DECONSTRUCTION

3. Design for Deconstruction

The movement toward Design for Deconstruction (DfD) instructs designers and planners' to be responsible for managing end-of-life building materials and to minimize consumption of raw materials. DfD's study guideline is to help architects and engineers design buildings that facilitate adaptation and renovation. The basic determinant of DfD encourages the reduction of overall environmental impact of end-of-life building materials by providing guidance on how to capture materials removed during building renovation or demolition and find ways to reuse them in another construction project or recycle them.[5]

3.1 Concept

DfD is a new concept for design and building community, intending to 1) maximize material conservation, 2) create adaptable buildings and to avoid building removable altogether, and 3) build an intelligent strategy to prevent obsolescence economic factors such as work labor for destructive demolition and disposal of building[6]. DfD helps buildings reduce new material consumption and waste during their full life-cycle, and encourages the reuse of building materials in the future. By enabling the control of material consumption, DfD strategy will facilitate buildings to recover their components for the next iteration. Furthermore, its management will provide both economic and environmental benefits for builders, owners, occupants, and communities where these buildings reside in.

The Six S's by Stewart Brand:

The base Idea of DfD is well captured by Stewart Brand. He has modified the six S's system in his 1994 publication "How Building's Learn." The six S stands for *Site, Structure, Skin, Services, Space Plan,* and *Stuff*[7]. It categorizes building as aggregation of layers that has different speed in changing cycle.

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[5] Ciarimboli, Nicholas and Guy, Brad. Design for Disassembly in the Built Environment: A Guide to Closed Loop in Design and Building, King County, WA, and Resource Ventures, Inc.
[6] Ciarimboli and Guy
[7] Brand, Stewart. *How Building's Learn: What Happens After They're Built*. New York: Viking, 1994.

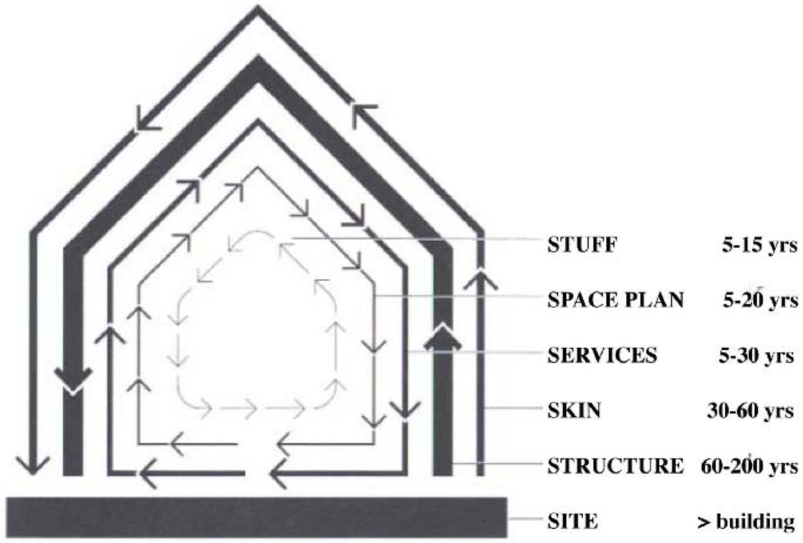

Figure 2
Stewart Brand's Six S's diagram

Shearing Layers of Change:

• ***Site***
Factors that can outlast the life of the building including:
- Geographical setting
- Urban location
- Legally defined lot

• ***Structure***
Structural element that can last 30-300 years including:
- Foundation
- Load-bearing elements

• ***Skin***
Façade elements that can change for repair or appearances every 25 years or so including:
- The building envelope
- Consisting of frame,
- Exterior finishes
- Glazing

etc.

• ***Services***
Factors that may reach the point of major replacement every 7-15 years and can cause demolition of an entire building if their embedded factor prevents alteration including:
- The utility
- HVAC systems
- Moving parts such as elevators

• ***Space Plan***
Attached-to-structure elements that can range widely from a commercial setting being overhauled every three years to a much longer life in a residential setting including:
- Division of space
- Cabinetry
- Interior finishes

etc,

• ***Stuff***
The things that can be changed daily to monthly including:
- Furniture
- Free-standing lamps
- Appliances

etc. (Brand, 1994)

This categorization expresses building's layers of change are in constant friction. Space Plan, which includes non-structural interior component, is faster changing layer but controlled by Structure, the slower changing layer. If the Space Plan needs its configuration in order to optimize the function of the building but cannot be accommodated because the limitation of the Structure, this means there will be high degree of friction. And this friction can cause the premature demolition of the entire building. The principle of the six S's system can help designers at the planning phase minimize this friction and facilitate end-of life disassembly, so that building can avoid dysfunction, high cost and waste in future configuration.

3.2 Selection of Material

To make a design that maximizes the building's life-span, we have to know the technical and service life of materials that are used in buildings. The technical life of a material refers to the life that the material will have excluding any influence of how it is intended to be used. The service life represents the material's life time that is predicted taking into account influences by humans and environmental stresses, or obsolescence cycles. The service life is potentially a shorter life-span, and it normally determines an actual life of the material[8]. Usually, the biggest friction that determines the life-span of the buildings occurs between building assemblies and components. For example, the replacement cycle for typical windows with metal or wood frame might be 25 to 40years whereas the replacement cycle for brick cladding is 75 years[9]. Therefore, the detailing of the connection between a window and brick cladding wall should

Figure 3
Installing window operation

Figure 4
Masonry wall

[8] Ciarimboli and Guy
[9] Ciarimboli and Guy

allow for the ease of separating without altering the brick when the it comes time to replace the window. Knowing the lives of materials is essential to DfD method. Information shown in table 1 can easily assist architects to select materials and create connection detail that has the greatest benefit. Creating simple connecting method between different systems and components that have the most disparate service lives will reduce waste and labor during repair and replacement cycles. This separation of longer and shorter-lived materials and components will be fundamental principle to maximize the building life-span, and this practice has practical and economical value.

Building Materials Types	Repair (yrs.)	Total Replacement (yrs.)
Flat roof BUR membrane	10	20
Pitched roof, cement composite shingles	20	50
Pitched roof steel sheet	usually not required	30
Brick cladding	25	75+
Acrylic stucco	20	?
Interior gypsum board	3 to 10	25
Interior concrete or block	10 to 20	75+
Metal or vinyl windows	10 to 20	40
Clad wood windows	10 to 15	25 to 50
Solid wood interior doors	4 to 8	15
Metal doors	5 to 15	25
Terrazzo	0 to 15	60+
Ceramic floors	10 to 15	40+
Vinyl composition tile	8 to 15	20
Hardwood floors	5 to 10	40+
Carpet	3 to 8	5 to 15

Table 1: Repair & Replacement Cycle for Typical Building Material Santa Monica Green Building Program

For the after-life of the material, considered design helps to minimize waste. Input of craft, chemical and physical properties, material production or manufacturing, etc, are all relating to material's economic value, toxicity, durability, flexibility for reuse, and potential for recycling[10]. More the materials maintain its purity or structural integrity and composition, the more the materials have utility for reuse or recycle. In this case, "wet" materials such as concrete, mortars, paints, and asphalt paving will reduce the feasibility for reuse, however they can be recycled or avoid contaminating other

[10] Ciarimboli and Guy

recyclable materials. Having a viable input for reuse and recycling materials, selecting "dry" or independent materials is reasonable.

Potential deconstruction tradition can be found in modern movements in architectural history. The International Style, for example, emphasized materials and structure's assemblies such as metal, glass, concrete and stone, with it came their inherent capability for reuse and recycling realized by method of connection detailing. Notable examples are Mies van der Rohe's Barcelona Pavilion and the Seagram Building, where separation and utilization of pure of materials, against decorative embellishment.

Figure 5
Barcelona Pavilion, Spain
By Ludwig Mies van der Rohe

3.3 Connection method

Material can be taken back to its constituent properties or remain embedded within assemblies, which is all dependent on the connection. Determining the connection strategy is one of the key roles of DfD which affects the efficiency of the projects throughout the life-time of the building. The scale of the connection controls the size and number of building components, labors and tools that is required in assembly process, and furthermore relates to economies of transport. In addition, connection is a very important factor for on-site disassembly process in terms of determining how much amount of manual labor and tool will be required. The connection method implies accessibility, readability, and efficiency of later operation such as repairing, replacement and reuse, and so on. If the connection is inaccessible or difficult to understand for people maintaining the building, then it will make the disconnecting process inefficient or prohibitive.

Type of Connection	Advantages	Disadvantages
Screw	easily removable	limited reuse of both hole and screws cost
Bolt	strong can be reused a number of times	can seize up, making removal difficult cost
Nail	speed of construction cost	difficult to remove removal usually destroys a key area of element - ends
Friction	keeps construction element whole during removal	relatively undeveloped type of connection structural weakness
Mortar	can be made to variety of strengths	mostly cannot be reused, unless clay strength of mix often over-specified making it difficult to separate bonded layers
Adhesives	strong and efficient deal with awkward joints variety of strengths	virtually impossible to separate bonded layers cannot be easily recycled or reused
Rivet	speed of construction	difficult to remove without destroying a key area of element - ends

Table 2: Connection Alternatives for Deconstruction. Adapted from SEDA, 2006

Again, “wet” connection such as mortars and adhesives will reduce accessibility for repairing and replacement and feasibility for reuse (see Table 2). Avoiding wet connections as much as we can at the planning phase will improve efficiency in the disconnecting process in the future.

3.4 Structural Method

Table 3 shows certain structural systems and their advantages and disadvantages. It is clear that some forms are more efficacious than others. Simple forms where structure is considered with less point or plane, reduces complexity in overall construction and deconstruction process. Efficient systems such as a grid post and beam or exterior load bearing with open span becomes more effective when they are combined with exposed connections providing visual data allowing for the ease of understanding the building’s disassembly potential[11]. In addition, form and structure should be determined by available laborers and manufacturers at the place. Panels or large members are appropriate for the construction process requiring machinery. Where less mechanical labors will be utilized, smaller and more members should be applied[12].

[11] Ciarimboli and Guy
[12] Ciarimboli and Guy

Type of Structure	Advantages	Disadvantages
Masonry	• individual components break down into small, easily reusable units • solid mass can be re-cycled if monolithic • re-use does not dictate design	• blocks need soft binder to be reused which reduces strength • may include reinforcement which is harder to deconstruct • requires heavy machinery to break down solid mass • may have lateral walls which compromise long term occu¬pancy pattern options
Light Frame	• structurally efficient, allows for multiple occupancy patterns • easy to deconstruct into reuseable elements if detailed appropriately (not concrete in-situ) • can be layered separately from cladding and insulation • can be factory made (not concrete in-situ)	• difficult to deconstruct unless framework is detailed with appropriate joints • notching, holes and binding with resins can reduce possibilities for re-use • depending on size and type can be manually or mechanically deconstructed
Panel System	• structurally efficient • factory made – gives precision • all components can be built in to minimize waste	• required mechanical deconstruction • materials are bound together and hard to separate • need for cross wall bracing reduces internal options
Post and Beam	• separates structure from envelope and other systems, can provide standardization of dimensions and homogenous materials • can reduce mass of structure to fewer linear components	• fewer larger members require mechanical deconstruction. • less multi-functionality is possible such as combining structure with finish, etc.

Table 3: Major Structure Systems Related to Deconstruction. Adapted from SEDA, 2006

3.5 Flexible building planning for changing needs

DfD method is very effective and practical in sustainable design. However, in reality a lot of buildings are demolished not because of their expired service lives, but because of the incapability of adapting to the changing needs of users or city fabric. In this case, renovation no longer makes sense due to amount of operation and cost comparing to a brand-new construction. Conscious design towards deconstruction/dissembling is important, but can be more effective when flexibility is incorporated during the planning of a building that can reflect the changing needs and new technology of the future.

In such projects as the Lloyds of London by Richard Rogers and the Centre Pompidou buildings by Renzo Piano and R. Rogers (See Figure 6 & 7), both exemplifies DfD concept of separating building elements that have disparate service lives as well as exposing visual data of the structure. These two buildings turned conventional building functions inside-out: Whereas mechanical and utilities system are normally set in the internal core, they have placed it on the outer layer of the building. Structure is treated as an armature to support all mechanical, electrical, plumbing systems. This method provides very open flexible floor plans within the building envelope. This allows not only ease of repairing and replacing building components over time but also the capability of accommodating functional changes in the future.

Figure 6
Centre Pompidou, France
By Renso Piano & Richard Rogers

Figure 7
Lloyds of London, England
By Richard Rogers

For flexible building planning, I have chosen Open Building System as an appropriate design method relating to social sustainability. Comparing to the micro approach of DfD, Open Building System takes macro approach towards sustainable building planning. In the next chapter, principle of Open Building will be discussed with several case studies.

4

OPEN BUILDING SYSTEM

4. Open Building System

The principle of Open Building System suggests that a building should be designed and built in such a way that both spaces and parts of the building can be clearly allocated to those parties and individuals who will take responsibility for them. The people and the community who are emotionally and monetarily invested in the place they live in will have the most influence on their built environment and the sustainability of their spaces[13]. The effort people will put into make their own place better and safer eventually leads to maximizing the life time of the place. A built environment that clearly distinguishes spaces and parts of a building can highlight the need for continued maintenance and hold accountable those who are responsible for taking care of it.

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How do we design the built environment to support both stability - in respect to long term community interests - and change - in respect to individual preferences? How, in other words, do we plan and implement a regenerative built environment?

-John Habraken
Habraken, MIT Press, 1998

4 .1 Concept

Today, many buildings are demolished not because of the structural integrity but because of the lack of flexibility of the building to accommodate occupants' needs. To see the problem, Open Building distinguishes built environment into levels. This study became the main core of Open Building principle that gives direction towards the design solution. Figure 8 shows our built environmental is divided into different levels: the tissue level (urban environment), support level (infrastructure of building), and infill level (fit-out). The higher level accommodates and limits the lower level. In turn, the lower level establishes certain requirements for the higher level to follow. Every level has its responsible social group, such as the customer (occupant) on the infill level, the developer or building corporation on the support level, and the

[13] Habraken, N. John. **<u>The Structure of the Ordinary</u>**, Cambridge, London, MIT Press, 1998

municipality on the tissue level. Open Building method insists this different level of decision making should be disconnected, yet coordinated.

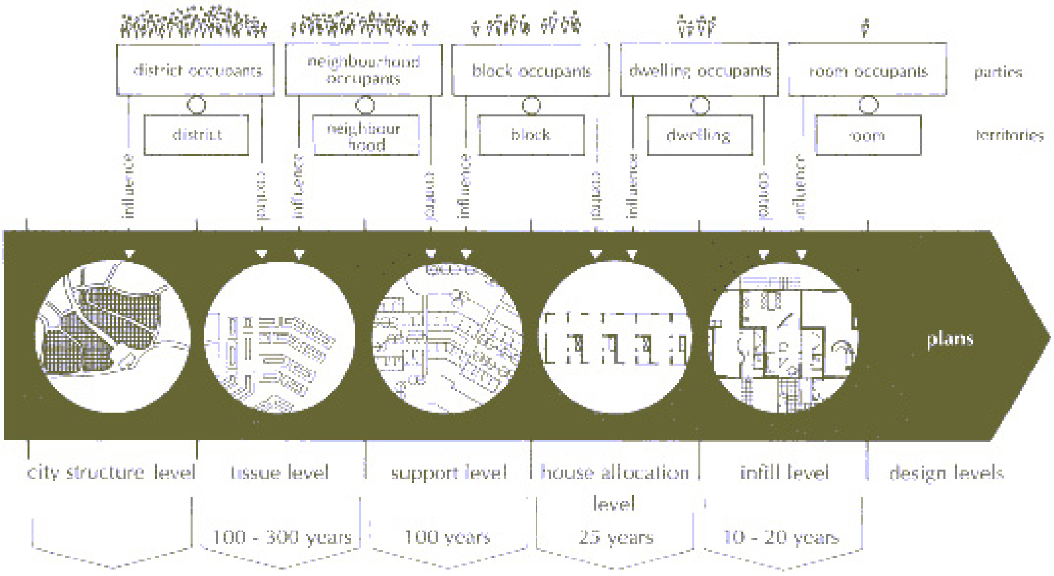


Figure 8
A Diagram of the Principle of Environmental Levels (Habraken, MIT Press, 1998)

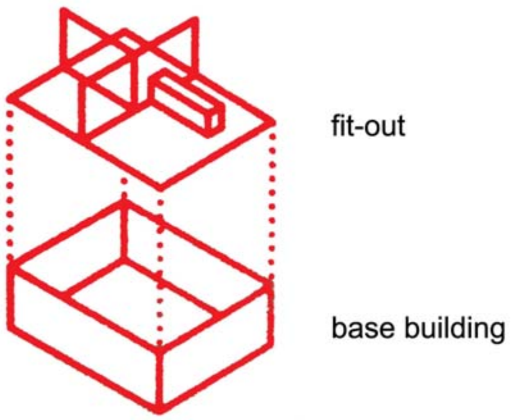
The original study of Open Building has been developed by John Habraken, a Dutch researcher. His study has focused on investigating laws to govern built environment that is revealed by patterns of transformation[14]. He introduced Open Building with his philosophy "We should not forecast what will happen, but try to make provisions for the unforeseen"[15], and suggested a design strategy providing flexibility between support and infill function of the building to accommodate unknown future changes. Open Building insists total planning in care, responsibility and technology.

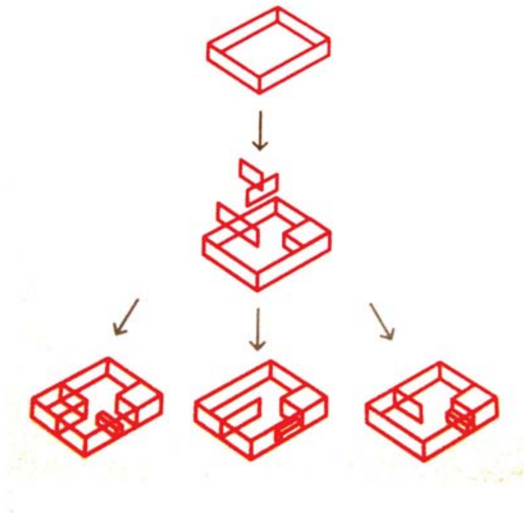
4 .2 Strategy

In order to achieve a sustainable architecture, a building lasting for long years with the efficient embodied energy, the building should be conceptually and technologically separated into systems that are sorted according to the lifecycle of the materials and components, the spatial and structural hierarchies, and most importantly social responsibility. In the design of Open Building, the infrastructure of building ('support') and fit-out ('infill') were treated as separate entities, with different life cycles, in order to build an environment that can respond to individual needs of the occupants. The

[14] Habraken, N. Jhon. http:habraken.con/html/biography.htm

purpose of separating systems according to the life cycle is to accommodate time and change for the future in the early design process. DfD which confines the design strategy to its environmental significance, systemization of Open Building is for user participation and economic management. It maximizes the capacity of the building to meet the changing criteria and demands of owners and users throughout its life time.





Clearly isolating the support from the infill also means users are simultaneously changing and managing the floor layout and interior finish without affecting any infrastructure of the building. In many concrete buildings today, the wiring and pipes are embedded in the structure. As a result, the concrete slab has to be partially destroyed during renovations or upgrades in the mechanical systems made with new technologies. In this matter, Open Building method permits quick easy operations without creating waste.

Efficient and cost-effective solutions are often reduced to mass production and unified form in the modern world. Meanwhile, such industries like the Mc-Manshions, cookie-cutter housings, and pre-engineered buildings are effective producing machines economically and environmentally, however they tend to remove individuals from the center of equation. Habraken criticizes “Man no longer houses himself. He is housed[16]”. The setup for Open Building Systems is similar with predetermined dimensions, positions and interfaces of parts, however, its intention is more to do with lifestyle and preference of the occupants.

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[15] Habraken, N. John. Supports, An Alternative to Mass Housing, The Architectural Press, London, 1972. (first published in Dutch, 1963)
[16] Kendall, Stephen H. *An Open Building Strategy for Converting Obsolete Office Buildings to Residential Uses.* the International Lean Construction Institute. July 2003

4.3 Application

To understand the principle of Open Building, I have selected four case studies, which have different approach from one another. These case studies will show that Open Building system can be applied to variety of projects such as renovation, new residential and mixed-use.

Case Study 1

The Kales Building, Detroit, USA: Renovation project for residential units

Figure 9
The Kales Building, Detroit, USA

A renovation building model was demonstrated by Dr. Stephan Kendall. His intention with the study is to show the advantages of Open Building System's marketability. In conventional large-scale building transformation projects, developers have to give 'pro-forma' in early phase of the design to estimate building value depending on the market demand.
This is difficult and since the time between program planning to actual lease-up or sale takes several years, and during this time the construction and labor costs, interest rates, and other economical factors can be inevitably changed. Kendall developed an innovative plan for The Kales Building in Detroit, USA, with the following objections[17]:

1) Offer the developer decision flexibility in meeting current and future markets.
2) Enable the developer to defer decisions about unit mix and layouts without risk, by making each dwelling unit as autonomous as possible.

[17] Kendall. 2003

3) Address the extremely limited space on the site for logistics of construction.
4) Develop a process that enables maximum use of off-site “controlled environment” facilities to prepare ready-to-install “integrated interior fit-out kits”.
5) Enable subsequent adjustments to the building to be done on a one-unit-at-a-time basis, including conversion to condominium units for sale, while assuring that improvements to the base building will minimally affect individual units.

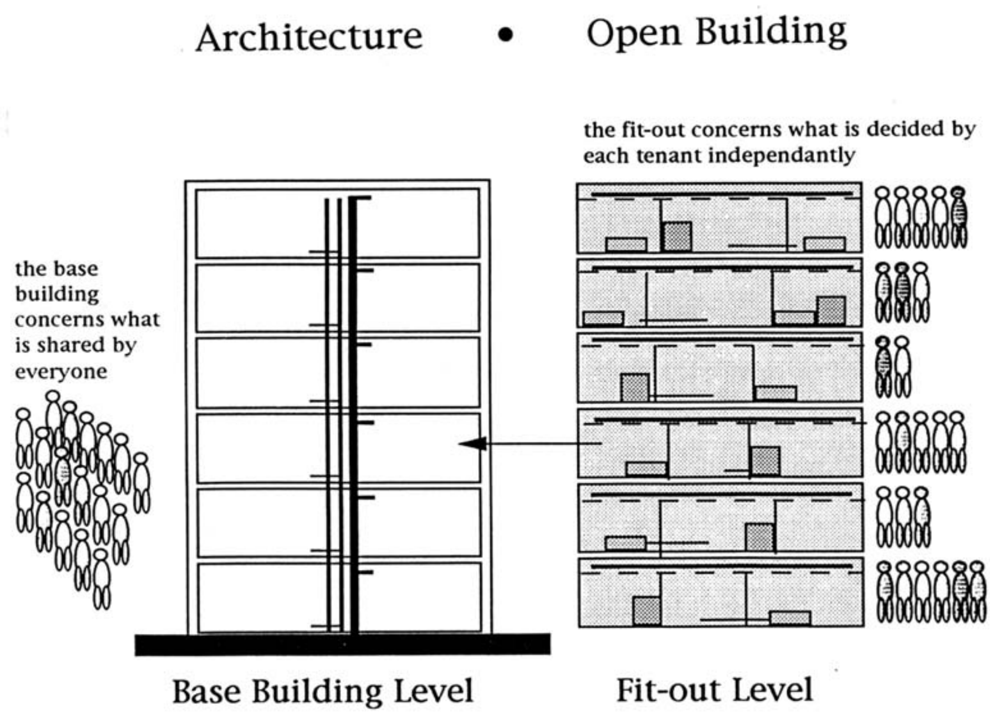


Figure 10
A Diagram of open building (Kendall)

Figure10 shows Kendall’s understanding of Open Building System. He observes the Base Building Level as a permanent foundation that is tied to the political, geotechnical, climatic and regulatory environment.[18] He offers tenants a number of unit layouts depending on family sizes. This variety of choices also helps tenants to prepare for their changing needs for future.

[18] Kendall. 2003

The Architectural Organization:

In the typical floor of the project, the Support including exterior, structure, stairs and central MEP shaft, and public corridors (showed in blue, Figure 11). They have not changed from the existing condition. New plumbing cores are placed in positions showed in pink, which allows possible layout variations of dwelling units. Each unit can even accommodate different floor plans that can be fully customized to meet occupant's preference and budget.

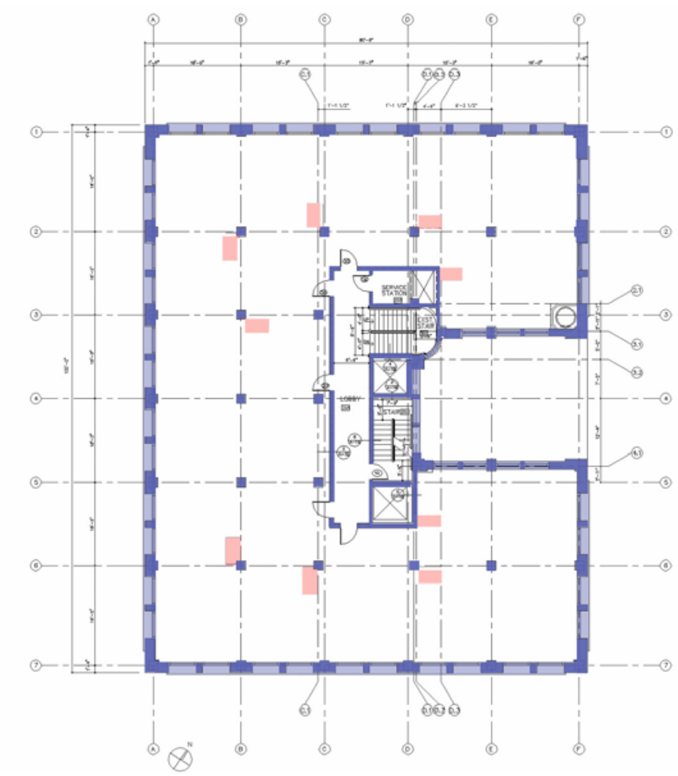


Figure 11
A typical floor showing the new plumbing cores and the existing building

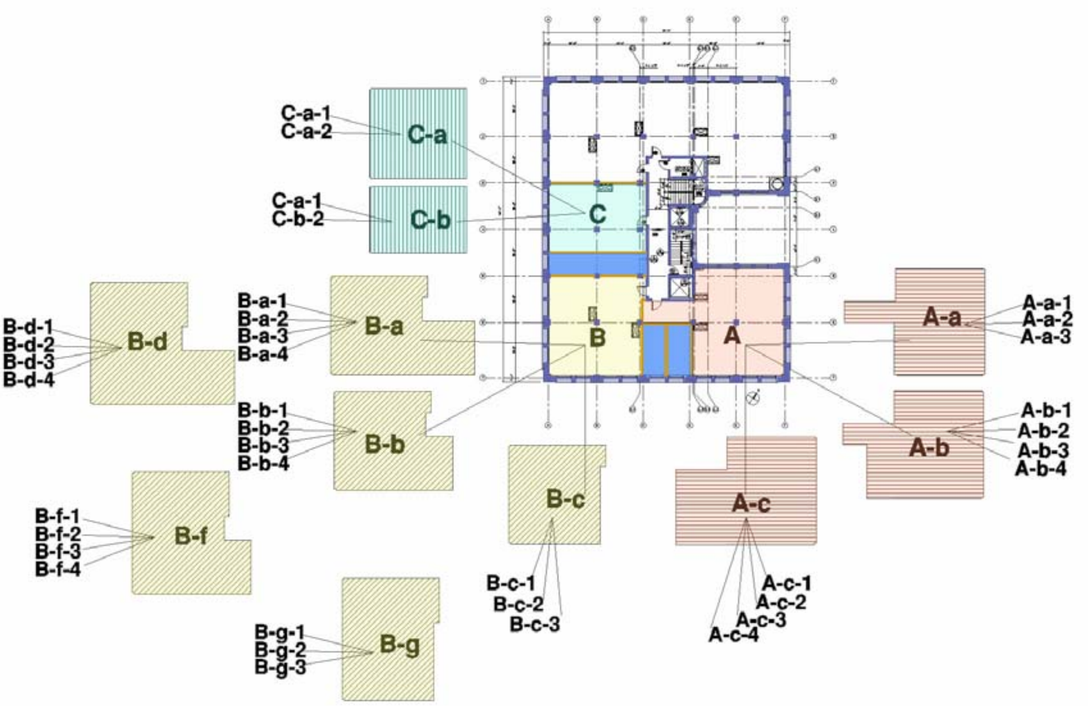


Figure 12
The capacity analysis of one typical floor of the building

The drawing on the right shows the empty condition of A-b. There are two MEP shafts shown in pink within this unit. Figure 14 and 15 shown below are example of two different variant unit layouts; one has one bedroom with one big living room space and the other has two bedrooms. Red lines on the drawing shows the horizontal piping that are extended form the new MEP shafts.

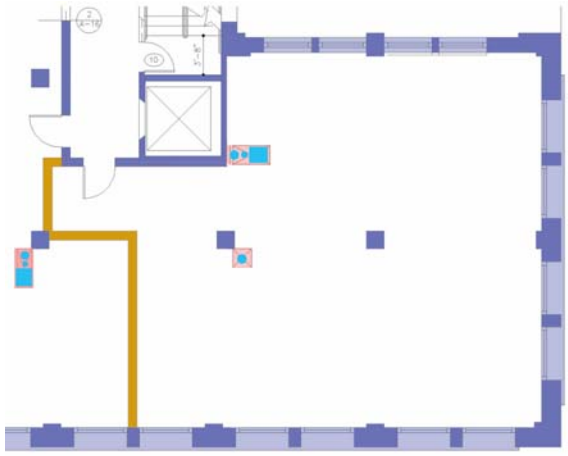


Figure 13
Unit A-b

Figure 14
Variant A-b-1

Figure15
Variant A-b-2

Kendall' s idea is that the developer can offer a menu of choices for 1) layout of the units, 2) either rented or owned, so that tenants do not have to look for a room that fits to their desire but they can make the room fit their needs.

Case Study 2:

Hötting West, Innsbruck, Austria:

New residential complex

Figure 16
Exterior view

This complex of compactly planned, mixed tenure housing blocks was built in 2000 on the edge of Innsbruck, Austria, animating an external skin of folding shutters. The complex contains 298 flats of varying sizes (from one to three bedrooms) divided more or less evenly between rental and ownership. Apartments are organized in six identical blocks (see Figure 18) between five and seven storeys high. The concept of the architects, Eberle and Baumschlarger design intention echoes Habraken's thinking on the separation of "Support" and "Infill." They have organized the building system into five levels [19](See Table 4). Complete separation of these five systems creates a great deal of flexibility and feasibility for changes in the inner layout of the building.

Figure 17
Exterior folding shutters

Systems	Lifetime (year)	Explanation
Infrastructure	200-1000	"All the outdoor public infrastructure stands much longer than buildings A City infrastructure may have a history of 1000 years; we have to be very careful about this when we design a building."
The load bearing structure, staircase	100	"The load bearing structure, combined with staircases, and in relation to all the safety problems, can stand more than 100 years without any change. (Unless an error occurred in design.)"
Façade, service core	50-60	"The façade and the main interior outlet piping system inside. It should last 50-60 years. We don't frequently change façades in our culture, as it is very expensive to do so"
Function layout	20	
Interior	10	Ceiling, lighting, finishing, etc.

(* summarized from an interview with Eberle.)

Table 4
Five systems of building classified by life time

[19] Beisi, JIA. A Theory of architectural Practice: Open Building Interrelated by Bauschlargger & Eberle. The 2005 World Sustainable Building Conference. Tokyo. 2005

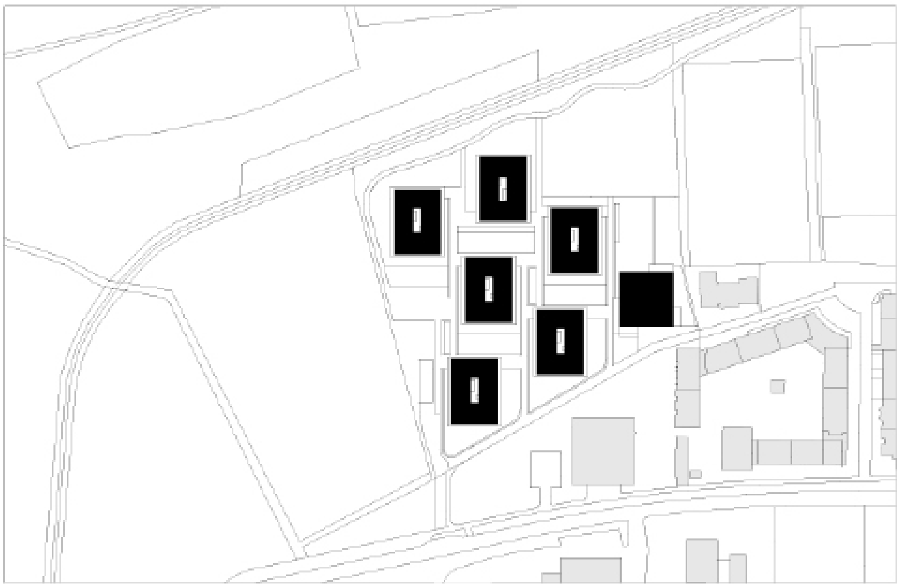


Figure 18
Site plan of the residential complex

The Architectural Organization:

The building layout shows very common typology of Open Building. There are two simple built structures: 1) the inter-core with a stairwell surrounded by utility closets and ancillary rooms, 2) the outer space surrounded by walls that are functioning as both structure and enclosure, there is no division of rooms in-between. Unit layouts are created by simply inserting and removing of partition walls. Basically, floor plans of each level are entirely up to occupants to decide weather the person want to have any divided rooms at all or any number of rooms. This typology allows very diverse and domestic arrangements within the apartment up to individual necessity.

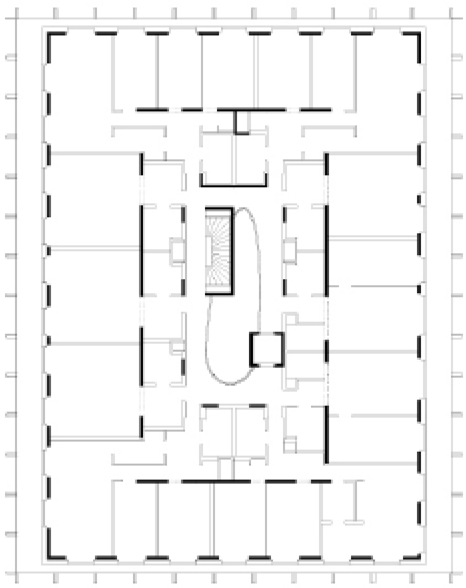


Figure 19
Typical floor plan of the building

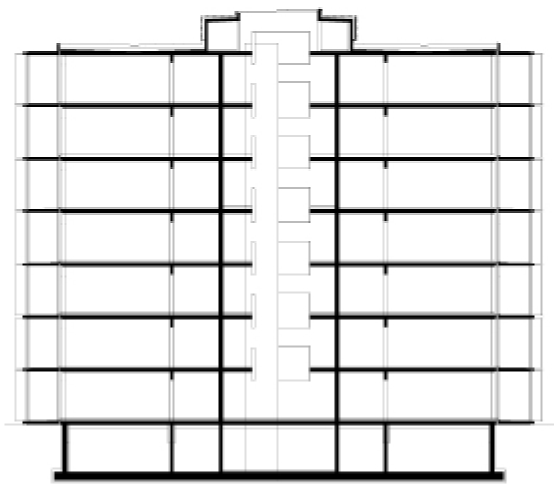


Figure 20
Section of the building

There are three strategies in this project to approach economic and green architecture. 1) compact form, 2)effective outer wall, and 3)sensitively adapted new technology.[20] Compact form is effective solution for energy and economic factor. Compact form reduces the surface area to volume ratio and applies less façade. Less façade means less material, which results in embodying less energy. In such cold climates like that of western parts of Austria, compact and well insulated form is effective to reduce the energy loss for heating.

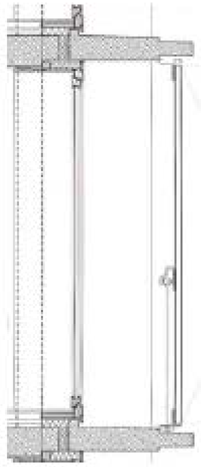


Figure 21
Operable façade in Hötting West

Eberle and Baumschlarger consider the façades to function as the structure ("support"). Façade is the component that distinguishes complicated inter-relationship between the exterior and the interior, the private and the public, and also controls embodied energy for the building. Therefore façades, the outer wall, are treated as part of the support and are designed to reflect the collective decision of the community and climate condition.[21] Yet, it is important that users or occupants are able to control the façade to adjust the natural lighting, ventilation, shading, views, and outlook as they wish. In this matter, outer wall becomes the most flexible elements in this building that can be changed or adjusted constantly.

[20]Beisi.2005
[21]Beisi.2005

Case Study 3
NEXT21, Osaka, Japan:
Experimental mixed-use tower

Figure 22
Exterior view

NEXT 21 was constructed in 1993 and located in central Osaka, Japan. The building consists of 18 individual housing units, which are designed by 13 different architects. [22] NEXT 21 is an experimental project sponsored by the Osaka Gas Company and demonstrates a new concept of multi-family housing that incorporate sustainable design as well as advanced technologies expected to be use in the near future.

Its purpose was aimed to fill the gap between highly individualized lifestyles and resource conservation efforts within a dense urban fabric. Today, the project still continues to test its unique collective housing method while accommodating the changing preferences and needs of individuals' lifestyle.

Building Descriptions
Stories: 1 basement, 6 aboveground floors
Building Area: 895.21 square meters
Total Floor Area: 4,519.14 square meters
Maximum Building Height: 22.66 meters
Architect-in-charge:
Yoshikita Uchida, Shu-koh-sha Architectural & Urban Design Studio

The Architectural Organization:
All parts of the building are unified with modular coordination. Sizes and the layout of the components are set based on a 90 centimeter module. The building is divided into three major zones: the house zone, the street zones, and the public zones.[23] The house zone represents the building framework. These zones are placed in six levels, and each floor has six units. There are three different sizes of modules for the house zones: the main module consists of units 7.2 meters x 7.2 meters, and the sub-modules come in two units 7.2 meters x 3.6 meters or 7.2 meters x 1.8 meters.

[22] Utida, Yositika. "Aiming for a Flexible Architecture", GA Japan 06, January - February, 1994
[23] Brower, Ryan. Keanery, Jennifer. and Kim, Jong-Jin. “NEXT 21: A Prototype Multi-Family Housing Complex”. http://www.open-building.org/ob/next21.html.Sep. 20. 2009

The columns, including the cladding, are 60 centimeters square in plan. The distance of surface-to-surface between columns is 6.6 meters, in other words columns are placed 7.2 meters apart, center-to-center. Spaces for ducts and pipes are provided in both the floor and ceiling plenums so that rooms, including wet areas can be located anywhere the occupant wants.

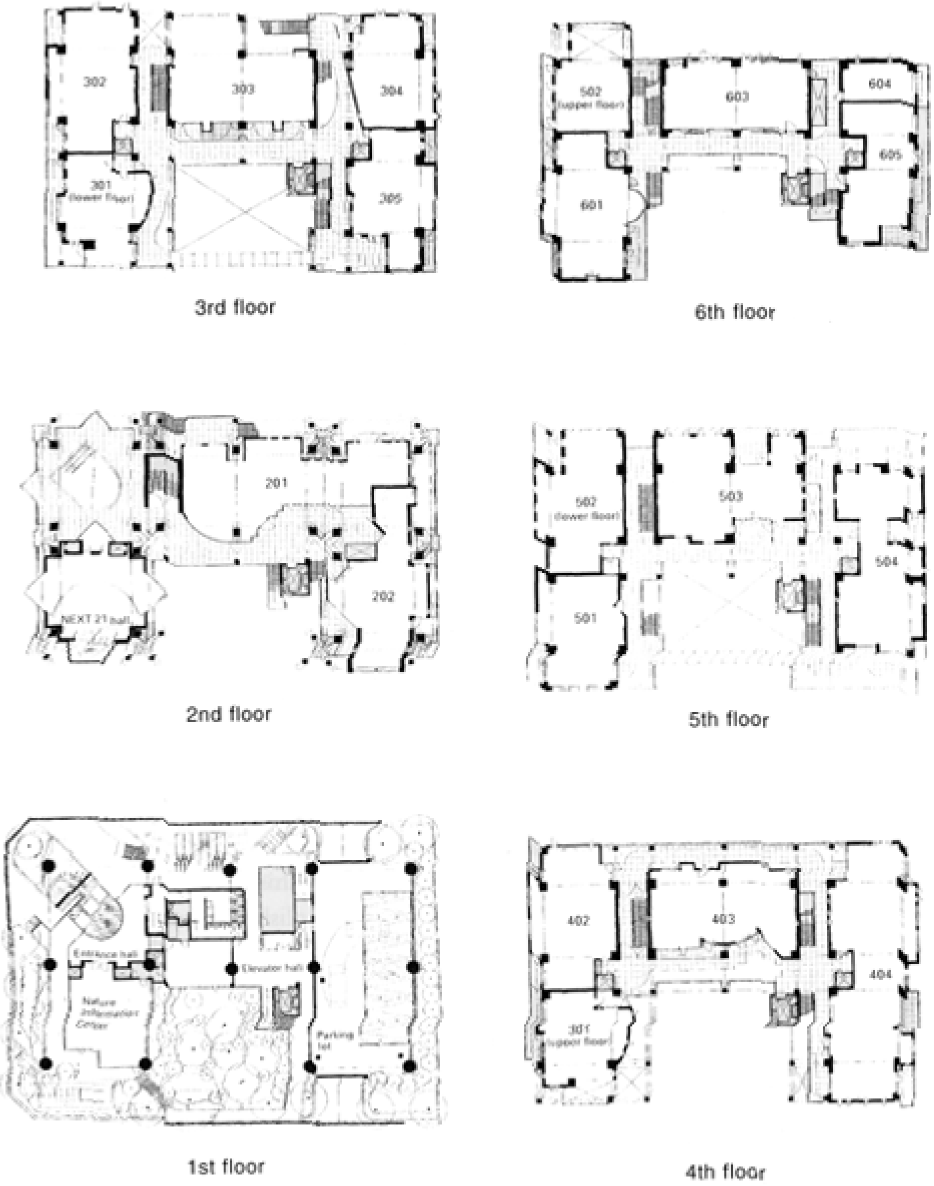


Figure 23
Floor plans of the building

The street zones include stairs, corridors, and void spaces and they are all 3.6 meters wide, surface-to-surface. These zones are created by the spaces between the house zones. Similar to the house zones, the floor and ceiling have plenums for the shared

Resources: Brower, Keanery, and Kim. 2009 ducts and pipes for the building. The street zones are deeper than the house zones in order to fit more pipe systems. The floor panels can be easily removed and put back again, which provides easy access for maintenance people to work on and replacement or repair systems.

Figure 24
Elevation of the building

The public zones are located on the lower levels of the building. Its public facilities include meeting rooms, parking, and mechanical rooms. (See Figure 23) The public zones use bigger modules, 10.8 meters x 10.8 meters or 10.8 meters x 9.6 meters. To achieve wider bay distances to fit these large modules, every four columns on the upper floors merge into one column on the lower floors (See Figure 24, 25, & 26).

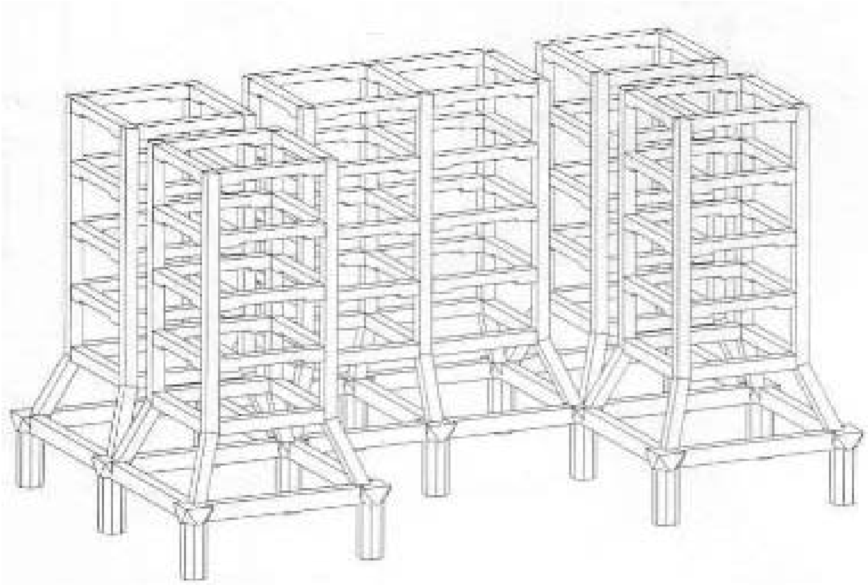


Figure 25
Building Frame

The structure is the only permanent element of the building. Cast-in-place concrete was used for beams and columns, and these structural frames are clad to protect from rain. The floor-to-floor height of the upper residential level is 3.6 meters, and lower public facility level uses 4.2 meters floor- to-floor.

Figure 26
Branching of support columns

A standard floor level is set to 240 millimeters above the slab frame. Floor is raised and constructed by a sound insulation method. Many of the tenants chose to have wood floor finishes. Wiring and pluming pipes are stored in the plenum space created by the raised floor and those mechanical systems are easily accessible just by lifting the floor components (See Figure 27& 28). The structural plan and the plan of the mechanical systems are coordinated so that pipes and ducts never go through the walls, floors, or beams. Thus, such infill subsystem maximizes flexibility of the plan layout within the unit: interior partitions and facilities can be located in anyway while maintaining access to the mechanical components.

Figure 27
Raised floor and utility system stored

Figure 28
Ducting in ceiling/floor plenums

The eighteen residential units in NEXT 21 project were designed by 13 different architects. Each unit is unique and none of them are the same. Some of them have two levels or large garden space (See Figure 30 & 31). Design of all units was undertaken during the construction of the building frame. Social involvement among designers, occupants, and technical experts were very important during decision making process in the project.

Figure 29
Court yard view

Figure 30
Private garden space

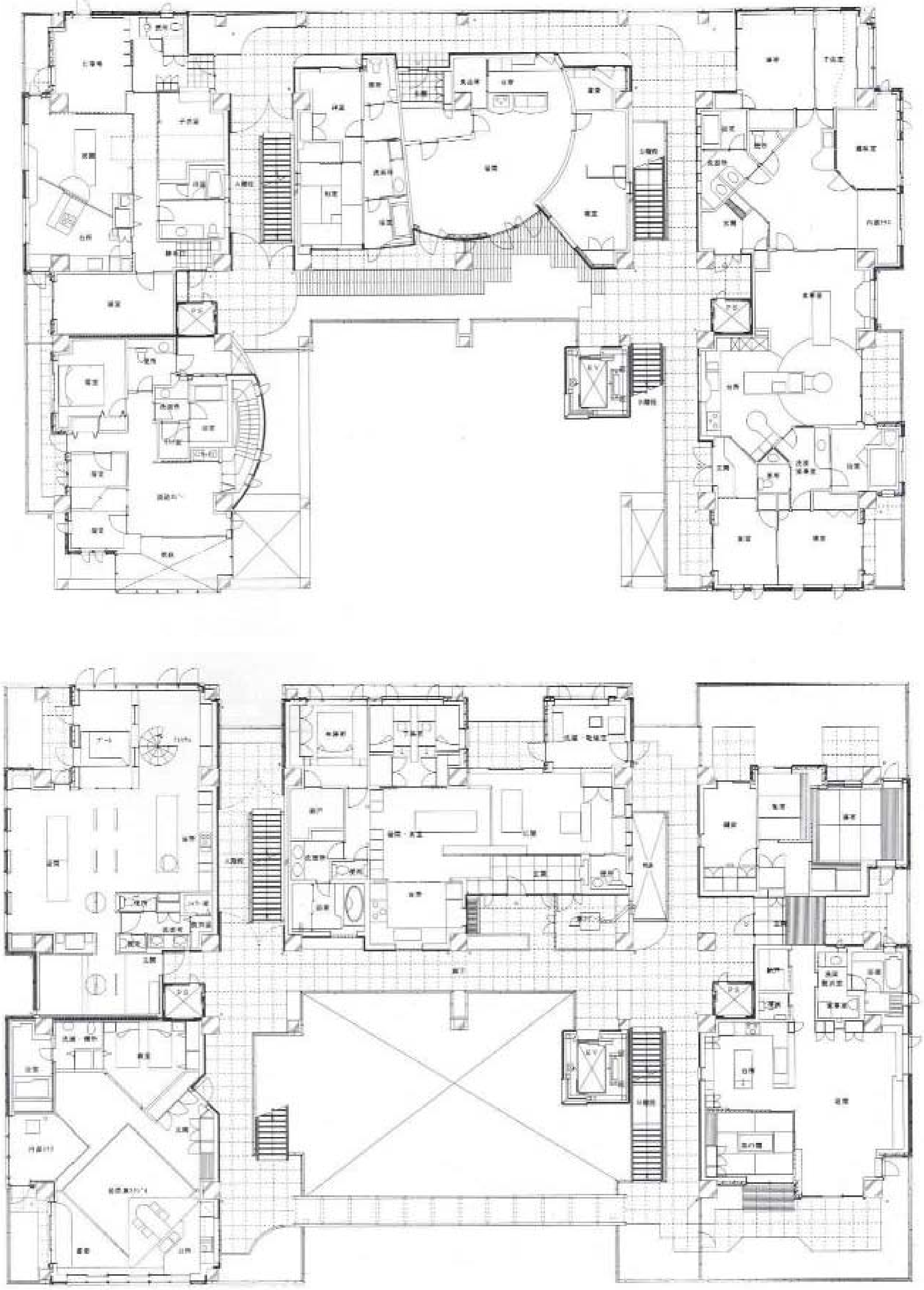


Figure 31
Examples of various floor plans

The exterior walls of NEXT 21 are placed at the tip of a cantilever in order to allow tenants to change them from inside without the needs for scaffolding. Stainless steel panel are used for the cladding. These panels are treated as an independent system on the infill level. The perimeter walls fit into 150 millimeter wide band. Insulation and exterior cladding are fixed to the outer walls so that replacement of these components can easily be done. There are geometric rules incorporated with the modular arrangement of windows, which also achieves to provide unified appearance from the street. There are other material choices besides stainless steel panels, such as tiles or siding. (See Figure 32)

Figure 32
Various cladding materials

Summary of Case Studies:

Open Building is a multi facetted concept, with technical, organizational and financial solutions for a built environment that can adapt to changing needs. Its approach in sustainable design has potential to be recognized internationally. The idea is new, however, it is the way that ordinary built environment can grow, regenerate and achieve total sustainability. A superficial comparison of Open Building and Design for Deconstruction suggests that they have much in common. Likewise, they both pursue design strategies to maximize building life by taking into account service life of building compositions. Where they differ, DfD insists sustainable buildings must maximizes service life by aiming to be cost efficient and reduce waste, while Open Building emphasizes social aspects founded in people’s responsibility and involvement toward the care and upkeep of their spaces

5

WOOD BASE BUILDING AND ITS POTENCIAL TOWARDS SOSIAL SUSTAINABILITY

5. Wood as an appropriate construction material for Social Sustainability

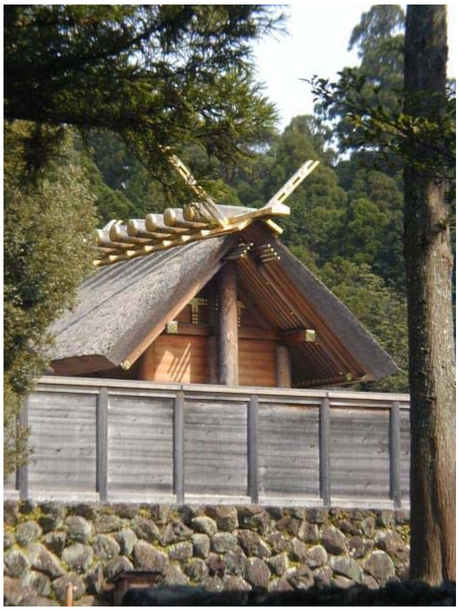


Figure 33
Ise Shrine, Mie, Japan

In traditional Japanese culture, highly dis-assembleable and re-assembleable wood joinery have been developed due to the presence of natural forest, the mild climate, and earthquake-prone geography combined with the skills of laborers to achieve pristine craft-intensive architecture. The Ise Shrine in Mie, Japan represents the epitome of this tradition where the inner sanctum is dismantled and reconstructed every 20 years for the last 1,300 years[24]. The process of construction and deconstruction includes forestry, the stewardship of the timber resource, to build each new iteration as well as the reuse of the dismantled shrine to repair other shrines across the country.[25] Each dismantling and rebuilding cycle protects the traditional carpentry skills from being forgotten and allows involvement from community to see and support the ancient practice. This is a great example of social sustainability, demonstrating that the building is maintained within a social community.

America's 2x4 timber-frame construction method is developed in the way that all building-related products follow certain rules in dimension. Lumbers, panels, and building components are fits to the increments system, so that everyone can understand how houses are laid out. Also, a great affordability was achieved by 1) speed construction and 2) light-weight. 2x4 housing can be built fast because construction adjustments for variations in the thickness of each log did not have to be calculated and accommodated. Light-weight 2 x4 members can be moved by a single man without machinery. In addition 2x4 housings are easily maintainable. Even ordinary house owner can make small repairing and replacement operation by

[24] Tange, Kenzo and Noboru Kawazoe. (1965). *Ise: Prototype of Japanese Architecture.* Cambridge: Massachusetts Institute of Technology Press.

[25] Ciarimboli and Guy. pg4

themselves. Wood was appropriate material because it is economical, locally available and easy to deal with. In the States, stores for lumbers, hardware, and home crafts are domestically available such like grocery stores.

In this chapter, construction-related wood products are studied from the point of view that wood is an appropriate material to pursue social sustainability because of its feasible application on DfD and Open Building method. Together with beneficial factors towards green construction evaluations such as Life Cycle Assessment and GHG reduction, I will discuss advantage of wood as construction material.

5.1 Wood application for Design for Deconstruction and Open Building

From my study in previous chapters, I come to explore wood construction utilized in the planning method of DfD and Open Building. I focus on current wood products and its application that are often used as structure and building envelope.

5.1.1 Solid lumber

Wood member of sufficient dimension has a great potential and flexibility for reuse and remanufacturing. It can be cut or formed to make new sizes and shapes with no loss of its base properties. Reclaimed wood in general can be associated with vernacular architecture, regionalism and other socially sustainable factors. Ultimately, construction by solid lumbers can exhibit high quality of craft and material that encourages people for their additional effort to maintain and reuse for the extended life.

Solid lumber

5.1.2 Light-timber framing

Timber framing

Timber framing is appropriate medium for Open Building since fit-out and partitioning are non-structural and timeframe itself is intended to last centuries. Room reconfiguration and partition location in timber frame building is can be relatively easily modified and organized over time without high expertise. Endoskeleton can be well protected from the weather outside and exposed in inside for inspection. However, while an efficient use of lumber, use of a large number of nails and many small increments of materials with relatively small dimension is problematic for disassembling. Clips, angles and plates, bolts, double-headed nails, are the solution to make the wood member to be easily separated. Replacing nails with easily removable connection also reduce the labor intensity on the site when the time of the dissembling. In addition, more effective way is to build light frame wall as a unit panel so that whole entire wall panel can be reuse with less work and maintain the high value. Timber framing is typically preferred as maintains larger sizes of members and use fewer large connections.

5.1.3 Engineered lumber

Glulam

The advantage of the engineered lumber over solid wood is utilization of fast-growing and small diameter trees in efficient manufacturing processes. It is great to not only minimize material but also performs high degree of quality and strength.   On the other hand, engineered products have been criticized over the years for unease of full recycling because of the use of adhesives and binders. Interestingly, current researchers have been searching a solution to above matters. The University of Georgia study and the National Association of Home Builders Research Center (NAHB) report found that engineered wood product waste generated on construction sites can be ground up and used as an effective and safe mulch[26]. Those grounded up mulch pieces were consists of dimension lumber, OSB, plywood, I-joist, laminated veneer lumber, southern yellow pine glulam timber, finger-jointed studs, and so forth which were picked from the waste in some residential constructions sites. The impact of the leachate, from those recycled mulch's, on water and soil were tested by the Environmental Protection Agency (EPA) as toxic (EPA Method SW 846), and concluded that there were no toxic contaminations in the leachates[27]. Furthermore, case study by the NAHB Research Center shows that the cost of all grinder operation, transportation, labor, tipping fees, etc., was less than disposing of those wood wastes in landfill. These results are great finding for wood industries, engineers, and designer to further contribute in sustainable architecture[28].

Application of glulum

Cross Laminated Timber (CLT)

Precut CLT panel

[26] Gaskin, J. 2004. Potential Environmental Risks of Onsite Beneficial Reuse of Ground Engineered Wood Wastes from Residential Construction. Cooperative Extension Service. Engineering Outreach Service. College of Agricultural & Environmental Sciences, University of Georgia, Athens, GA.
[27] Gaskin, J. 2004
[28] Lund, E. 1999. On-Site Grinding of Residential Construction Debris: The Indiana Grinder Pilot. National Association of Home Builders Research Center, Inc.

5.1.4 Structural Insulation Panels (SIPS)

Pre-fabricated SIPS combine sheathing, structure, and insulation all into one, is lightweight building component. Normally, these panels are comprised of rigid insulation in the core, bonded to two layers of engineered wood on both side. Expanded polystyrene (EPS) and extruded polystyrene (XPS) in the insulation have been questioned over the chemical used in their production and their potential effects on health. Currently, polyisocyanurate, polyurethane foam, compressed straw or mineral wool are more used as alternatives. Comparing to traditional framing methods, SIPs install more quickly and are more energy efficient. In the States, the panels are typically built in coordinated sizes such as 4”, 6” or 8” width and up to 20’ lengths in 4’ increments to fit 2x4 constructions, and these products can be applied as wall, partition, floor, and roof construction. SIP wall panels are effective with timber frame since it can connect its bottom spline directly to wood sub-floor or to a sill. Simply removing this spline, the panels can be separated from each other or released from the structure. Removing operation is very easy as either by cutting behind the wood spline and re-routing a new spline, or by cutting at the seam between the spline and wood sill or top plate. SIP is flexible in terms of reuse because each panel remains an integral unit even if it is trimmed down to smaller panel. For example, SIP wall panels that were removed from demolished building can be resized to fit new construction for a second use. Some SIP panels can be recycles by parts. Substituting wheat-straw for expanded polystyrene (EPS) as infill insulation material can achieve less environmental impact and has great potential for recycling and biodegradation.

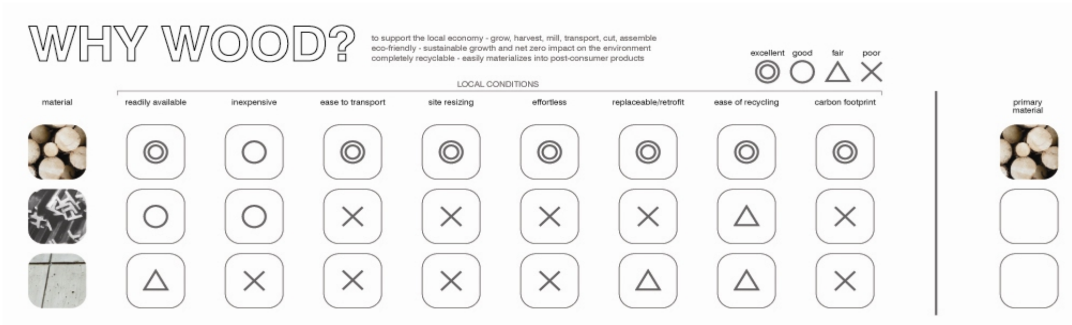
Structural Insulation Panels (SIPS)

5.2 Wood and Lifecycle Challenge

Construction-related Materials have been emitting huge amounts of greenhouse gases from their extraction, refining, manufacture or processing and delivery. The production of cement and steel alone account for over 10% of global, annual greenhouse gas emissions[29]. Planners, developers, architects and builders are asked to be aware of the climate change impacts of construction materials and consider appropriate selection of materials for building projects.

Steel and concrete have high Green House Gas (GHG) emissions in the process of extraction, refining, and manufacturing.   Wood, on the other hand, has negative carbon intensity since CO2 is taken from the atmosphere rather than being emitted during its growth. By substituting wood for conventional building material, we can reduce GHG emissions significantly because of the amount of carbon that is offset when wood is utilized. Having wood as the main building material, the building functions like a carbon sponge. It soaks up carbon dioxide; every kilogram of wood can store up to 1.8 kg of CO2[30].   In addition wood is flexible in terms of feasibility and its ease of operation. When it comes to process of re-sizing re-forming and re-use, wood has great advantages. Compared to other materials, wood products require less energy and effort during transportation and recycling. Furthermore, it requires no high skilled labor, no heavy machinery, low embodied energies, and low cost. DfD studies also show wood can be fully reused, recycles, bio-degraded or burned for utilization for its energy content as long as it has not been contaminated with toxic preservatives, paints, or adhesives.

Wood is light, adaptable, recyclable, and beautiful, and can always be related to regional culture and craftsmanship. The whole premise behind sustainable architecture can only be achieved by using sustainable resources. Use of local wood encourages sustainability of both forest and community in its region.



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[29] ECCM Report 2006, *Forestry Commission Scotland Greenhouse Gas Emissions Comparison Carbon benefits of Timber in Construction,* Edinburgh Centre for Carbon Management Ltd. 2006

6

DESIGN PROJECT: PROTOTYPE TIMBER BUILDING FOR FUTURE SCHOOL

6. Design Project
Prototype Timber Building for Future School

6.1 Project Objective

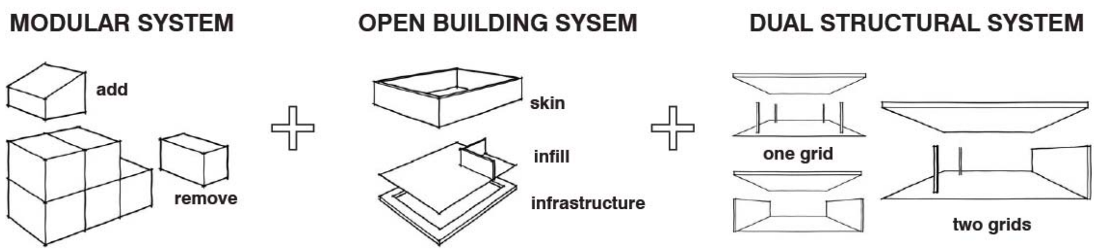
School is always an integral part of the community to an extent. My design attempts to push the envelope by extending the role architecture can play. Using the school as a tool to teach individuals, to improve the neighborhood, and bring together industries, businesses, carpenters, craftsman, users, and residents, social sustainability and responsibility can be brought to the doorstep of everyone in the community. With a flexible program, communal spaces used by the school during the day can be used to benefit the community at night. The goal is to aid local businesses and workers by providing them the opportunity to tackle the project. As part of the strategy, the design ultimately meets the criteria of small needs and can later be expanded upon as more space is required. The target is to make new construction affordable short term, in the mean while inherently building in a long term planning objective within the system of modular design.

[30] GOETHE -INSTITUT. http://www.goethe.de/ges/umw/dos/nac/leb/en3122653.htm. Sep.20.2009

6.2 Modeling School – Flexible Building Strategy

CONCEPT

IDEA



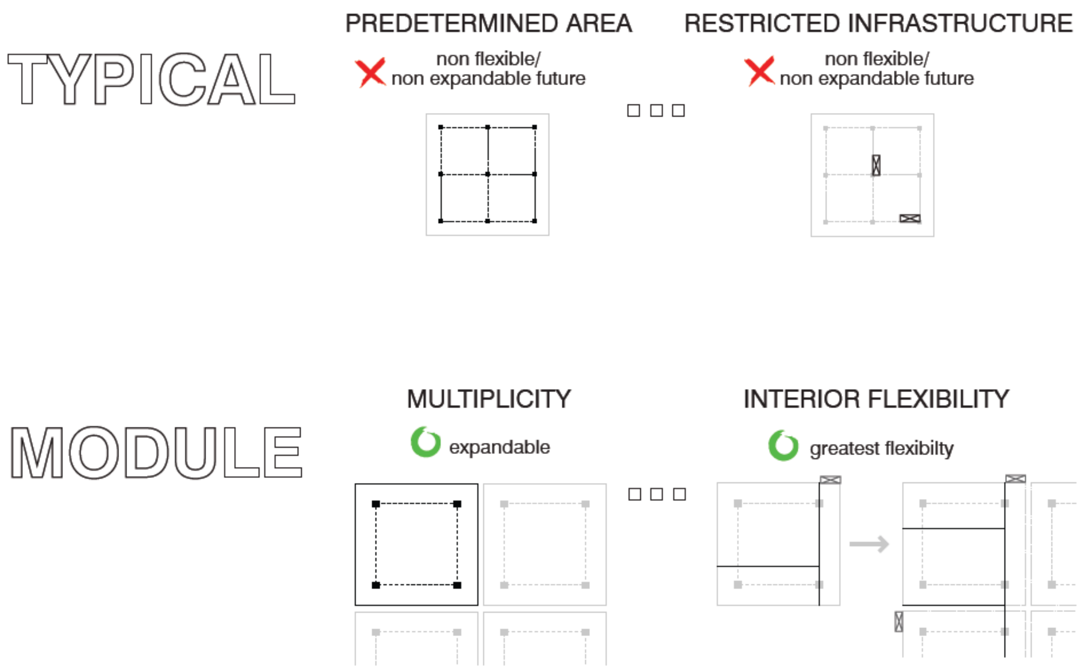
= FLEXIBILITY

School MOD is result of 3 structural systems combined in order to maximize flexibility:

Modular System (outer flexibility):
Based on the premise that repeated parts and techniques reduce cost and assembly time, modular systems are highly efficient and effective. Modular strategies reduce waste by coordinating dimension. Also, it encourages re-use of building components such as Interior dividing walls which can be disassembled, stored and re-placed again during tenant improvement.

Open Building System (inner flexibility):
The base building (skeleton) and partitions (infill) are treated as separate entities with different life cycles. All utility and mechanical systems are preset under the floor which provides flexibility for room layout adjustments. The purpose is to build an environment that can respond to any changes towards program and future needs.

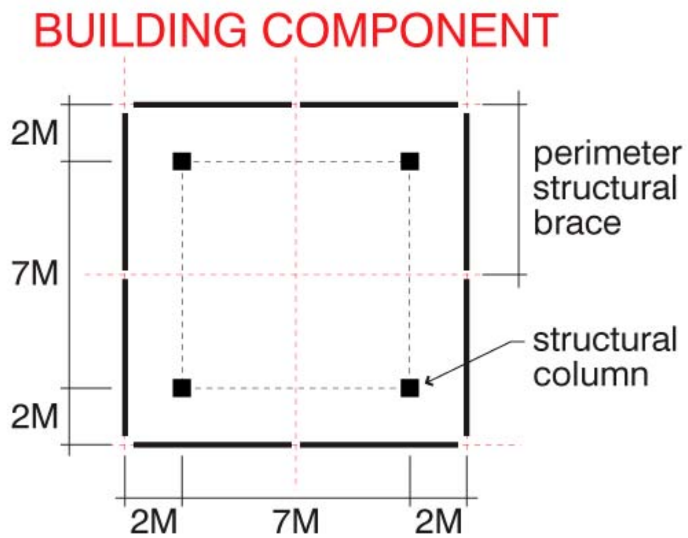
Dual Structure Grids System:
It avoids limitations inherent in one structural arrangement. Having two offset grids – one is the load bearing wall and the other post-and-beam – when one system does not provide the necessary spatial requirements or visual connections, the other grid is able maintain structural stability.

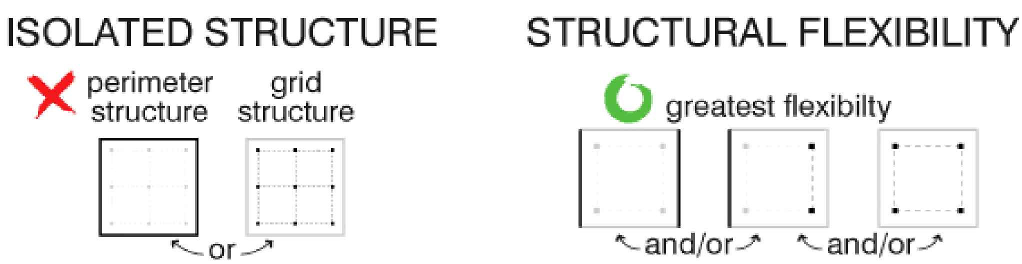


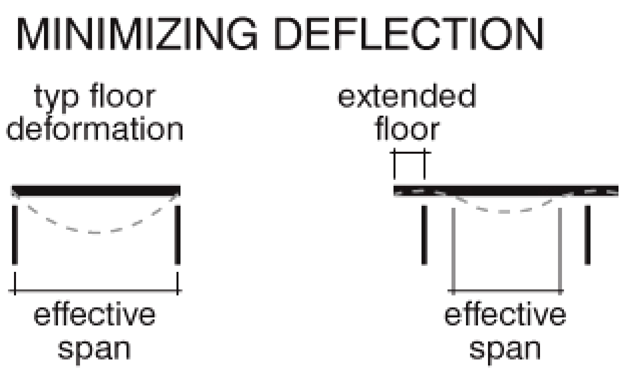
Conventional school building tends to have set perimeter of the building and have fixed MEP vertical shaft. Structure might allow some changes in the inner layout but it is limited by predetermined envelope and MEP location. Using Modular Systems and Open Building's separate utility access idea, building can grow its perimeter and accommodate any changing needs of the school. Dual structure grid system is a new idea maximizing flexibility. In Open Building method, "support" or structure are considered to be constant and permanent while "infill" or inner function are changed overt the time. In this project, by selecting wood as base structural material, even "support" can be reassemble and repaired, which will extend the life of building and provide flexibility even in building envelope.

Support

For the structure, there are two grid systems in a modular unit of 11meter x 11meter. One grid is for load bearing outer walls (11meters x11meters), and other grid (that is 2 meters offset from outer grid) is for columns. Basically, these two grids provide beams two possible locations to be supported. This means that the interior layout determined by the use will decide which of the structural combinations (column-column, column-wall or wall-wall) is employed to effectively utilize the space. In the future when program needs expand, modules can be attached using the same assembly techniques undergoing the same process as the initial construction. In the same manner, modules can be removed without additional hassle or demolition of any part of the building.

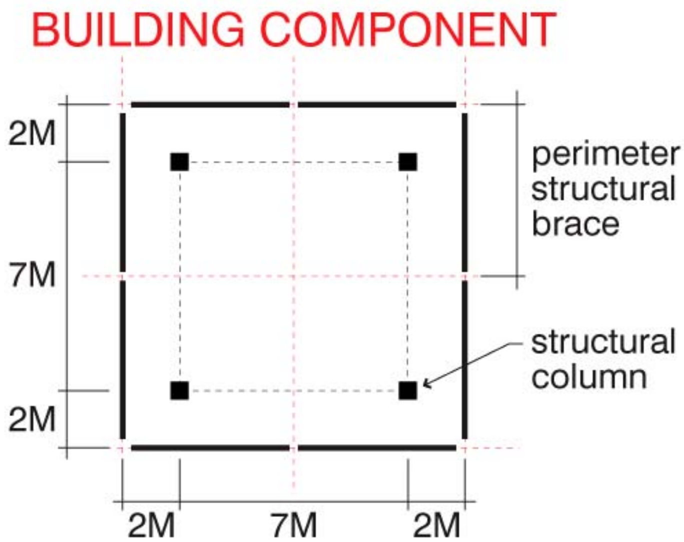


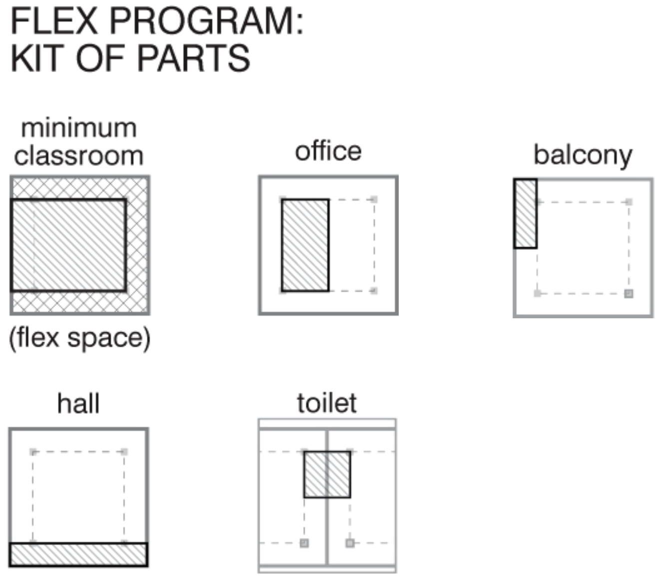




Infill

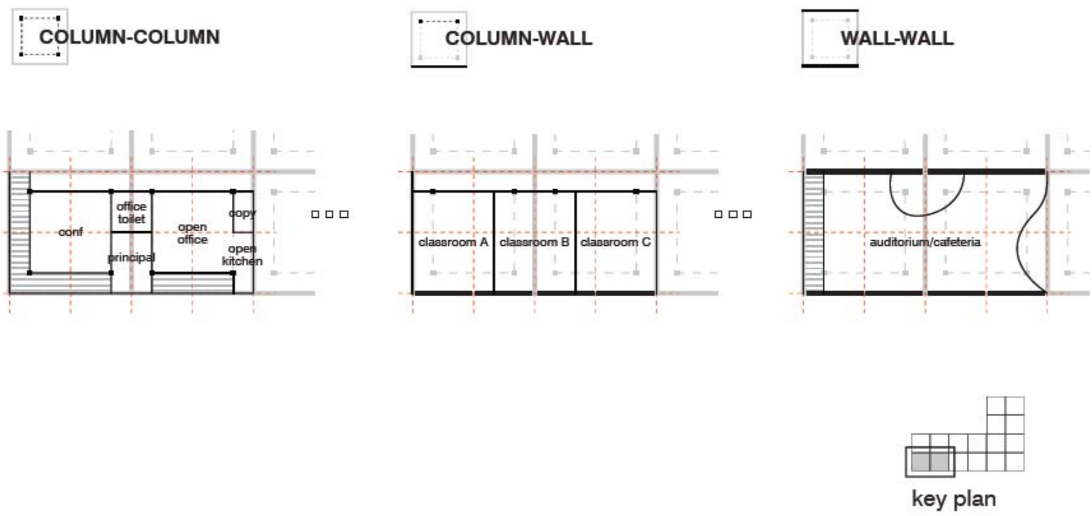
Interior layouting works like “kit of parts.” Two grids system offers variety of spaces: 2, 4, 7, 9, or 11meters wide. Hallways, classrooms, bathrooms, offices, and outside balcony and so forth (shown below) can be placed anywhere in any ways.





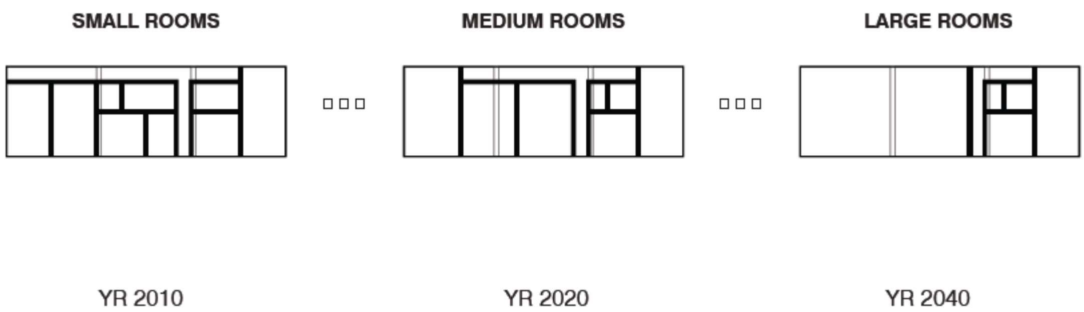
STRUCTURAL ARRANGEMENT

Within 2 modules, the given program determines the structural system that is most useful and advantageous for the needs of the users. Once the needs change, the structural system evolves to its new arrangement with ease.



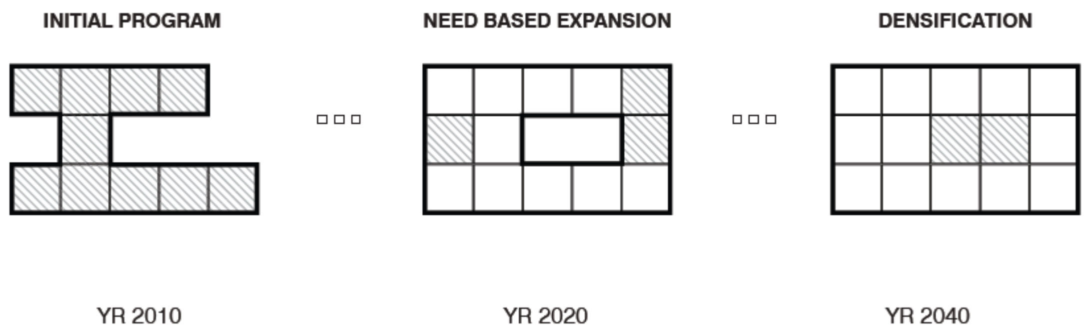
INNER CHANGE

Flexible interior layout can be advantageous when considering the dynamic relationship between school and community use. As programmatic needs change walls can be disassembled, stored, or reused. This avoids entirety the demolition of walls, ceiling and floors.



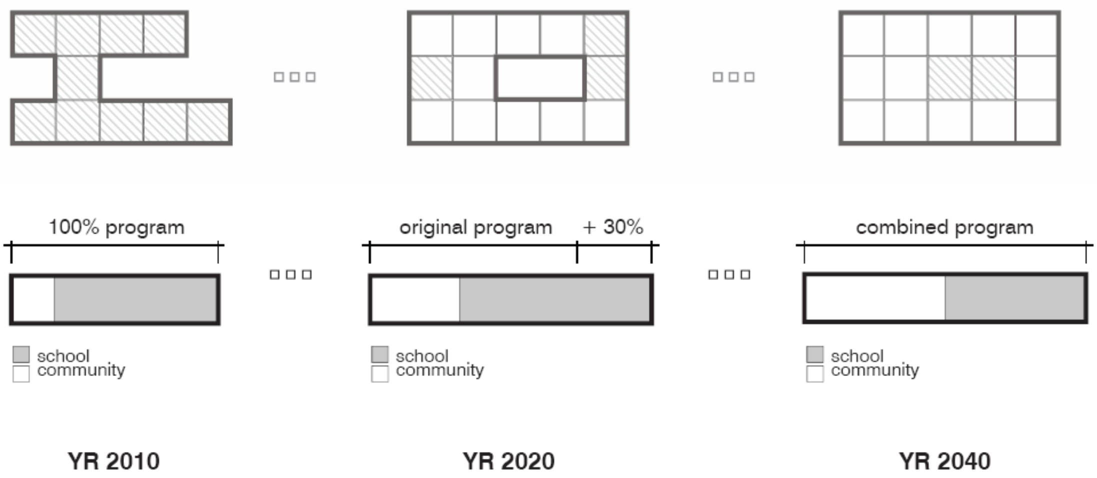
PROGRAM EXPANSION

Expansion is a luxury belonging to long term thinkers. As part of the strategy, the design ultimately meets the criteria for small needs and can later be expanded upon as more space is required. Additional modules can be added using the same techniques initially used during construction. The design favors building assembly that can be achieved by the able not requiring any special trainees or experts.



PROGRAM COMPARISON

School is always an integral part of the community to an extent. My design attempts to push the envelope by extending the role architecture can play. Using the school as a tool to teach individuals, to improve the neighborhood, and bring together industries, businesses, carpenters, craftsman, users, and residents, social sustainability and responsibility can be brought to the doorstep of everyone in the community. With a flexible program, communal spaces used by the school during the day can be used to benefit the community at night.



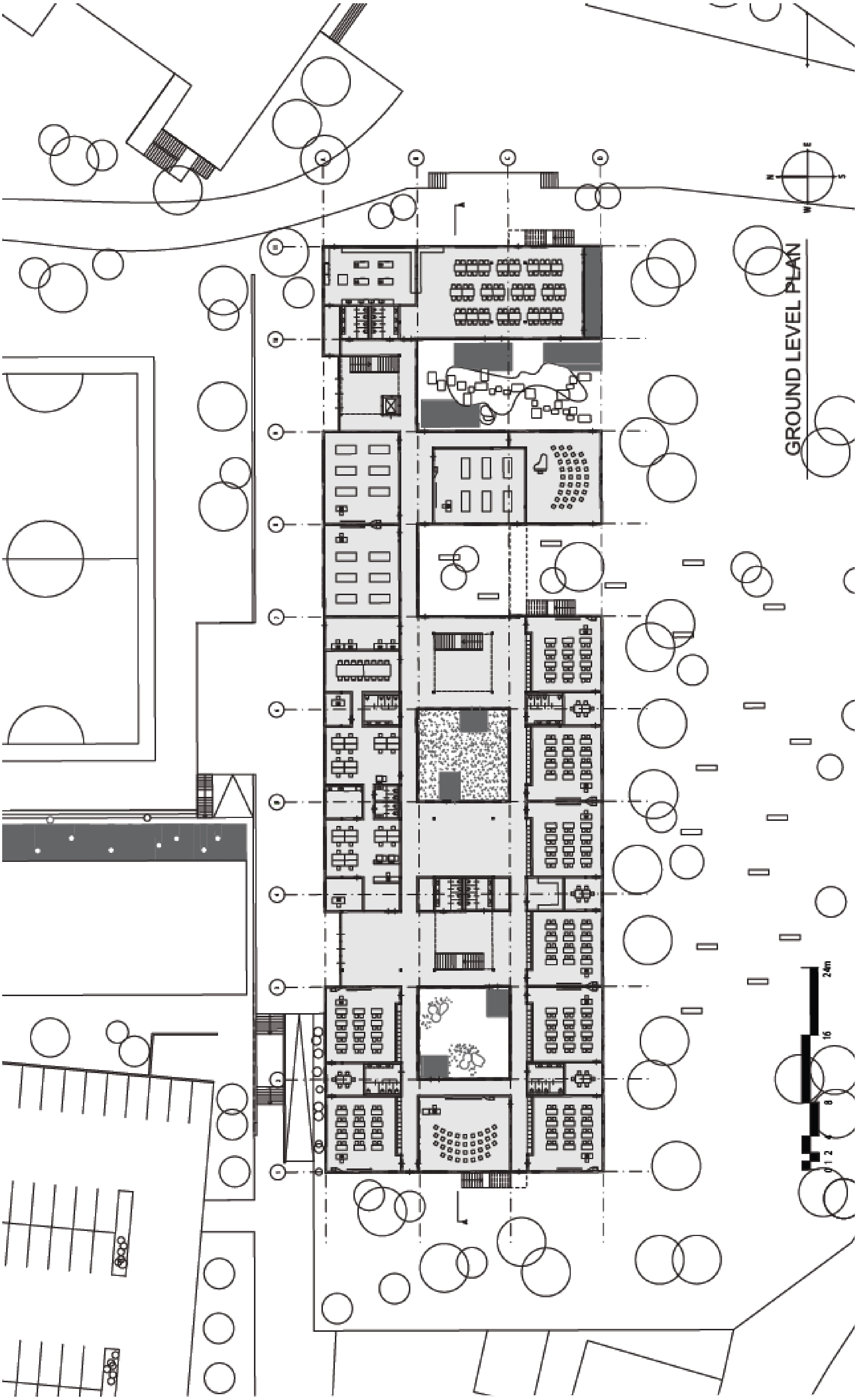
6.3 Design Outcome

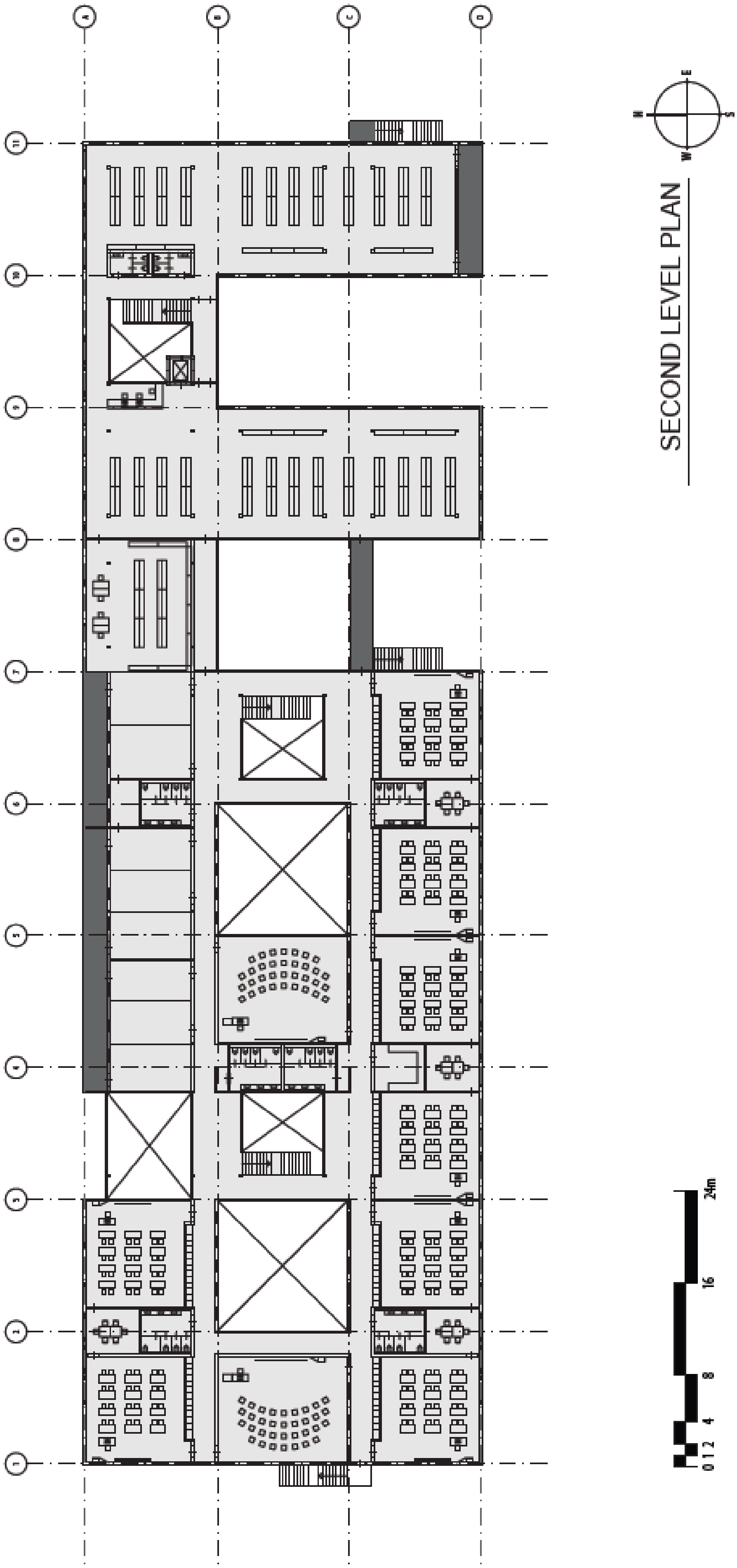
Project Description:

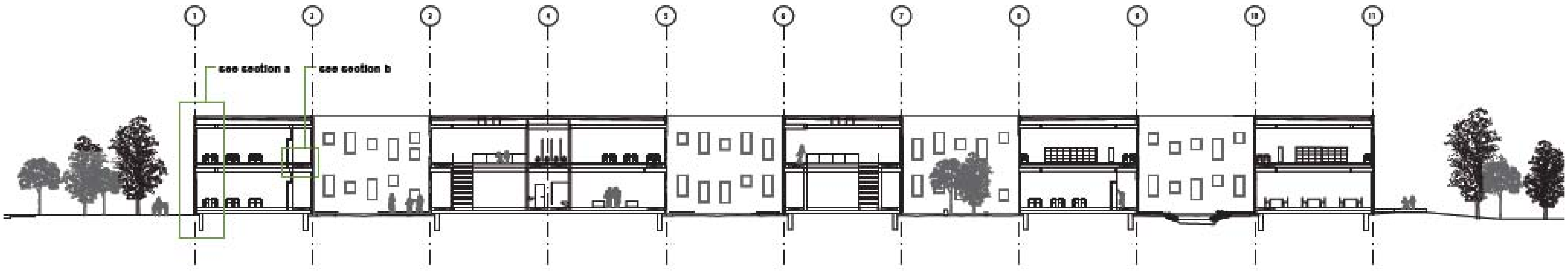
- Name of the project: School MOD
- Location: Atlanta, USA
- Area of the building: 2904m²
- Total floor area: 5633 m
- Type: K-8 school
- Number of student: 400²
- Construction: 2 Story Timber

This prototype school building challenges sustainable architecture by focusing on feasibility and maximizing flexibility. By designing a construction technique that any individual can assemble with materials locally available, the community now has the means and the methods to locally sustain current needs and future growth. The usual constraints of fixed areas and programs are resolved with a 'trifecta' approach toward a universal system for the utmost flexibility – utilizing the benefits from each M, O, and D systems: modular system, open building system, and a dual structural system. As the needs of the community change – growth in the number of kids attending, technological advances in education, new community centers – modules can be added and the interior rearranged. Mostly made of wood, the school's existence low in embodied energies has a limited impact on the environment and can be one solution to the long term problem of global warming. With the school, it is vital to educate people of our actions and its implications on Mother Earth.

As an advocate for flexible assembly, the benefits can be realized at all stages of a project and building life cycle. As school or community needs change, desired layout and room sizes must be as flexible and easily interchangeable as the curriculum. The design favors interdependent systems that are assembled based on the desired outcome.


GROUND LEVEL PLAN

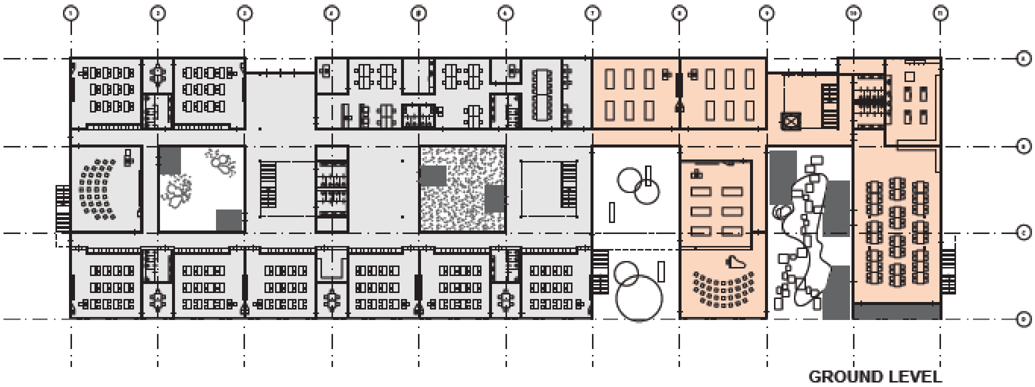

SECOND LEVEL PLAN
0 1 2 4 8 16 24m

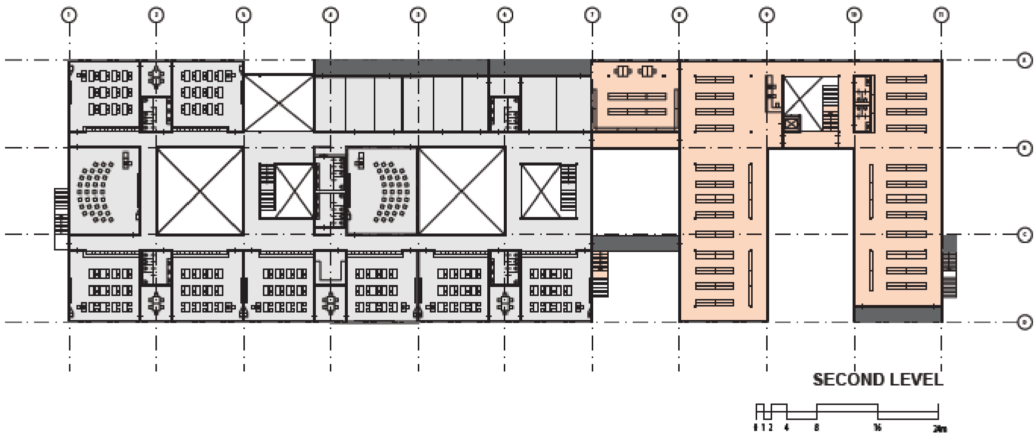


BUILDING SECTION A-A

PUBLIC & PRIVATE

The building is separated in two parts. One is spaces for only school use that involved with security and activities during school operation or day time such as classrooms, office, and school exhibition space. Other part is open to community for the time after school, weekends, and holidays. Community can use the library, kitchen, and other special class rooms as their gathering space for educational or recreational purpose.





space for school

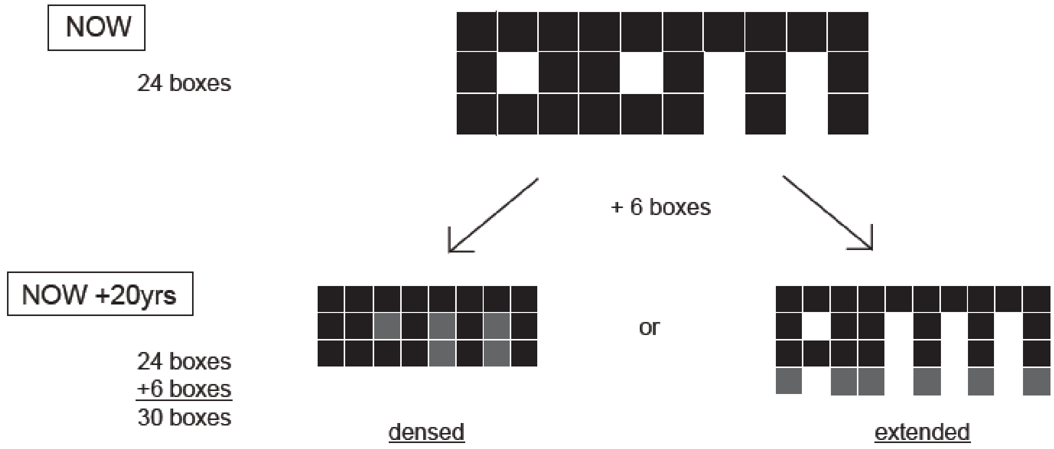
- class rooms
- administration office
- teachers / principle / stuff offices
- school exhibition spaces

space open to community

- library
- cafteria / conferance room
- spesial class rooms:
  - -science lab
  - -music room
  - -art room
  - -computer lab
- kitchen

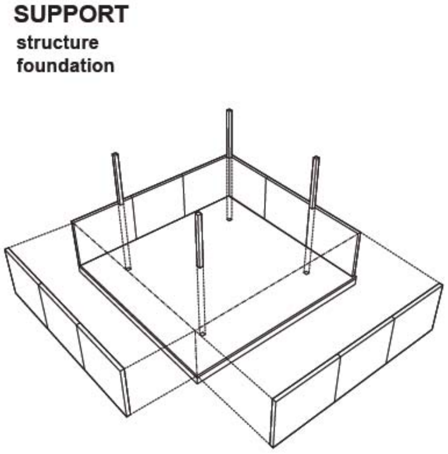
HOW TO GROW

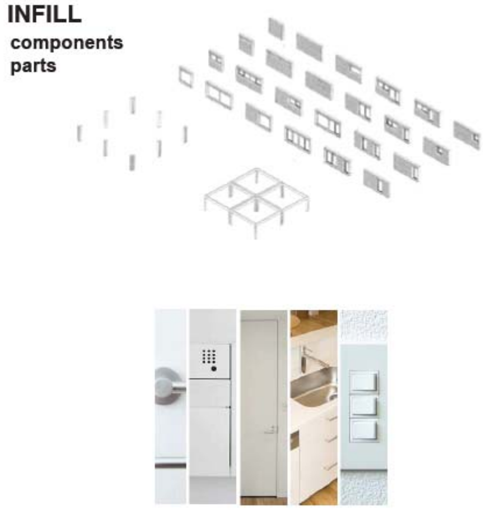
The diagram below shows how the school can grow after decades. Depending on the condition of thesite, for example urban area or rural area, it can grow either denser or wider.



SUPPORT & INFILL

Following Open Building System, the building has clear separation between structure and fit-out.   Users are able to simultaneously change and manage the floor layout and interior finish without causing any damages to the infrastructure of the building.





STRUCTURE

TIMBER FRAMING:

For exterior walls, timber framing wall construction is used. 2" X 8" (50MM X 200MM) wood studs are placed on a 24" o.c. module rather than a more conventional 16" o.c. with 2" x 6" studs. According to the DfD guideline, just this one step saves approximately 30% of framing lumber[31]. To do so the floor plan needs to be carefully laid out on this module, so that room sizes, window and door openings.

conventional 16" o.c. 2" x 6" wood frame construction

24" o.c. 2" x 8" wood frame construction

Figure 34
Comparison of two stud methods placed by different intervals

POST & BEAM:

Glulam members and metal connections are fastened by bolts. This method prevents complication and difficulty at the time of disassembling process. Partial repairing and replacement can also be done by this method.

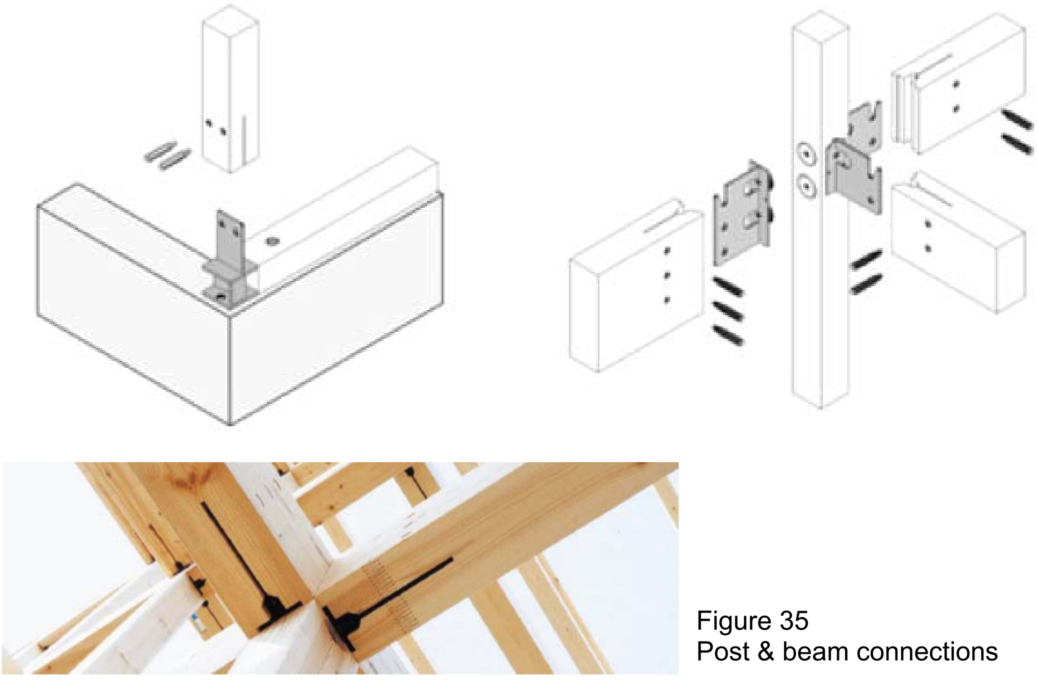
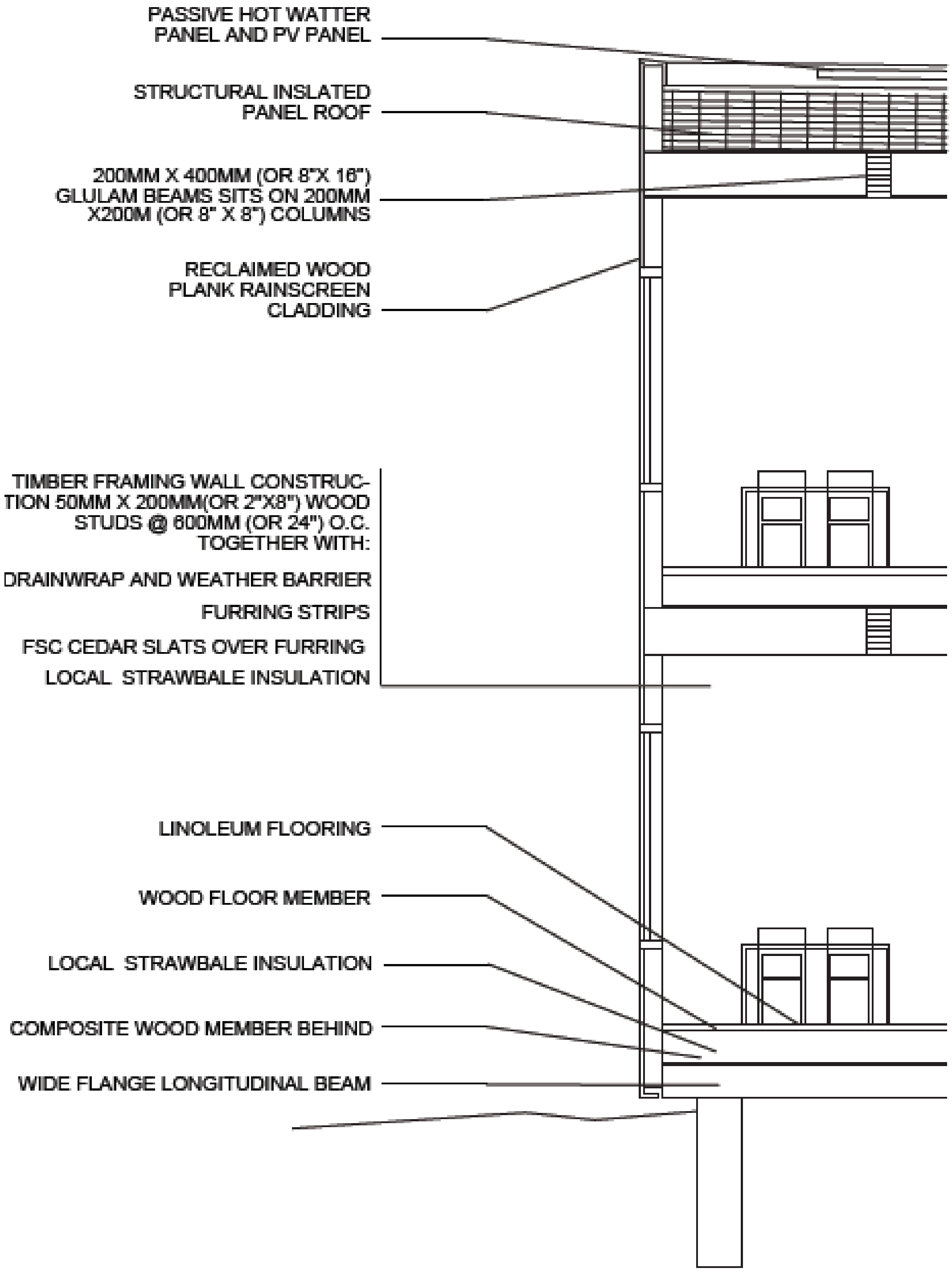


Figure 35
Post & beam connections

[31] Chartwell School case study done by DfD.

BASE MATERIALS AND COMPONENTS

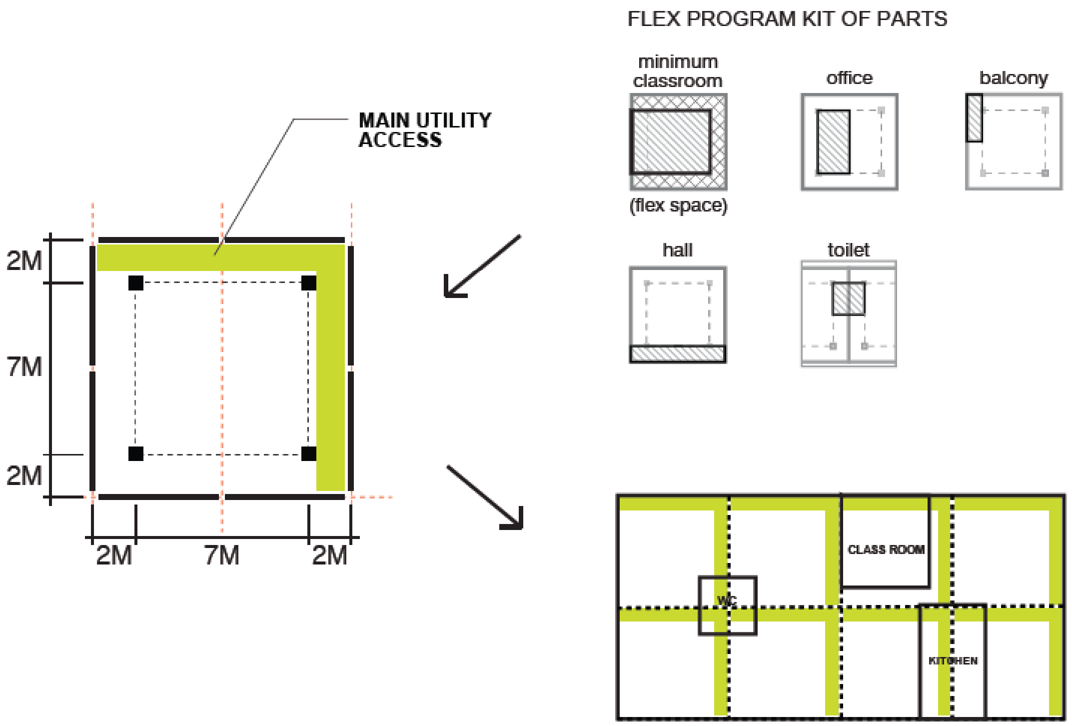


section a: WALL SECTION

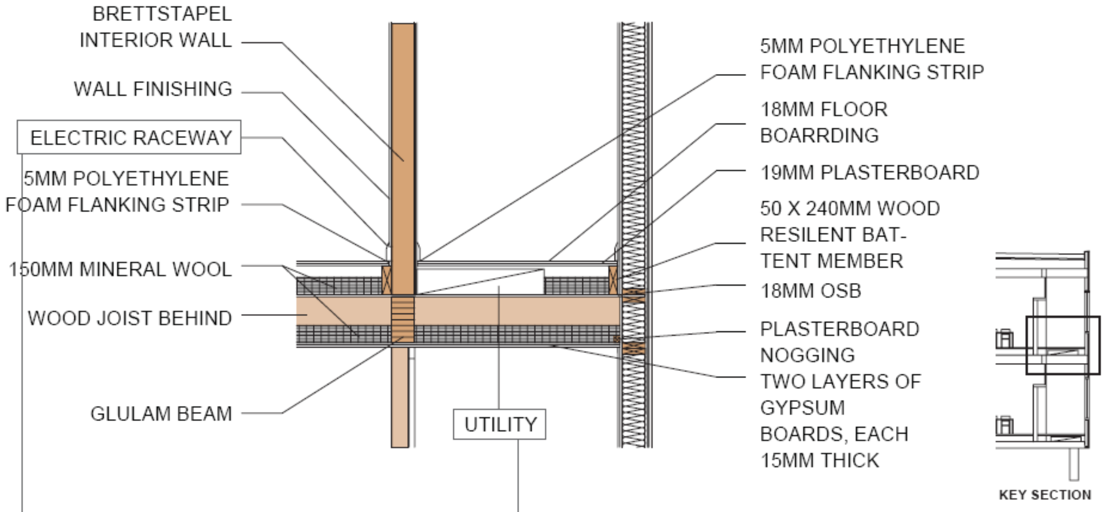
FLEXIBLE UTILITY

Building mechanical systems have shorter lives than the building frame. Therefore, the aging of the pipes and duct components of mechanical systems has a major impact on the life span of the building.

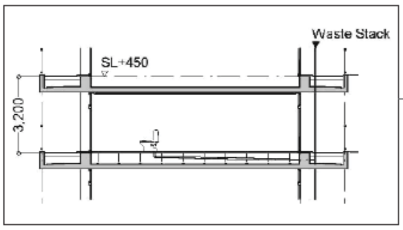
When modular units are combined, 2 meters perimeter within the units can be good space for pacing pathway, bathroom, kitchen and small room (see diagram below), and this 2 meter space could be used for main mechanical systems, including main wiring, pipes and duct works, arranged in grids. All floors are raised 30cm so that any mechanical system each requires will be able to fit under the floor. All it needs to be done is reaching to the 2 meter perimeter of the module where main system goes through. Raised access floor systems (see the section drawing on next page) not only store plumbing system but also eliminate duct work and place electrical and telecommunication utilities under a raised floor grid rather than overhead.



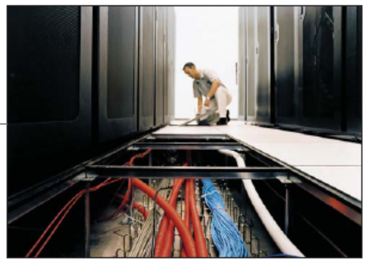
FLOOR & WALL



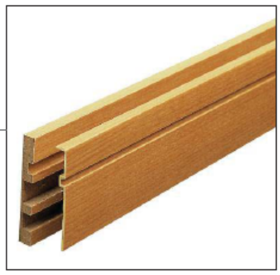
section b: **FLOOR & WALL SECTION**



Raised floor



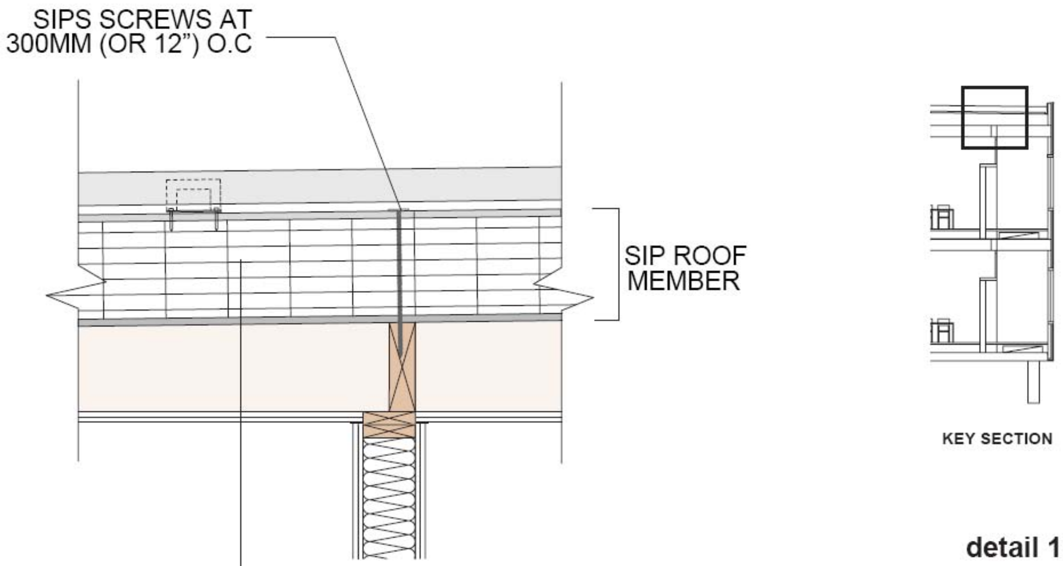
Access floor system



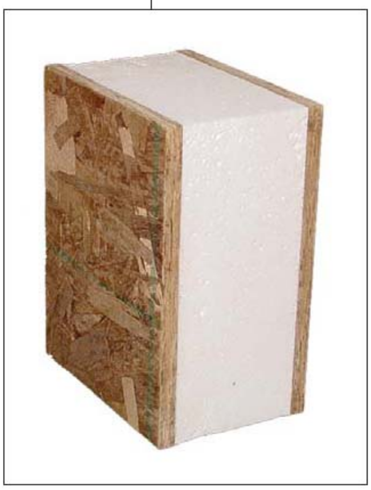
Buit-in wires baseboard

In conventional wall, electrical wires are embedded in the wall structure. School MOD uses an innovative raceway system, which is separate from the wall structure, to distribute the electric wires. By creating a small cavity along the baseboard of a wall, with a clip-on baseboard cover, wiring cab be inserted hidden while remaining readily accessible. The section drawing shows where the utility is placed. The plenum that is created by the raised platform can also be space for air distribution system. By use of modular kit-of-parts system, the floor panels also can be altered by increments.

ROOF



detail 1:
STRUCTURAL INSLATION PANEL (SIP) W/SIP SCREWS OVER TRUSS MEMBER

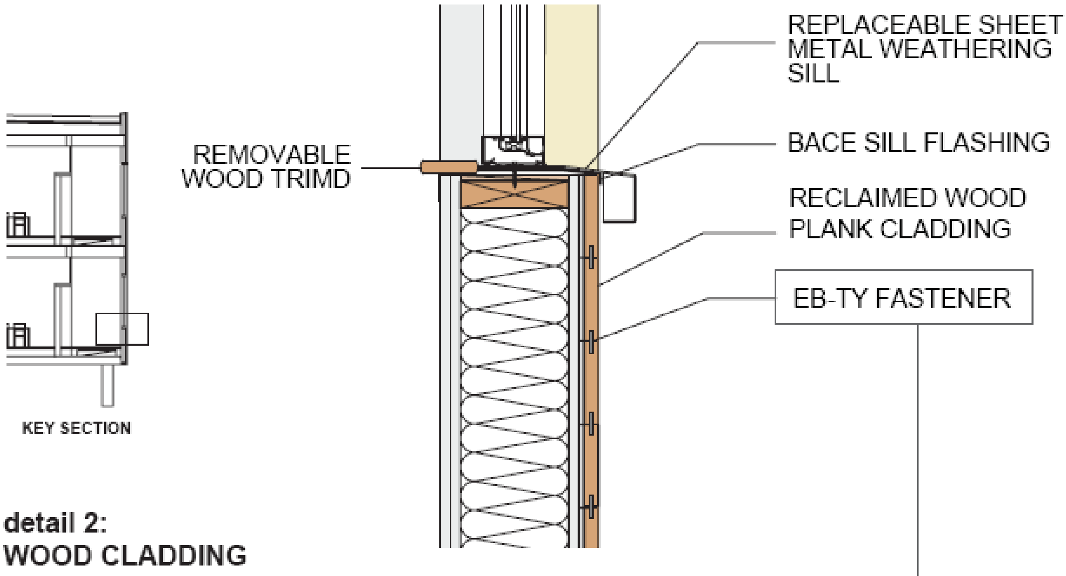


SIP roof panel with OSB

Conventional roof sheathing connection method

The room assembly presents a great opportunity to DfD method. Conventional roof assembly (shown above) includes plywood roof sheathing, dimensional lumber with batt insulation, and normally have gypsum board ceiling below. To connect all these members, it requires many hardware clips at the roof and wall interface. This creates a very strong connection, but difficult remove. Structural Insulated Panels (SIPS) is a great solution for this matter. Its one combined form simplifies connections and can be easily fastened with large screws (as shown in the detail drawing). The design intent is that SIPS could be easily dissembled later and reused as whole component.

WINDOW & CLADDING



Eb-Ty fasteners

Vertical application

For water tightness, windows are often buried below the exterior finished such as cement plaster, or with the exterior finish butting up again the frame. This works well in terms of insulating the window, however, causes difficulty and high cost when the time replacing the window. Above detail drawing shows innovative way to install the window for the school. First, the exterior finish is done typical way with water sealing, but the interior window is trimmed out with a removable wood trim. This allow window to be removed from inside. On the outside, installed sheet metal weathering sill is also removable so that the base sill flashing can be remain in place while this weathering sill is replaced.

School MOD explores a unique application of the cladding. Conventional wood siding tends to lose quite bit of material in section (see Figure 36) to give overlapping profile.

They tend to be damaged easily during removing operation. Theoretically, remaining as much a rectangular cross section as possible, makes more easier and possible the wood piece to be recovered or reused[32]. Figure 36 show the case study done for the DfD guideline. It shows the development of sidings that installed with screws as replacement of the nails. The section drawing on the very right demonstrating use of double bended clips as a connector so that a wood is fully remain rectangle for reuse. However, the gap created between the boards and where they overlap has become high risk of fire. School MOD applies their later experimented siding attachment option shown in the sectional drawing (in the previous page). It conceptually uses a fastener system currently used for decking. Eb-Ty fastener, the football shaped polyethylene connector, fits into the slots in the edge of the siding board cut with a biscuit plate jointer[33]. The 1/8" gap between boards to boards suggests an approach similar to a rain screen to this wall assembly.

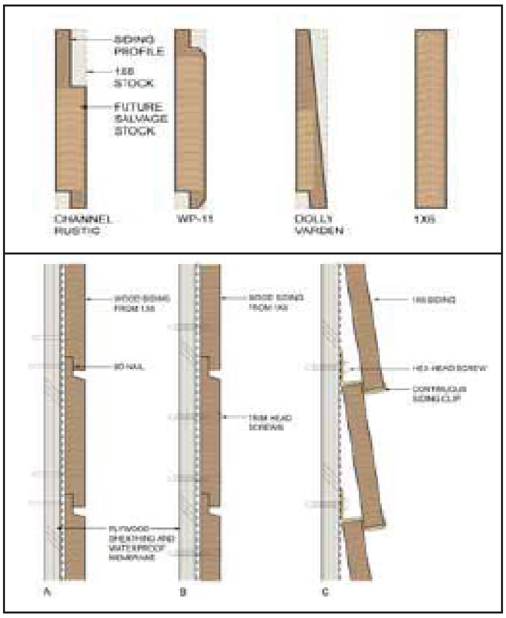


Figure 36
Exterior siding options

[32] Shell, Scott. Gutierrez, Octavio and Fisher, Lyn. Design for Deconstruction: The Chartwell School Case Study, et al for U.S. Environmental Protection Agency, Region 9

[33] Shell, Scott. Gutierrez, Octavio and Fisher, Lyn.

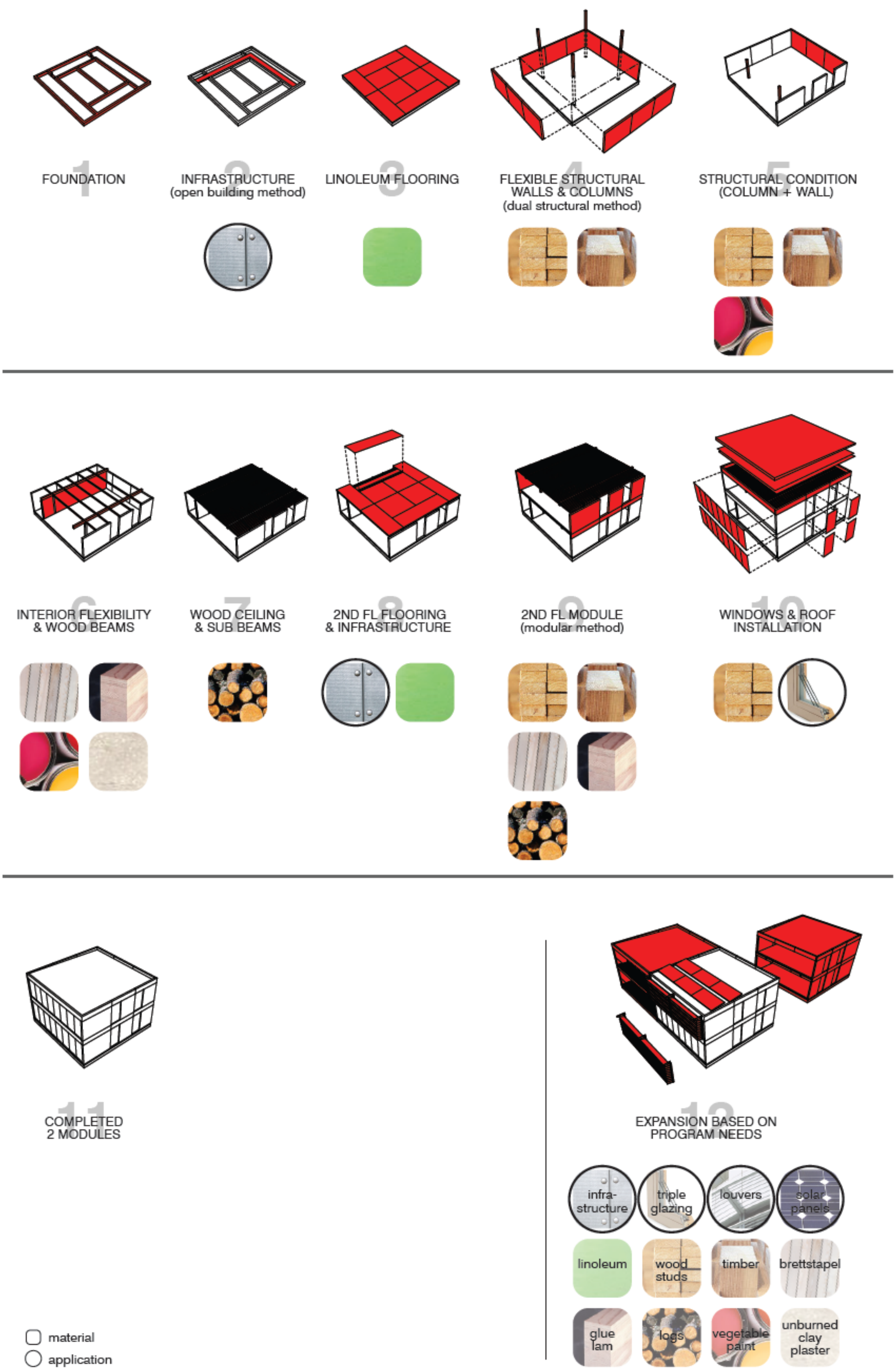
6.4 Life Cycle Challenge

6.4.1 Recycle and Deconstruction Strategy

My mission is to reduce the impact that this buildings have on the environment. Some of our standard building materials such as the most widely used concrete and steel require exhaustive expenditures of energy up till the point of erection. Those materials could be economical choice for new construction, however, the cost for equipment to deconstruct the structure will be very expensive. With the design fro School MOD, I have substituted the standard building material with wood to reduce the total embodied energies of the project. Other advantages of utilizing wood are for its ability to be recycled after its lifecycle. As structural members lose its capacity, it can be cut out and replaced. This wood can be used in other parts of the building or used throughout the community. For wall construction, I have selected the use of Brettstapel panels which are formulated from small bits of timber which are joined using dowel rods. The assembly eliminates the use of glue to avoid toxic gas emissions when burned. Logs that are used for the sub beams are collected from the forest maintenance practices to allow for healthy growth of other trees and also from wood that is rejected by mills for quality assurance. My intention once again is to avoid further emissions from transport and manufacturing by rerouting the wood that would normally be sent to manufacturers of OSB and other wood-chip based products. The only other energies spent will be from the hands of the carpenters cutting to fit and installing the wood. As for the flooring, linoleum serves as an eco friendly, low emissive material that is durable for the high traffic flow schools experience. Lastly, finishes used will be that of vegetable oil based paint to further reduce toxic emissions into the environment. Another affective design strategy is the clear separation of the mechanical systems and the building frame. This is accomplished by the concentration of the vertical shafts for the mechanical systems, as opposed to the typical method in which vertical shafts are located inside the individual units. The latter approach makes the repair of old pipes difficult and increases the amount of debris that must be disposed of after repair work. Concentration of the vertical shafts and separating them from the building frame facilitates the maintenance of pipes and wiring.

Above strategies help building to maximize its life cycle over the time. The chart on the next page summarizes the material choice and design application through the process of assembling.

BUILDING PROCESS & MATERIALS



brettstapel	Made from small bits of timber that are joined using dowels, therefore no glue is used which causes toxic gas emission	unburned clay plaster	Extremely good at soaking up and releasing moisture
logs	Bad quality wood are usually removed from the forest so that surrounding trees can grow better. Those wood removed are diverted from mills instead are used as sub beams.	vegetable paints	No toxic emissions released

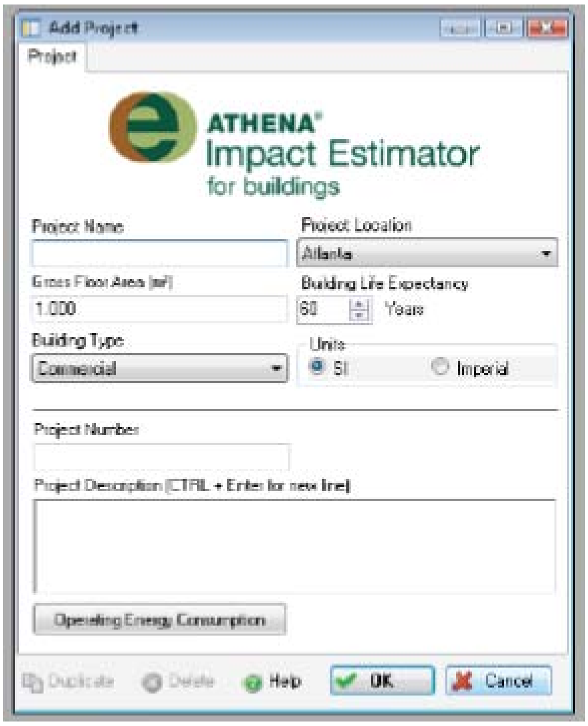
6.4.2 GHG reduction

Steel and concrete have high Green House Gas (GHG) emissions in the process of extraction, refining, and manufacturing. On the other hand, wood has negative carbon intensity since CO2 is taken from the atmosphere rather than being emitted during its growth. My approach toward reducing GHG emissions is by substituting wood for building materials that have high carbon intensity. Also, wood can be locally maintained. It requires no high skilled labor, no heavy machinery, low embodied energies, and low cost.

In addition, wood is an efficient material when it comes to process of re-sizing re-forming and re-use. Compared to other materials, wood products require less energy and effort during transportation and recycling. In this project, all interior and exterior wall panels are made of massive wood and are all removable therefore can also be reassembled for a new layout. The whole premise behind sustainable architecture can only be achieved by using sustainable resources – wood. Use of local wood encourages maintenance (outlook and care) for forests in the region.

Athena Eco-Calculator

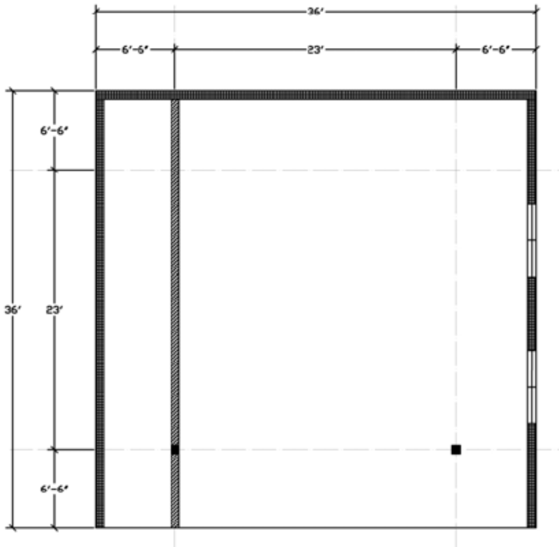
By the Athena Eco-calculator, 1 module, include 2 floor with a roof covered (see the plan drawing in next page,) is tested for its environmental impact by the ATHENA® *EcoCalculator for Assemblies,* which is a plug-in type calculating program developed by the ATHENA Institute in association with the University of Minnesota and Morrison Hershfield Consulting Engineers. The five environmental impact factors, primary energy, global warming potential, weighted resource use, water pollution, and air pollution,



that occur in the assembling process can be examined in the scale of 1 modular unit from the project. Atlanta, USA was set for the site for the measurement. Tested unit is set to listed condition below and the program is experimented based on areas in plan:

Tested modular unit
Condition:

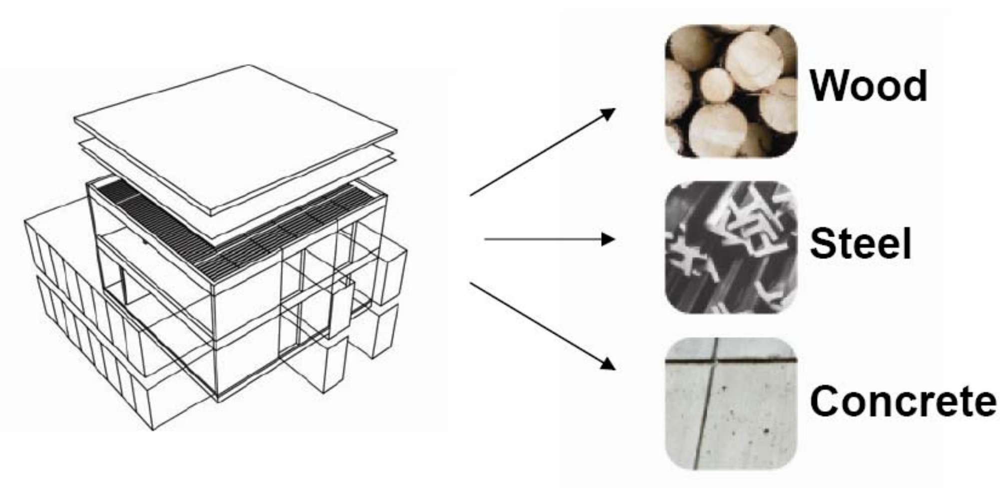
- 1 side wall with 2 window openings
- 2 side walls with no window
- 1 side wall with large glazing
- Includes concrete foundation, lower floor, upper floor, and roof



Total areas:

- Columns & beams 171 sq ft
- Intermediate floor 1296 sq ft
- Exterior walls 135 sq ft
- Windows 5 sq ft
- Large glazing 28 sq ft
- Roofs 1296 sq ft

For better understanding of the test result, I have also examined two other cases assuming if the same modular unit was built with steel structure with steel cladding and concrete structure with brick cladding. My results will be discussed by comparing the environmental impact of the timber structure to other construction methods.



TIMBER structure with wood clading

Assembly Type	Components		Square footage	Primary Energy (MMBtu)	GWP per SF(lbs)	Weighted Resource Use per SF (lbs)	Air Pollution Index per SF	H2O Pollution Index per SF
Columns & beams	Glulam	Structural Composit Lumber	171	0.03	2.23	23.38	0.21	0.006
Intermediate floors	Wood truss and OSB decking system	Gypsum board; latex paint	1296	0.05	4.17	33.25	1.12	0.0024
Exterior walls	Wood stud 24"o.c., wood cladding (pine) WPS sheathing, mineral wood insulation, vapor barrier, gypsum board, latex paint		135	0.07	5.64	36.63	1.46	0.0027
Windows	Aluminum		5	0.59	70.73	112.75	9.85	0.0021
	Curtainwall vieable glazing		28	0.27	61.76	99.17	7.26	0.001
Interior walls	Wood stud 24"o.c., gypsum board and latex paint each side		87	0.03	2.44	13.66	0.4	0.001
Roof	Wood truss (flat) w/ WSP decking PVC membrane, butt insulation, vapor barrior, gypsum board		1296	0.09	7.36	33.23	1.76	0.0019

TOTAL IMPACTS BY BUILDING COMPONENT		Primary Energy (MMBtu) TOTAL	GWP per SF(tons) TOTAL	Weighted Resource Use(tons) TOTAL	Air Pollution Index TOTAL	H2O Pollution Index TOTAL
Columns & beams		5	0	2	36	1.03
Intermediate floors		68	3	22	1448	3.08
Exterior walls		9	0	2	197	0.36
Windows		11	1	2	253	0.04
Interior walls		3	0	1	35	0.01
Roof		119	5	21	2280	2.5
WHOLE BUILDING		214	**9**	50	4249	7.02

STEEL structure with steel clading

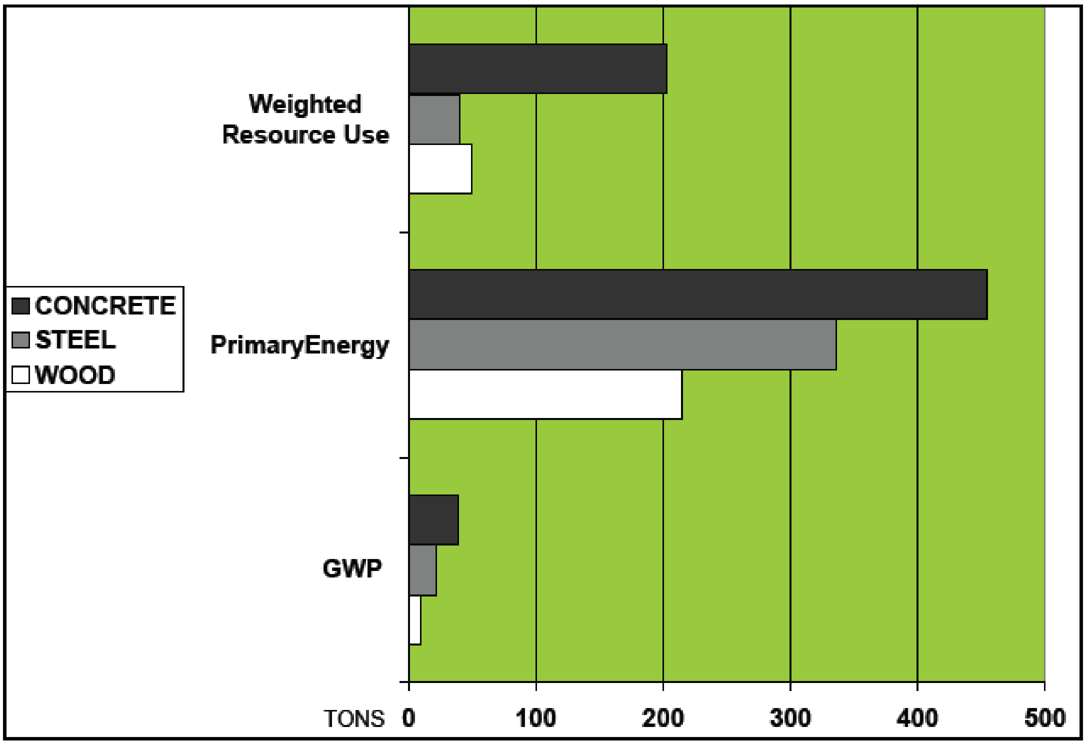
Assembly Type	Components		Square footage	Primary Energy (MMBtu)	GWP per SF(lbs)	Weighted Resource Use per SF (lbs)	Air Pollution Index per SF	H2O Pollution Index per SF
Columns & beams	Wide-flange steel	Wide-flange steel	171	0.09	8.19	21.56	0.57	0.0107
Intermediate floors	Steel stud joist and OSB flooring system		1296	0.06	9.39	26.95	0.77	0.0217
Exterior walls	2x4 Steel stud 16"o.c., steel cladding (26ga), gypsum board sheathing, butt insulation, vapor barrier, gypsum board, latex paint		135	0.18	40.04	31.4	3.32	4.9896
Windows	Aluminum		5	0.59	70.73	112.75	9.85	0.0021
	Curtainwall vieable glazing		28	0.27	61.76	99.17	7.26	0.001
Interior walls	Steel stud (16"o.c.); gypsum board and latex paint each side		87	0.03	3.51	10.78	0.46	0.0034
Roof	Open-web steel joist w/ steel decking EPDM membrane, rigid insulation, vapor barrior, gypsum board		1296	0.15	16.04	25.06	1.96	0.013

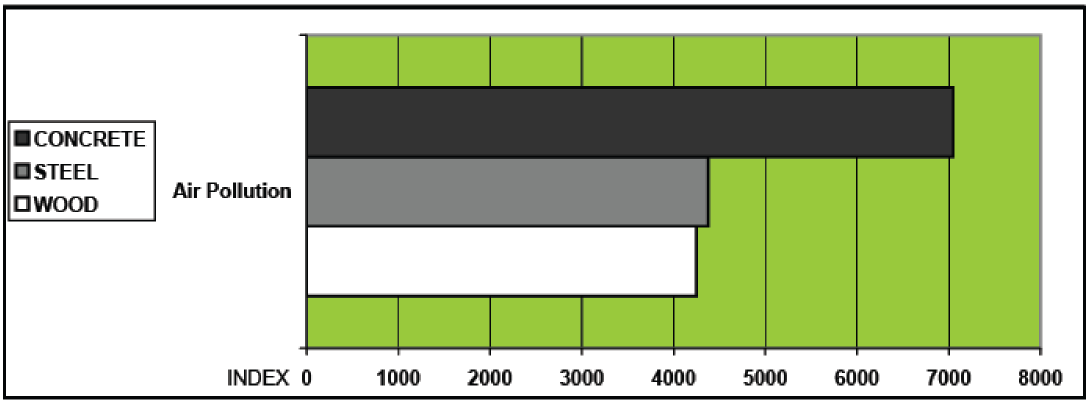
TOTAL IMPACTS BY BUILDING COMPONENT		Primary Energy (MMBtu) TOTAL	GWP per SF(tons) TOTAL	Weighted Resource Use(tons) TOTAL	Air Pollution Index TOTAL	H2O Pollution Index TOTAL
Columns & beams		15	1	2	97	1.84
Intermediate floors		83	6	17	997	28.13
Exterior walls		25	3	2	448	673.59
Windows		11	1	2	253	0.04
Interior walls		3	0	0	40	0.3
Roof		200	10	17	2543	16.81
WHOLE BUILDING		336	**21**	40	4378	720.7

CONCRETE structure w/ brick cladding

Assembly Type	Components		Square footage	Primary Energy (MMBtu)	GWP per SF(lbs)	Weighted Resource Use per SF (lbs)	Air Pollution Index per SF	H2O Pollution Index per SF
Columns & beams	Concrete	Concrete	171	0.13	20.24	115.14	1.39	0.005
Intermediate floors	Concrete flat plate and slab column system 25% flyash	Gypsum board; latex paint	1296	0.16	32.05	212.41	2.46	0.0025
Exterior walls	CIP concrete, brick cladding rigid insulation, latex paint		135	0.19	30.18	138.24	3.02	0.0008
Windows	Aluminum		5	0.59	70.73	112.75	9.85	0.0021
	Curtainwall vieable glazing		28	0.27	61.76	99.17	7.26	0.001
Interior walls	6" concrete blocck; gypsum board and latex paint each side		87	0.11	15.92	32.31	1.53	0.0015
Roof	Precast double-T EDPM membrane, vapor barrior, gypsum board		1296	0.14	19.52	66.65	2.18	0.0003

TOTAL IMPACTS BY BUILDING COMPONENT		Primary Energy (MMBtu) TOTAL	GWP per SF(tons) TOTAL	Weighted Resource Use(tons) TOTAL	Air Pollution Index TOTAL	H2O Pollution Index TOTAL
Columns & beams		23	2	10	238	0.86
Intermediate floors		203	21	138	3184	3.26
Exterior walls		25	2	9	408	0.1
Windows		11	1	2	253	0.04
Interior walls		9	1	1	133	0.13
Roof		184	13	43	2832	0.38
WHOLE BUILDING		455	**39**	203	7047	4.77





Key terminology

Primary Energy:

Amount of energy used in the extraction, processing, transportation, construction, and disposal of each material. Measured in millions of Btu's (MMBtu).

Global Warning Potential:

Amount of green gases created in the extraction, processing, transportation, construction, and disposal of each material. Measured in tons.

Weighted Resource Use:

Amount of row materials required for extraction, processing, transportation, construction, and disposal of each material. Measured in tons.

Air Pollution

Impact on air quality created in the extraction, processing, transportation, construction, and disposal of each material. Measured as an Index.

Water Pollution

Impact on the water quality created in extraction, processing, transportation, construction, and disposal of e ach material. Measured as an Index[34].

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[34] ATHENA Institute. http://www.athenasmi.org/tools/ecoCalculator/index.html. Sep.20.2009

RESULT

1) Amount of GHG emission per box in assembling process:

- Wood- 9 tons
- Metal- 21 tons
- Concrete - 39 tons

Assumption:

- Building the project with timber construction method reduces nearly 77% of GHG emission comparing to building it with concrete.
- Building the project with timber construction method reduces nearly 57% of GHG emission comparing to building it with steel.

2) Other GHG Reduction Factor:

Assuming 2904 m² of wool carpet floor in the school replaced by linoleum floor finish.

Tons of carpet reduced:

40 oz/yard = 1.354 kg/m2

1.345 x 2904= 3906 kg = 3.906 ton

≈3.9 tons

GHG emission of flooring:

Wool carpet 13.65 tons/m²

13.65 tons/m² x half floor 2904m² = 39640 tons

Linoleum floor 1 tons/m²

1 tons/m² x 2904m² = 2904 tons

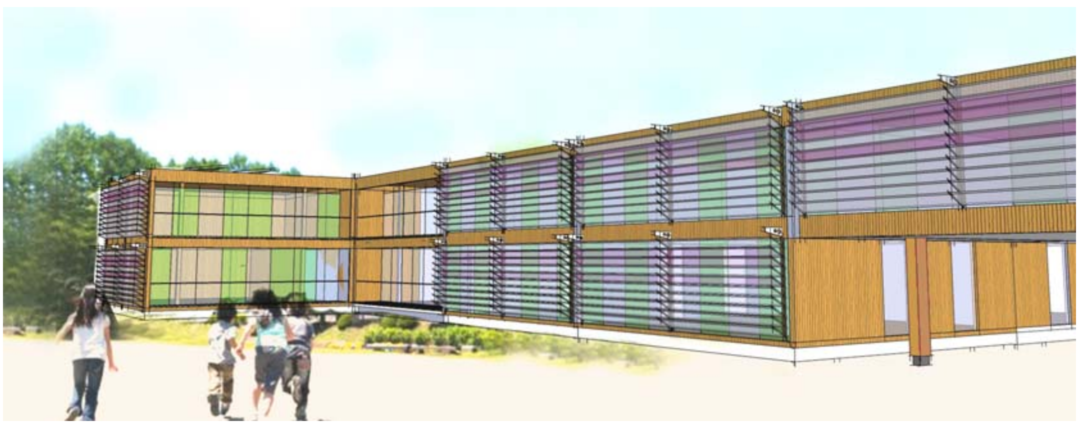
Therefore, by replacing wool carpet with linoleum floor, 36736 tons of GHG emission can be reduced.

6.5 Social Sustainability

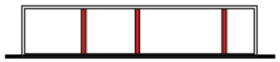
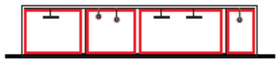
School MOD demonstrates a design method focusing on process of design, construction, and operation and maintenance for future school and socially sustainable community. A variety of energy and resource conserving design methods and technologies could be found in this project.

As a product of its teachings, the building promotes environmental concern as well as social sustainability. My responsibility is not only to the environment in which this project build but also the means by which this project carry out the task. Building assembly can be achieved by anyone not requiring any special trainees or experts. This strengthens community involvement and interaction on site bringing together the local trades and shops. Even children attending can have a helpful impact on site helping with landscaping. In addition, the knowledge they gain of the materials used in the building will be the key to the sustained maintenance of the building in the future. In summary, everyone within the community has a role and responsibility that is shared for the mutual benefit of all.

To conclude this project, I summarized my design approach to social sustainability by organizing built environment, structure, and buildings components associated people's responsibility of care (See next page.)



SOCIAL SUSTAINABILITY

	component description	component section	life time (yrs)	material		maintenance & responsibility	
structural strategy building components (local industry/carpenters)	- structure - load bearing		60 +	- glue laminated wood beam - metal connections - load bearing massive wood member (brettstapel)		- architect & engineer - city - forester	
	- external wall (skin) - service core		30 - 60	- windows - wood siding - water proofing	- solar panels - stairs (safety regulations) - sub beams (logs)	- architect & engineer - city - forester	
	- interior wall - functional - layout - program		10 - 30	- patition walls		- local carpenter - local industries	
sustainable planning (local shop)	- internal infrastructure		10 - 30	- plumbing - kitchen appliance	- sink / toilet / urinal - other equipment	- local businesses - local workers	
	- finishes - surfaces & treatments - installations		5 - 10	- lighting - floor finishes	- wall finishes - doors	- local businesses - local workers	
high performance strategy (local involvement)	- environment - public space		seasonal	- landscape - tree - plants	- benches - water feature - paths	- community - local organizations - school	
	- work - use/reuse		monthly/daily	- exhibition - decoration		- individual - local organization - school	

7

CONCLUSION

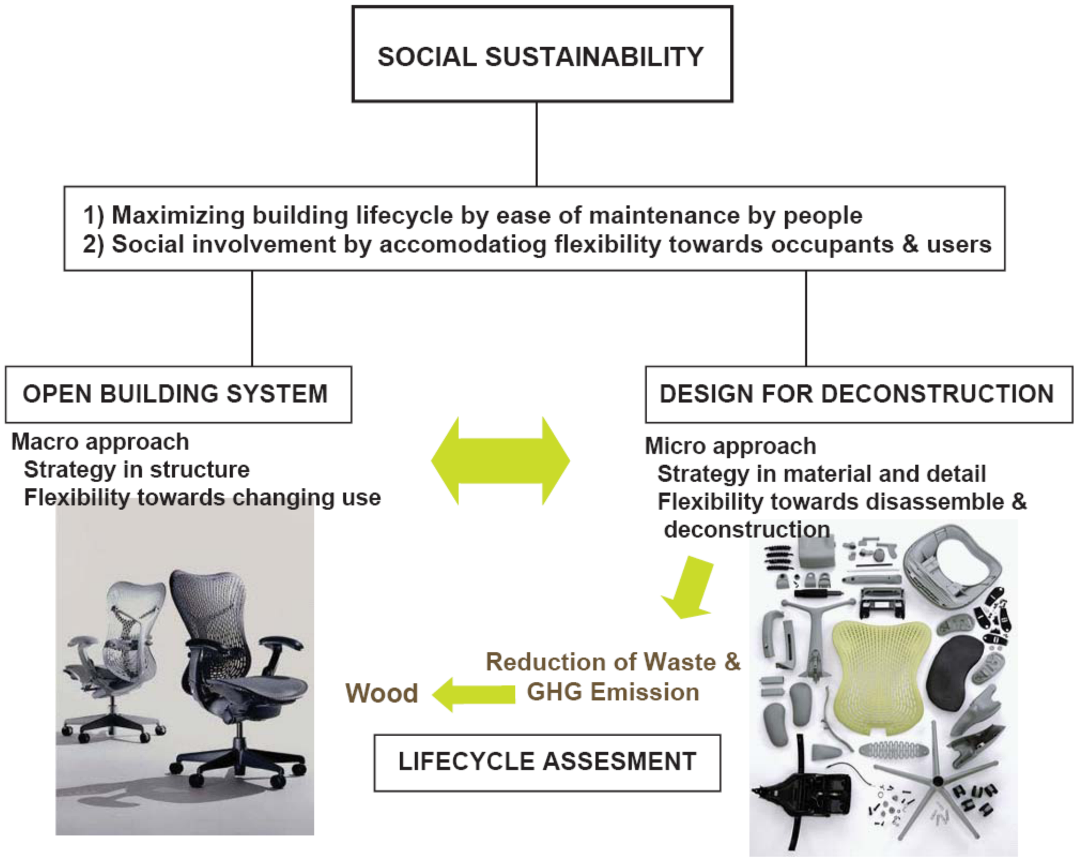
7. Conclusion

Social sustainability is the idea that people, who care about the place they live in, are the most influential to the sustainability of their place. Buildings are always bound by the specific social, cultural and technological conditions of a particular location. Architects and engineers should challenge sustainability to emphasize their ability to create a living space that's of high quality design appropriate to the site and holistically easy to maintain with local means. The quality of architecture relies on the interpretation of certain social, cultural and technical conditions of the specific place where a building is situated. Therefore, architects and planners should have awareness towards the diversity and technological potential for the future of the community.

Today, architectural developments have been driven by technology that tends to cost more than the typical building method. This issue presents challenging argument about the feasibility of the project from the initial stages as well as possibly preventing the involvement of the community who may lack the expertise to be responsible to take care of the building. Another issue is the disparity between the life time of the building and life time of the technology. Having one overall technical solution for all systems, that have different service lives, can never be the answer. To find the appropriate solutions, two respectful design methods had been developed toward sustainable architecture today:

Design for Deconstruction is micro approach to social sustainability: its concept suggests that we have to consider the life-cycle of each material, component and people who maintain all such things. Therefore, sustainable design should occur mostly in the planning phase to maximize time spent on developing the assembly method and figuring out critical elements such as materials, components, connections, and information and management systems. The recovery of the building materials for reuse or recycling is intended to maximize economic value and minimize environmental impacts. This total planning process enables flexibility, convertibility, addition, and subtraction of the whole building.

Open Building System is macro approach to social sustainability: its strong concept and contemporary methodology can confront society's uncertainty arising from constantly changing circumstance. Design method of the Open Building System is a very strong tool for building technology and for organizing people's responsibility



associated with the building process, without changing the role of the architectural profession. The actual application is practiced through a number of projects today. All of those Open Building projects insist on the categorization and separation of four subsystems in the building structure, facade, infill, and utility. In order for these subsystems to be compatible and harmoniously produce a well integrated building, geometric coordination (in the size and shape) of the building is crucial to effectively distribute spaces and materials. By setting grid and rules on dimensions for building components, the job site waste during construction can be avoided. During a building's occupancy and use, independent subsystems make it easy and economical to replace components. After a building's life, the disassembly of its component is convenient, and useful parts could be easily recycled or reused. For these reasons, Open Building method could be regarded as a strategy for Design for Deconstruction and social sustainability.

Thus, design guidance followed by Design for Deconstruction and Open Building have much in common and symbiotically benefit from one another. Both results help improve feasibility for maintenance and maximizing the building lifecycle to pursue social sustainability

As an appropriate material toward social sustainability, wood use for construction was discussed. Together with its benefits in green construction such as life cycle assessment and GHG reduction, affordability and feasibility of wood construction can be utilized. Wood members of sufficient dimension have great potential and flexibility for reuse and remanufacturing. It can be cut or formed to make new sizes and shapes with no loss of its base properties. Wood in general can be associated with vernacular architecture, regionalism and other socially sustainable factors. Ultimately, construction using solid lumber can exhibit high quality craftsmanship and be an attractive material for most people that it can encourage people want to maintain it and reuse it for an extended life cycle.

To conclude my ongoing quest to achieve social sustainability, I hope future sustainable architecture will contribute not only to ecology and consider economic factors, but also social factors and accentuate the specific qualities of a place, such as craftsmanship, regionalism, and education to support cultural values as well as be at equilibrium with our natural surroundings.

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