CHAPTER 5

DEVELOPMENT OF READY-TO-ASSEMBLE (RTA) SELF BUILD HOUSING SYSTEM

5.1 Introduction

This chapter re-examines the basic principles stated in Segal techniques and its similarities with Malay Traditional Construction to be adapted into local culture and housing approach. The design process takes into consideration the outcome of the quantitative findings on top of results from interviews with selected local authorities in previous chapter. The first section of this chapter reviews Segal principles versus the Malay Traditional Construction (MTC) technique as well as other prefabricated modular houses. Later followed by the design development of the ready-to-assemble (RTA) self build housing system through a single space module prototype.

5.2 The Segal Method

People build considerable numbers of homes every year for their own use. Normally the intention is to build a typical home but a better and affordable one. A new approach to self build was formulated in the 1970s by architect Walter Segal[1] (Figure 5.1) to enable ordinary people with no previous skills to build their own house in the United Kingdom. His idea was to simplify the building process using post and beam construction which could be erected entirely by hand to provide a home of

[1] Walter Segal is a Dutch architect settled in England where his passion on housing issues developed. He was constantly searching for a more efficient and reliable building process which eliminates problems in the traditional method and this later in his life formed the foundation of his self build approach.

unconventional appearance but with a number of substantial rewards: variety of possible layouts, levels of insulation, easy maintenance and flexibility for extension or alteration.

Figure 5.1: Walter Segal.
Source: http://www.segalselfbuild.co.uk/

Segal's reputation came by accident, when he decided to demolish and rebuild their home at Highgate, London and to accommodate a temporary house at the bottom of the garden to live in, which would eventually be demolished and the materials recycled. As a result, he managed to erect a lightweight timber structure, with no foundations other than paving slabs, using standard cladding materials and linings in market sizes, which took two weeks to build and cost £800. Refer Figure 5.2. The result was a simple and practical four-bedroom timber house frame with infill panels. Segal applied for permanent planning approval for the house and it became a pilot project for Segal approach to self build later on in his life.

Figure 5.2: Walter Segal First Lightweight Timber Structure.
Source: Borer and Harris (2001)

The first community self build project using his technique started in Lewisham, South London back in 1978 and provided the builders with a low cost route into home ownership. The potential of this technique for helping people on low incomes are acquire skills, confidence and a home. Later it began to inspire the imagination of people in different parts of the country resulting a lot more homes began to be built. Other techniques for achieving the same aim have been developed by other architects and the first self build for rent scheme began in Tower Hamlets in 1988 using the same approach. As at March 1995, 36 schemes providing 214 homes have been completed and a further 20 improving 200 homes are under construction.

Porteous (2002) refers Segal's architecture as a remarkable Zen-like confined by its pragmatic constructional methodology like the CLASP[2] system, which flourished in Nottinghamshire in the 1960s. This system is comparable to Segal method, apart from the type of construction materials and details, of which CLASP system depends on load

[2] British prefabrication system specially formulated to provide rapid and cheap method of constructing modern schools up to 4-story height. The CLASP system is useful where mining subsidence are present, due to its pin-jointed construction.

bearing steel structure with pin-jointed dowels while Segal's uses timber with bolts and nuts.

To further understand how Segal's method work, the following sections 5.1.1, 5.1.2 and 5.1.3 elaborate further on its construction approach as well as procurement before and during the self build process takes place. It is crucial to understand this approach as mentioned earlier in Chapter 2 that as there are many other prefabricated systems, Segal has been chosen due to its similarities to traditional Malay house. On top of that, the research area is in the rural which would make it more relevant to this rsearch.

5.2.1 The Principles

There are similarities of Segal's approach to medieval English house, or the American frame-house, or the Japanese house, it could also lead to our local Malay traditional houses too, with certain features regulated to suit the vernacular environment (W. Mohamed 2005). The only contrasting feature is that the timber frames are calculated and based on modular dimensions to avoid waste and to facilitate alterations and enlargements. Midon et. al. (1996) developed a construction manual on prefabricated timber houses based on platform method with the usage of nails, unlike Segal which uses bolts and nuts to encourage recycle on used panels.

Segal's method aims to achieve optimum performance with minimum resource, and the underlying theme of the method is simplification of the whole building process, from conception to completion. The idea of simplification is imposed in four areas:

1. Reduction of the number of trades on site

Working with timber frame with an infill panel system eliminates or reduces "wet-trades" of concreting, bricklaying and plastering on site, allowing the whole operation to be dominated by one trade only, which is carpentry. Other trades such as roofers, electricians, plumbers can be involved only when they are needed.

2. A rational selection of building materials

The practicality and suitability of timber to the overall concept made it the best choice. Timber can be purchased easily in large selection of standard sizes. It is relatively lightweight and can be used directly without further processing, hence easier to work with.

3. Simplification of the nature of site operation

Segal emphasised simplicity in all stages of construction. Simplicity would increase the buildability of the house by the inexperienced owners as well as saving time and cost. All the joints and detailing were designed by Segal with the aim to keep it simple. Double handling of materials on site is inefficiency in construction; hence this is eliminated by erecting the frame and roof of the house to act as a sheltered storage. Materials are ordered in the order of their stages of erection. The house is raised on stilts. This reduced cost considerably because elaborate foundation work is not required. The use of paving slabs and concrete are sufficient to provide the necessary foundations.

Figure 5.3: Housing development at Segal Close, Honor Oak Park, Lewisham.
Source: Author's collection

At the same time stilt construction allows a house to be built on uneven sites. Furthermore it can do away with damp proof membrane for the ground floor, as the raised construction prevents contact with soil and it is therefore well ventilated. The lifted underside of the floor acts as servicing platform with flexible service distribution configuration, allowing greater freedom in planning. The undercroft provides not only storage space, but also allows the accommodation of wind bracings, hence eliminating them in the wall proper.

This type of construction is similar to the characteristics of Malay traditional houses, which can be found in villages among the low income families. In addition, the knowledge and skills of carpentry that is easily found among the villagers hence elevate the need to introduce the concept of self help.

4. Simplification of administrative procedures

Documentations are in A4 sheets made up of drawings (often freehand with minimum annotation), calculations, and list of elements, standard details and

installation instructions for the whole building. Segal, acting not only as the architect but he is also responsible for administration works, to achieve further savings in overhead costs. All these savings must be viewed not as a profit maximisation exercise on the part of the architect, but rather as a step to minimise cost in order to achieve good value for money on the part of the client.

5.2.2 The Procurement

The process of Segal's method self build housing is divided into two main phases. The first phase is the Planning Process and followed by the Building Process.

A. Planning Process

Stage 1:

Confirmation of the available or intended financial resource for the project from a client is necessary to avoid failure of professional incompetence. This is important to ensure if there is any financial support needed, necessary actions will be taken before the project begins.

Stage 2:

Using grid paper and models, Segal worked out the basic plan layout to suit the client's need. He worked within the modular grid set from the width of the infill panels (600mm or 450mm) and from the structural thickness (50mm).

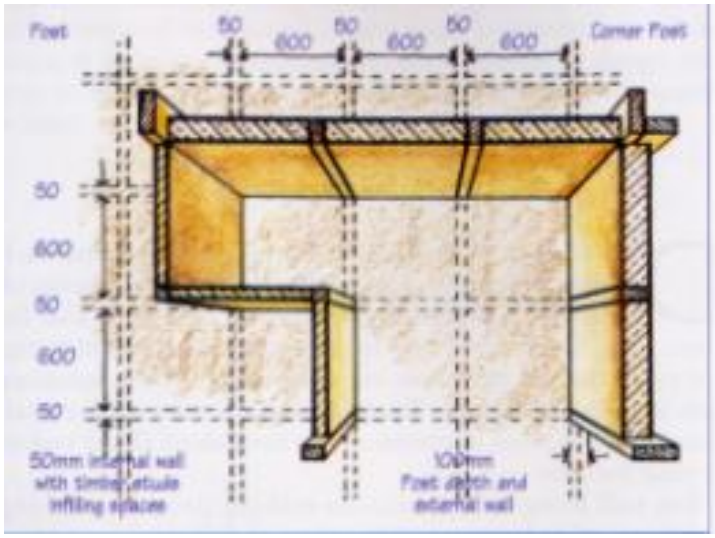


Figure 5.4: Tartan Grid is Implemented to Separate Structure and Wall Components.
Source: Borer and Harris (2001), p. 22

To achieve higher level of thermal insulation, a wall thickness of 100mm or 150mm is commonly used either with foam plastic insulation or double layering of studs with horizontal counter battens. This avoids formation of cold bridges through walling. The walls are non-load bearing, allowing flexibility in the space planning as well as the openings. The vertical dimensions are controlled by height of panels. The ceiling panels are fixed between structural frame without cutting, or if cut, then without waste.

Stage 3:

Upon confirmation of the layout, all required drawings are drawn freehand. These drawings are used in conjunction with reference to structural framing, schedule of materials and other documentation.

Stage 4:

The architect works out the structural layout based on the agreed basic layout. Columns are spaced 6 modules apart, allowing up to 3.85m span in either direction. For larger span, composite beams or trusses can be employed.

Stage 5:

Calculation of each structural member is essential to ensure its adequacy in strength to support the load. These calculations are then submitted for building regulations approval.

Stage 6:

Once the structures have been calculated, the detailed drawings of the frames, which include the foundation layout, roof plans, sections and detail of joints, are to be prepared.

Stage 7:

Next, the detailed schedule of materials is arranged in the order of the erection stages. Apart from being the specification list, it also acts as a bill of quantities for the building. This leads to an accurate costing, which is obtainable at a very early stage in construction. The final preparation in this process is to complete the description of how the building will be constructed - a kind of a working manual on site. The most crucial step is involving the households to contribute their capacities not only in construction skills but also in management and wellbeing of the participants during the building process.

Figure 5.5: Self build Group in Action
Source: http://www.segalselfbuild.co.uk/

B. Building Process

1. Foundation

Holes are excavated, filled with concrete and capped with paving slabs to provide point foundations. The post stands on a piece of lead to prevent it from being affected by moisture rising through the end grains. The topsoil beneath the house is removed and replaced with gravel bordered by perimeter slabs.

Figure 5.6: Pad Foundation Used for Self Build Housing at Segal Close
Source: Author's collection

2. Structural frame

Cross frames with rigid joints (using galvanised steel bolts) are assembled flat on ground; then raised and braced into position to form the overall structure. Temporary props are used to achieve accurate positioning of frames.

3. Roof

Flat roof is chosen as it is easy to construct, economical and flexible to fit over any plan. To avoid leakages, the most common failure of traditional flat roofing, Segal lay out a waterproof membrane in table cloth manner instead of fixing it.

Figure 5.7: Flat Roof Construction
Source: Author's collection

This allows the membrane to shrink or expand without restraint and is free from stress caused by structural movement. Roof outlets are placed in the overhanging area of the roof, so the joint is fail-safe. The membrane is weighted down by shingles. A flat roof is not suitable for the climate in Malaysia; therefore an adaptation of a pitch roof from this construction should be studied or designed in this case.

4. Floors

The floors use tongue and groove softwood boarding joists, where insulation is laid between joists and panels. The panels are removable to allow access for services.

5. External walls

The completed floor provides the working platform to construct the walls. Originally, Segal designed walls made from non-structural infill panels clamped into the structural frame using bolts. This type of construction has a few deficiencies. Rigid insulation materials are expensive, can be environmentally unsound and the construction can be draughty. The latest method of construction is to include the use of studs between clamping battens.

Figure 5.8: Self Build House, Segal Close
Source: Author's collection

6. Windows

Upon completion of the external walls, windows are installed based on the materials available in the market. The preference over prefabricated system is due to the fact that modular coordination, tolerance, dependence on a single source of supply and delivery delays are minimal. The positioning of windows is flexible and based on the modular panels of the external walls.

Figure 5.9: Modular Panels on Walls and Windows
Source: Author's collection

7. Partitions

Internal partitions are made by clamping panels into frames with timber battens. A panel is made of structural core, normally with 50mm woodwool slab with painted plasterboard on both sides. It is held in place by a sole plate at the bottom and structural joists at the top.

8. Ceilings

These are painted plasterboards laid between the joists on battens, which can be removed for access to services. Cover strips are used to mask the joints. Each panel is 600mm wide. Insulation and services are placed within the void of the structural depth.

9. Stairs and other features

Treads are supported either on hangars, posts or cantilevered beams. The basic structure can produce features such as seats, porch, trellis, veranda and pergola. Bay windows or a conservatory (for UK climate) can also be incorporated.

Figure 5.10: Staircase Construction
Source: Author's collection

Figure 5.11: Verandah with Pergola
Source: Author's collection

10. Services

The voids in the floors, roof and walls provide flexible space for service runs. They are accessible by unscrewing a batten or lifting out a panel.

Figure 5.12 is a summary of the Segal method construction stages that has been illustrated clearly in Borer and Harris (2001).

Foundation and Site works:

1. Provide access road, if needed.
2. Installation of temporary services and site office.
3. Setting out and clearing of site, of which topsoil is removed.
4. Digging of trenches for drains and services.
5. Digging of foundation pads filling them with concrete.
6. Installation of drains and services.

Structural Frame:

1. Organize timber delivery
2. Assemble into timber frames (marking, cutting, drilling where necessary)
3. Stacking of frames in reverse order of raising.
4. Raising of first frame and brace it to ground.
5. Followed by subsequent frames, taking note on the distance of the frames.
6. After all frames are braced up, apply damp proof course under each post.

Figure 5.12: A Series of Illustrations on Stages of Self Build Under Segal Methods
Source: Borer and Harris (2001), p. 34-35

External Skin – Roof:

1. Using scaffolding around the perimeter of the house, roof timbers (rafters, joists or purlins) are installed.
2. Installation of roof covering (tiles or slates on battens, turf on a membrane on a timber deck).
3. Fixing of fascia boards, gutters, soil and vent pipes.

External Skin – Floor:

1. Installation of floor joists (cutting and fitting according to spaces planned).
2. Floorings are completed later after house is weather-proof and services have been installed.

External Skin – Wall, Windows and Doors

1. Refer to drawings to position windows and doors.
2. Constructing timber stud work.
3. External sheathing, windows and doors are fixed.
4. External panels are fixed (timber weather-boarding, sheeting and cover strips).

Internal Walls, Services, Insulation and Finishes

1. Firstly, wiring and plumbing need to be installed.
2. Insulation for roof and walls and floors (this is usually omitted in our local climate)
3. Finishing the installation of flooring.
4. Construction of internal wall studwork and door frames. Plasterboard with timber strips is used finishing.
5. Staircases, external steps, verandas are completed.
6. Electrical and plumbing are fixed. At this stage some might hire an expert to complete the specific job.
7. Landscaping work is done at the end such as paths or roadways.

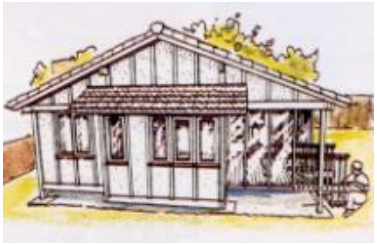


Figure 5.12: continued

5.2.3 Accessibility

The fundamental of the Walter Segal self build construction approach is the use of lightweight construction techniques using simple timber frames and locally available building materials with minimal cutting. It eliminates the need for wet trades such as bricklaying and plastering, which results in this light-weight construction and can be built with minimal experience. Foundations are simple, often just paving slabs as the strength of the structure comes from the geometry of their construction. This environmentally friendly building approach has given accessibility to the low-income households in London to actually have a decent home. As the design of the construction is flexible whereby the usage of bolts and nuts are introduced, the owners are able to incrementally change or add their spaces accordingly to their requirement throughout the time. Segal houses are comparable to Japanese houses and also Malay traditional houses. Construction costs were reduced significantly and the homes were made further affordable through the use of a shared ownership financial mechanism. With all these features in Segal houses, accessibility to own a house has made it easier and affordable for the low-income households.

5.3 Similarities Of Segal Approach To Malay Traditional Construction

There are numerous references on Malay timber housing construction. Lim (1987, 1988), Gibbs (1987) and Raja Ahmad Shah (1988) has discussed in length on the principles of the traditional house from the rituals to the production of various details in construction, while Waterson (1990) gives a comprehensive view on its development in Southeast Asia. Traditional buildings and its assemblies are made popular in the past decades; fortunately, there are still efforts to conserve such buildings that are worth protected.

Malay carpenters have a long wood-working tradition and they are found namely in boat and house making. A study by Ismail and Ahmad (2006) that looked into the modularity of Malay traditional houses stressed on the principle of dividing building into several elements. These elements have three main categories i.e. physical, spatial and functional (Ismail 2006). Refer to Table 5.1. Seeing that prefabrication is very much associated with physical elements, further grouping is done to clarify the components. There are sections, units and compound units (Ismail 2006).

Table 5.1: Prefabrication in Physical Elements of a House

Functional	Related to usage		
Spatial	Related to spaces		
Physical	Related to structure	Section	A larger structure that consisted of more than one compound e.g. wall.
		Compound	A combination of many units to form a module e.g. a door or window with frame.
		Unit	A single element by itself and can be combined to form a larger component e.g. window pane or door panel or brick/block.

This study concluded that traditional Malay houses can be constructed using the high technology of prefabricated industry due to its modularity in design (Killman 1994; Ismail 2006). The evidence showing multiplication and addition of spaces are done through modularised system of three-column or four-column module to suit the needs of each household (Ismail 2006). The notion of such modularity in traditional Malay house gives similarities to the Sears, Roebuck houses that also highlighted in some of the American traditional houses sold through mail (Sears 1910; Stevenson 1996)..

Earlier, a list of principles in Segal approach of self build housing has been discussed. Based on these, there are similarities in physical characteristics as well as the principles that is comparable to Malay Traditional Construction. This research has prompted a comprehensive design on a self build housing system, referred as RTA – Ready-To-Assemble. It is developed and tested among the local respondents through their participation in a simplified self build housing technique. Refer Table 5.2. As prefabricated system seems to be one of the preferred solutions to solve the provision of low cost housing in Malaysia, it is hope that other than mass producing these monotonous appearances for the future, a more individualised form through self help method could be implemented as part of the public housing policy. Self help housing can still carry out the identity of traditional Malay house that is near extinction (Ismail 2006) through its construction method and material usage (W. Mohamed 2005).

Table 5.2: Comparison of Basic Principles

BASIC PRINCIPLES	Segal House	Traditional Malay House	Sears, Roebuck House	RTA Self Build System
Modualrity	Modularity using existing current materials	Modularity in design and repetitive rhythm revealed through studies	Pre-cut panels and components in catalogue	Modularity using existing current materials
Materials and Technology	Use existing dimensioning by available materials in the market.	Timber construction but evolved using brick work for extensions	Using imperial dimensioning.	Use existing dimensioning by available materials in the market.
Connection of components	Bolts and nuts	Nails and wedges (traditional joints) on top of tongue and groove	Nails, bolts and nuts	Bolts and nuts Nails are used during pre-assembly.

Table 5.2: continued

BASIC PRINCIPLES	Segal House	Traditional Malay House	Sears, Roebuck House	RTA Self Build System
Housing Procurement and Documentation	Practice self help approach among a group of participants, sweat equity, Land is provided by municipality, Drawing in A4 or A3 size	Practise traditional mutual help among family members and local community, but currently hire contractors to build. Land is self-owned No drawings required. Tacit knowledge through experienced carpenters involvement	Practise self help method among the neighbours and family members. Land is self-owned Purchase the house using a brochure which comes with a set of instruction on to assemble	Practise traditional *gotong royong* or mutual aid among family members and local community, but currently hire contractors to build Land is self-owned A set of illustrated manual for assembly.
Architectural Appearance	A modern outlook	Maintain traditional features (vernacular)	Maintain traditional features (vernacular)	Contemporary

Setting aside the vernacular architecture of the houses, one being an American and the other a Malay house, with a more simplistic and practical approach to support prefabricated industry, Segal houses has accomplished all of the aspects of economics, labour intensity, period of construction, open system approach and lower skill level. Over and above, Segal houses do promote self build activities offering an alternative to own a house for the low income families.

5.4 The Advantages Of Prefabrication In Self Build Housing

Kieran and Timberlake (2004) expressed that when modernism adopted the process of segregation: the architect separated from the contractor, or material scientist

segregated from product engineer; it creates devastating ramifications. Solutions and productions are treated as independent entities. For this reason, an introduction of prefabrication in the process of manufacturing building components are similar to those in automotive, shipbuilding and aircraft industries has become no longer entirely linear. Prefabrication is often referred to as “architecture’s oldest new idea”. It has been around for a long time and most of that time it’s been solicited as the next impactful idea in architecture. The British has started to use wooden panelised building to house a fishing fleet in Cape Ann, Massachusetts back in 1624, which marked an early experiment as a temporary settlement. In later years of early 1900s other companies have started to introduce “ready-cut” kit houses and were able to deliver through mail to end-users.

Currently there are many modern prefabricated houses returned in well-designed units to the mainstream, save from its reputation as low-cost. These innovative new ideas have popped up in large numbers, ranging from Modern Cabana in California to a more classy and expensive Micro Compact Home in Austria even as post-disaster homes of Katrina Cottages for Gulf Coast hurricane victims. There are scrutiny’s and skepticisms surrounding prefabricated houses. Some argued that while it is promoting for its ability to be mass-produced, its deliveries are relatively only to few, while others note that it promises affordability, modern prefab is often too expensive for a small space.

Davies (2005) listed a few of those prefabricated homes that were identified as self build such as SIPs (Structural Insulated Panels) technology by Border Oak, BoKlok flats by IKEA and many more as the years progressed.

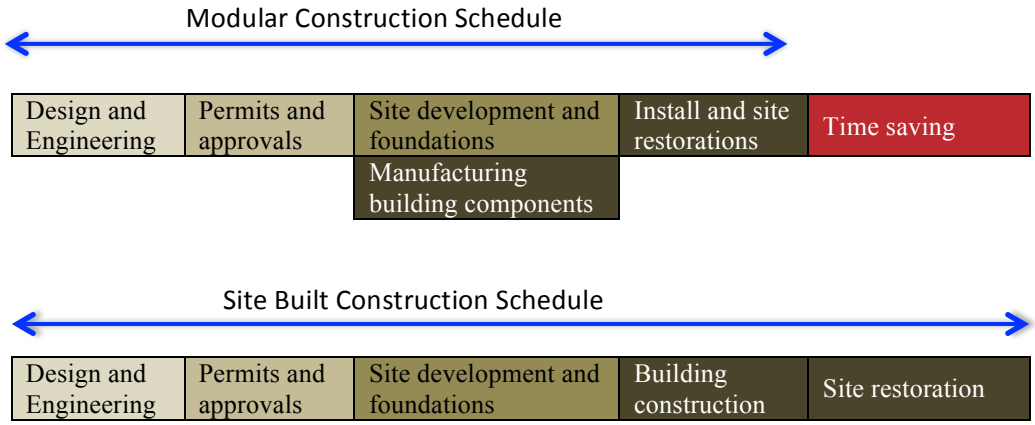
Lu Na (2007) through a survey from a mixture of 138 practicing architects, engineers, and general contractors in the United States, revealed the benefits associated with prefabrication are as follow:

1. Reduced overall construction time and efficient scheduling due to parallel production activities
2. Inreased building quality and craftsmanship
3. Increased labor productivity
4. Increased labor safety
5. Reduced construction schedule disruptions due to the use of a weather-protected work environment
6. The minimal environmental impact of the construction process on the site

It is perceived that prefabrication has the following main advantages which seems to be most relevant to the idea of self build housing.

1. Quality: A factory allows a much higher level of quality control, while automating parts of the process with equipments not available at a job site. In addition, walls are structurally superior as compared to conventional walls of MTH.
2. Cost: Less labour through efficient manufacturing as well as lack of job-site risks such as theft, mistakes, wastage of materials help to reduce overall cost. On top of that, prefab houses helps end-users to adapt individual current financial expenditure.
3. Speed: A prefab house takes significantly less time to build from start to finish. It also reduces wasting of time on site since all have been pre-designed and – decided at an earlier stage. Refer Figure 5.13.

Table 5.3: Classic Modular Construction Schedule Illustrating Time Saving Attributed To Onsite Construction In Parallel To Offsite Component Fabrications.
Source: Schoeborn (2012)



4. Performance: The process and material selection of prefab houses could comply with 'green building' standards.
5. Value: As compared to conventional MTH, it is worth at least the same due to its quality-controlled components and usage of higher standards materials.
6. Transparency: the highly-planned and pre-set process of prefab project allows for a much greater transparency in the entire project either for trades involved or end-users.
7. Dissemination of Knowledge: The establishment of community associations and provision of technical training is an important factor to facilitate self build housing. Through education, people are aware of modular coordination and prefabrication using timber or low technology.

5.5 The Design Process of Ready-To-Assemble Self Build Housing System Prototype

It is known that there is two main systems in self build market: load-bearing brick or block as opposed to prefabricated timber frame. Based on the previous chapter, the favoured material is brick as it is regarded as a safe investment, while timber is seen as dangerously experimental and temporary. However, brick is regarded as wet construction and would require longer duration to complete. Tam et al. (2007) declared that the following strategies are necessary in order for modular construction to be considered effective:

1. Complete mechanizing of the production process
2. Eliminating the amount of site work required as much as possible
3. Maximising the usage of recycled materials for prefabricated building components

Daligan (2007) explained that the Segal method is a **dry construction** which eliminates the need for wet trades such as brick laying and plastering, hence it is practical and simple to be used in self build construction. The obvious similarities of Segal Method to Malay traditional construction combined with the readily knowledge of the local carpenters and self builders, have led the usage of timber in the development of RTA self build system. The RTA self build housing system is created based on a five basic principles that has a potential to be applied mainly in Malaysia but it is also possible to apply in other countries that require fast erection of either temporary shelter, resettlement or for post-disaster houses. The system is designed to encourage self build process in erecting a house rapidly by means of low skilled labour

using minimal specialised equipments. The system provides the option of pre-assembled components to some degree before they are delivered to the site.

The need to identify the basic principles is crucial as it would guide the design to be closed to what is intented. The following are the main principles that have been identified through Segal approach while designing the RTA self build homes.

1. Using available current market construction materials whereby these materials are accessible in any parts of Malaysia.
2. The materials use are either in their uncut sizes or minimal cutting, therefore the sizes of windows and doors correspond to other materials available in the market and promoting zero or minimal wastage on site.
3. The housing components (wall, floor, columns, beams, roof trusses) are modularised to ease the non-skill worker during the construction process.
4. Drawings are kept at smaller sizes (A4 or A3) listing the schedule of materials indicating budget.
5. Through modularisation, the presence of machineries can be avoided.

5.4.1 The Grid

After careful consideration, tartan grids (Figure 5.16) is selected to be implemented in order to separate the structural components, mainly, columns and beams, with the wall dimensions (Figure 5.17). This provides the freedom for self builders to decide their own sizes of the structural dimensions without intruding into the wall length.

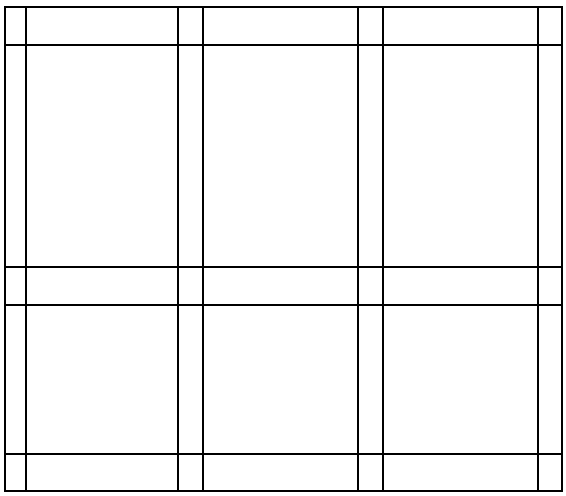


Figure 5.13: Tartan Grid Framing.

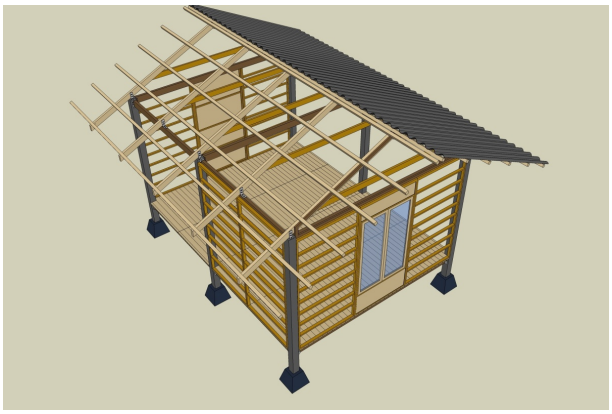


Figure 5.14: Basic Modular Plan is Important Where Multiplicity is Easily Applied for Personalisation and Ease Of Construction.

5.4.2 The Structural Framing: Post And Beam

The structural frames of the system are connected only using bolt, nuts and screws together with specific metal hangers and brackets (Figure 5.16, 5.17 and 5.18). This is to ensure the components could be recycled or relocated when self builders decide to change their house plans in the future. All of these steel brackets are prefabricated and installed at factory.

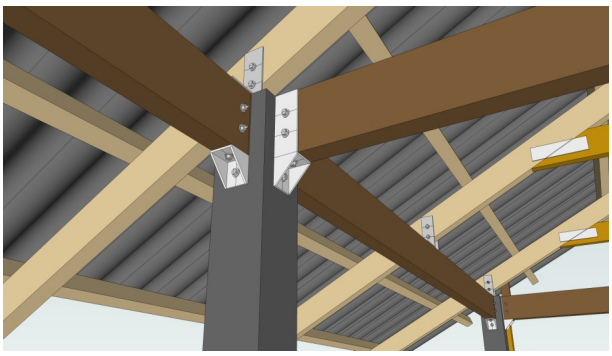


Figure 5.15: Steel Brackets Located at Upper Column to Receive Roof Beams

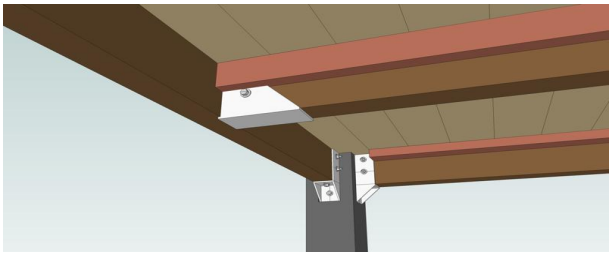


Figure 5.16: Steel Brackets Located at Floor Beams to Receive Floor Joists

Figure 5.17: Steel Brackets Located at Lower Column to Receive Floor Beams

5.4.3 The Modular Wall

The walls are in modular panels of 4'X8' to simplify the assembly process, whereby minimum of 2 persons could do the job. Furthermore, the size is still in imperial dimension as it refers to the sizes of most local materials available in Malaysia i.e. plywood, cement board, corrugated zinc, asbestos sheeting etc. This gives the flexibility to self builders creating and designing their own facade treatment according to their budget.

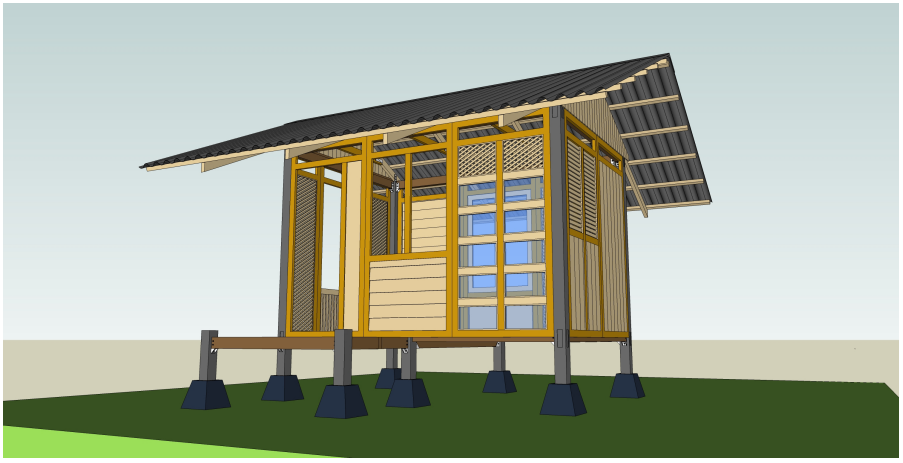


Figure 5.18: Variety of Wall Panels with a Standard Size of 4' X 8'

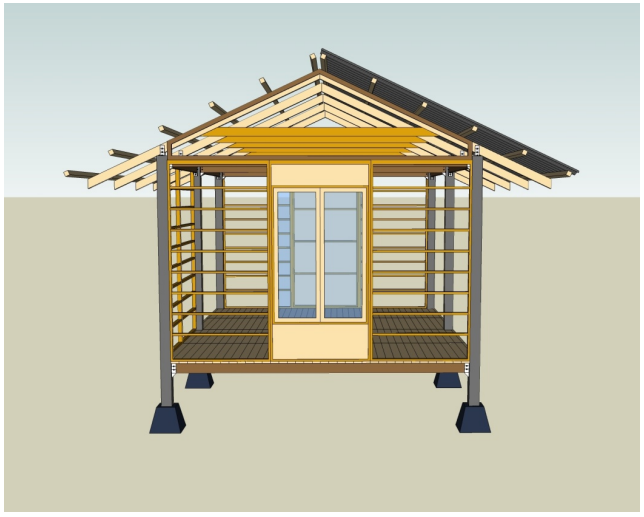


Figure 5.19: Flexibility in Choosing the Wall Panels Based on the Floor Plan

5.4.4 The Modular Floor

The floors are also in a 2'X6' modularised panels to reduce error in handling woodwork especially if self builders are non-skill workers. Treatment for the corners of the floor module is cut to fit against the columns. All floor modules will be received by floor beams that are readily attached with bolts and nuts to the floor beams making it effortless for self builders to set up the whole flooring section of the house before putting up the wall.

The structural outer floor beams are grooved on upper one side to receive the end of the floor module while the floor joists are grooved on both upper sides in order to receive the longer sides of the floor modules. The floor modules are placed in between the beams and joists just like placing a bed.

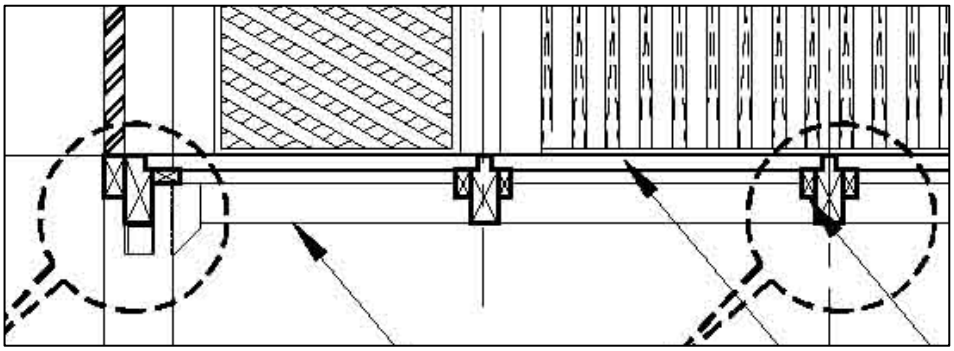


Figure 5.20: Detail of Floor Module

Figure 5.21: The placement of the Floor Module as Seen From Below

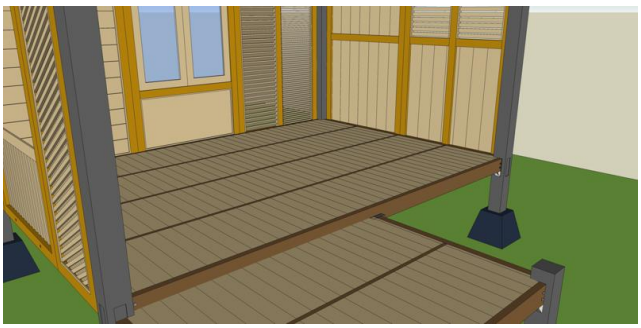
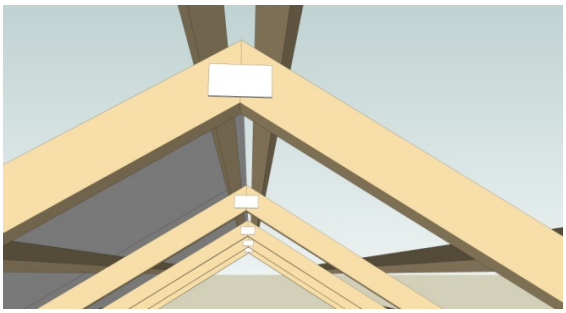


Figure 5.22: The Placement of the Floor Module as Seen FromAabove

5.4.5 The Simplified Roof Truss

The roof beams are fixed with coupled L-angles to receive roof trusses. The trusses are constructed without using roof ridge instead the purlins are use to tie the trusses together.



5.23: Roof Trusses Connections

Figure 5.24: Roof Battens are Placed Accordingly to the Brackets Pre-Fixed on the Trusses

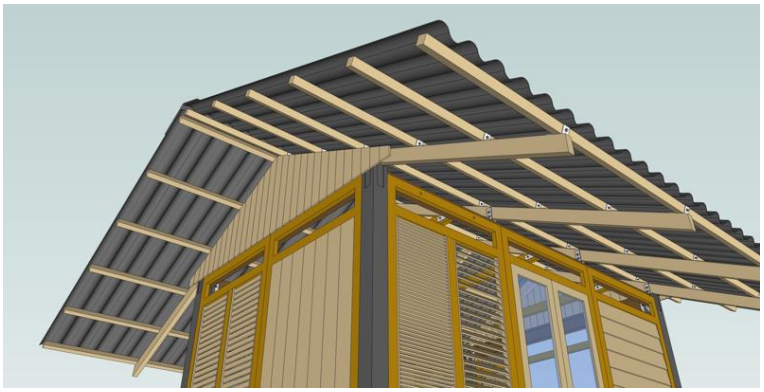


Figure 5.25: Corrugated Metal is Just One of the Materials That Can Be Used in This Construction

5.4.6 The Connectors

The connections are using either bolts and nuts or screws to promote reuse of the modular components in the system. Due to the flexibility and ease of using these types of connectors as compared to nails, the modular components can be recycled, relocated or redesigned without damaging the modular components.

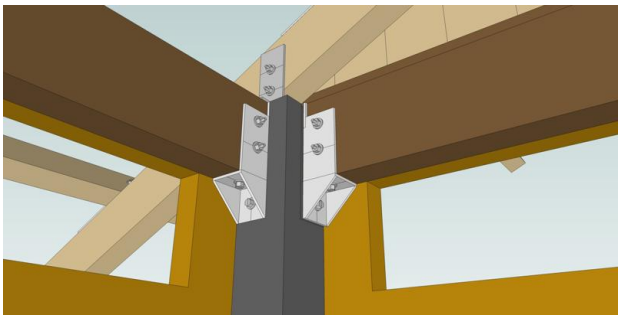


Figure 5.26: Connectors for Column/Roof Beam

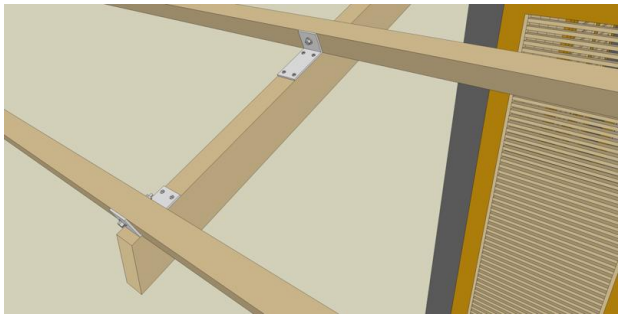


Figure 5.27: Connectors for Roof Batten on Trusses

Figure 5.28: Connectors for Roof Trusses

5.4.7 The Schedule Of Materials

One of the most important preliminary actions of self build program is the preparation of the schedule of materials. This would determine the intended expenditure in relation to the description of components so that the end-users can predetermine the quantity of components needed and design required together with the pre-financial arrangement. Refer Table 5.4.

Table 5.4: An Example: Schedule of Materials

Project: Ready-to-Assemble (RTA) Self Build Prototype Unit in Kedah

Material	Description & Location	Grade (Species Group – SG)	Section/ Unit size	Length & Quantity/ Area
Hardwood	**Main structure:**			
	1. Columns - to predrilled metal brackets to receive floor and roof beams	2	5"X5"	10'0"/ 6 nos.
	2. Floor beams (primary) - to predrilled metal joists hangers to receive intermediate floor beams	2	2"X5"	14'0"/3 nos.
	3. Floor beams (intermediate)	2	2"X5" 2"X5"	10'0"/6 nos. 6'0"/8 nos.
	4. Roof beams (primary)	2	2"X5"	14'0"/3 nos.
	5. Roof beams (intermediate)	2	2"X5"	10'0"/4 nos.
	6. Ledgers	2	2"X4"	3'0"/48 nos.
	Roof structure:			
	7. Roof ridge - pre-cut with grooves to receive rafter as per drawing	2	2"X5"	18'0"/1 no.
	8. Roof rafters -	2	2"X4"	10'0"/10 nos.
	9. Purlins	2	2"X2"	18'0"/4 nos.
Steel	10. Metal brackets			28 nos.
	11. Metal joists hangers			12 nos.

As for the wall modules, there is a range of selection that could assist the end-users to decide on either financial capacity or the final outlook of the house. These wall modules are priced differently based on their designs and materials use. The cheapest wall module is the one using plywood (Figure 5.30).

Figure 5.29: The Variety of Designs in Wall Modules That Can Be Chosen to Suit Financial Capacity and Facade Design

5.6 Comparison Of Rta Modular Housing System To Other Similar Systems

There are many modular housing systems that have been developed in other parts of the world responding to fast solution in providing new homes for different purposes. Modularity of the housing units is defined ranging from the smallest component of a house such as posts and beams up to a bigger production of house frame such us shipping containers. The basic idea of modularity is to be universally produced and can

be reused or resold under different circumstances. The following (Table 5.4) is a summary of modular houses, which are made of various materials that are being advertised and sold in different parts of the world. This selected inventory of modular housing system is recorded as a reference to compare the RTA modular housing system developed for the low-income household in the rural of Malaysia.

Table 5.5: Summary of Selected Prefab Houses Designed in Most Self Build-Practiced Countries. (Source:http://www.scrapbookscrapbook.com/DAC-ART/modular-kit-houses.html) [Accessed 18th February 2010].

Name and origin	Description
Form and Forest (Canada) 	Designing flat pack cabins for 1-4 persons or 4-8 persons using panelised walls and components creating modular homes whereby the house is divided into sections and are moved on a flat bed truck along with siding, doors, windows and roofing materials.
Qube (UK) 	Constructed using structural insulated panels (SIP) that fuses a foam core between 2 outer layers of oriented strand board (OSB) on concrete pads with adjustable screw-jack supports that allow variances in site levels. It could be clad with any wood panelling i.e. red cedar or pine. This is built for the purpose as an extra house depending on the usage.
Spacebox (Netherlands) 	A self-contained living unit built using 5 composite panels as a lightweight prefab building system. Each wall panel of 88mm thick is equipped with fire resistant material, a Resol foam core and polyester smooth finish. The system developed a 'plug and play' system to meet the requirement as temporary habitat for student accommodation and fast assembly (recorded 84 units within 4 days).

Table 5.4: continued

Name and origin	Description
Metro Cabin, Maximo Cabin (US) 	Also referred to as prefab micro-housing where the building package contains pre-assembled wall panels, doors, windows, roof system, trim, siding and interior part that uses precision pre-cut. It is either built on concrete slab or wood timber foundation system, depending on local soil condition. The cabins are "system built" structures meaning that they are built under controlled environment of a factory.
Flatpak (US and Canada) 	A system consists of a menu of components that is based on an 8' wide one story wall component. The components are made up of different configuration tailored to suit individual usage of interior space. The house is equipped with seismic requirement with additional bracing and a site-cast seismic engineered concrete. The flexibility of the system allows for additional spaces later on.
Modern Modular (US) 	Modern Modular has a contemporary style, receptive to surrounding using modern technology. There are a group of innovative architects that facilitates the design/build process of this high-quality, prefab system houses.
Push Button House (Italy) 	A fully functional home using industrial containers to transform into a house with bedroom, kitchen, living, dining and library at the push of a button. The design is considered to be sustainable since most of the materials used are recycled and recyclable materials.
Cusato Cottages (US) 	Originally intended for temporary housing as an alternative to trailers while waiting for main house to be rebuilt after disaster happened. It is a compact design of about 308 – 1807 sq. ft. The requirement of the house is based on back-to-basic design and there are 19 designs sold through catalogue similar to Sears, Roebuck & Co. homes during the early 20th century.

Table 5.4: continued

Name and origin	Description
Boklok (Sweden) 	An Ikea partnership housing concept with one of the property companies in Sweden offering families to buy affordable houses from boxes especially for large scale development whereby it takes a day to be assembled. Timber, as we know is the only renewable construction material, is used in all BoKlok products. The usage of open-plan layout gives the flexibility to adapt other usages and due to its space-saving and clear-cut architecture, the production of these houses became cost efficient.
Modern Cabana (US) 	Modern Cabana offers 3 fully finished packages of different sizes 10'X12', 10'X16' or 20' and studio 12'X25' (with bath and kitchen). It comes in pre-assembled panels in order to simplify and expedite installation. These cabanas use concrete piers thus eliminating the need to pour concrete for foundation. The configuration is adaptable without the need to be highly customised. It is also referred to as one of the greenest prefab as it uses FSC-certified wood, denim as insulation and reduces waste in manufacturing and shipping. This is cabana is also referred to as mini modular.
Marmol Radziner Prefab (US) 	It consists of 2 types of modular package; one has a single module with large spaces and the other composes of mix and match system of 4 basic models of 61 – 242sqm using recycled steel frames as a module instead of using posts and panels. These customised prefab requires cranes as the units are heavy and large to be handled by 2-3 persons.

Table 5.4: continued

Name and origin	Description
HIVE Modular Housing (US) 	Hive houses use modular construction system which consist of various types referred to as B-line, S-line, C-line, X-line, A-line and M-line that refers to various configurations of cuboids with area ranging from as small as under 1000 sq ft up to 4049sq ft. per house. Hive is transported on a flat-bed concrete truck and used boom crane to lift it up and position it at site.
LoftCube (German) 	This is a self-contained unit that is transported using helicopter since it is to be used on rooftops of buildings. This is suitable for dense urban areas and making use of odd spaces such roof tops to be used smartly.
Quick House Kit (US) 	This kit includes 5 modified containers (3 bedrooms & 2 1/1 baths) that use recycled shipping containers turning them into simple looking houses stacked on top of each other for those who want double story.
MODABODE E-BODE (Australia) 	E-bode is a prefabricated, modular unit that is constructed in a factory with a modern stylish design and encourages flexibility. E-bode sizing 3.6m X14.4m consists of bathroom and kitchen, high ceilings, timber floors and a wrap-around veranda that appears as a fundamental section of the living space.
SmartShax (Australia) 	SmartShax is a lightweight and environmentally responsive hut appropriate to Australian coastal climate. The shack shares a principle that architecture should blend in with its environment hence large sliding doors/windows are created. It uses timber with galvanised steel stirrups and designed in an individual block of 63 sq m (15m X 4.2m) opened to a large deck of 18 sq m.

Table 5.4: continued

Name and origin	Description
Bachkit (New Zealand) 	It is a modular home sliding glass, aluminium louvered panels and lots of outdoor decks. Bachkit has a typical rectangular plan that has generous decking area as an extension to the limited interior space.
M-house (UK) 	M-house (pronounced 'mouse') is designed a bit like a shoebox except with additional details. M-house arrives in two pieces, each 3m (10' approx) wide, which are then joined together on site, which takes about a day. It comes completely fitted-out and ready for you to move into immediately.
Top Housing (Scandinavia) 	Top housing is a pre-engineered sectionalised housing system to cater for international professionals staying or working in 2 different climate – Tropic and Nordic climates. It has a flexible open layout and uses first class building materials and components.
Landmark Panelised Home Kit 	Panelisation is simply the process of making wall sections in a factory instead of out at the construction site. By doing this we reduce waste, control costs and insure a consistently high quality product. The manufacturer claims that this is neither a modular nor manufactured home since they offer more than 1600 plans that end-users are able to choose and fit according to their requirement.
Fabrik-International Panelised Home Kit (Canada) 	It also uses panelisation concept with pre-cut components for ease of transportation and assembly. All exterior walls are pre-built using 2” X 6” spruce on 16” centre. Inside partitions are pre-built using 2"X 4" spruce and anti-torsion bars. All components are numbered for easy assembly by your local crews. Sections may pre-build in 8 foot length and up to 40 feet when a 3 man crew and a crane are available. But due to its large panels, cranes are required on site to position these panels at their respective places.

Table 5.4: continued

Name and origin	Description
Knock-down houses, Indonesia 	Varying from 1-bedroom, 2-bedroom and 3-bedroom do-it-yourself kit packages with size ranging from 25m2 to 500m2 using a simple assembly manual that developed interlocking system where screws are hidden.
SABS, Malaysia 	A skeletal construction which used for developing design assembly for physical building components in a modular industrialised building system (IBS), characterised in that the Spacer Architectonic Building System includes spacer having predetermined shape for use in formulate modular form of building component;

Most of these modular housing kits are modern in their designs and some require bigger transportation to be sent to site and some require cranes to lift big heavy panels or frames during the assembly process. All those recorded above are prepared in a controlled environment of a factory to achieve the precision and quality of those components and panels.

There are so many in the market to choose the ideal modular home that would suit individual capable skill as well as the team to assist in self build process. Unfortunately, most used higher technology with exception of a few like Modern Cabanas or Cusato Cottages that are considered of slightly lower technology. As the idea of RTA modular housing system is designed specifically for local context, hence the usage of appropriate technology is a must. The ideal situation is to be able to test this actual design by making sure that selected respondents go through the process of assembling the unit themselves. Promoting modular in this design is to simplify the construction process

hence encouraging more self builders among the rural people. Then the idea of ‘freedom to build’ is aptly referred to as what Turner (1972) debated.

5.7 Strength of RTA Modular Housing System

Having established many considerations and comparisons made together with the development of designing the RTA self build system, the following sections discussed many of the advantages or strengths that are seen in it. These strengths demonstrated the system’s abilities to address sustainable issues within the local context and answered some of the respondents concerned and inquiries on self build housing.

5.7.1 Consistency

This consistency refers to production of components. It is crucial for RTA self build system components to be fabricated with accurate measurement and sizes. The achievement of such performance in this system can be achieved due to the manufacturing process in an enclosed environment. The one important thing that is needed in producing the panels is the set of detail drawings or shop drawings. These shop drawings are created specifically for manufacturing processes.

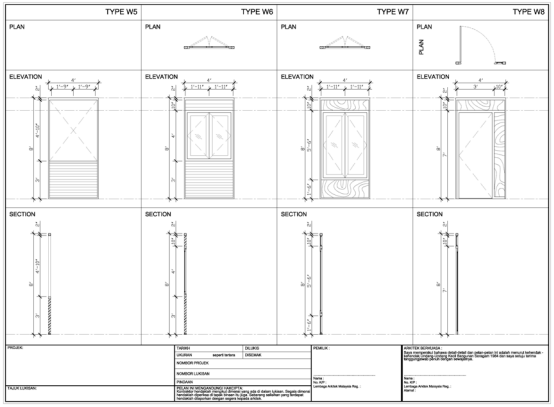


Figure 5.30: Shop Drawings That are Needed in Manufacturing Production

A preliminary set of drawings should be first completed before a manufacturer is brought onto a project. Later, drawings are duplicated for factory workers to manage all of the work for a particular task (walls, floor, roof, structure, etc.). The shop drawings reflect the precise requirements of the task at hand. Preliminary coordination and constant dialogue with the manufacturer throughout design development and component manufacturing are required to maximise production time. Through these sets of shop drawings, many other local carpenters can become manufacturers of these components, hence making it consistent through its sizes, design and quality for others to add later on. This would reduce capitalism in prefabrication industry whereby only one or specific producers are in the market.

5.7.2 Availability

As many materials are invented throughout the years, there are only a few that can be accessed in rural or remote areas. These materials are usually the traditional ones that never age through time – timber. Timber is easily available in basically ALL places in Malaysia, even in faraway land. Hence many of the respondents justified the choice of this material since it is easily obtainable.

The sizes of cut timber are of standard measurement across Malaysia. The usage of imperial dimension is still valid even though the metric measurement is imposed. Moreover, the local carpenters and users are still interacting using the imperial dimension. RTA self build system is designed and documented based on those measurements.

Figure 5.31: Manufacturing Prototype of RTA Components in a Local Carpenter's Workshop

5.7.3 Flexibility

Each module is made up of a series of timber frames, which receives structural load that is then transferred to pad footings, making the whole building raised above the ground. This method eliminates the need to level sites and destroy existing trees or shrubs. The whole building can be easily adapted and extended to meet the requirement under different site conditions.

Further more, the RTA modular housing system consists of modular components from the structure up till the walls, floors and roofs. Due to this principle, the planning of the spaces can be personalised. Refer Figure 5.32. The system's flexibility provides unique housing forms and elevations according to individual preferences and resources. Refer Figure 5.33. There is also the flexibility of introducing other materials other than timber to be used in the wall panels, such as thatched wall or cement board materials. Refer Figure 5.34.

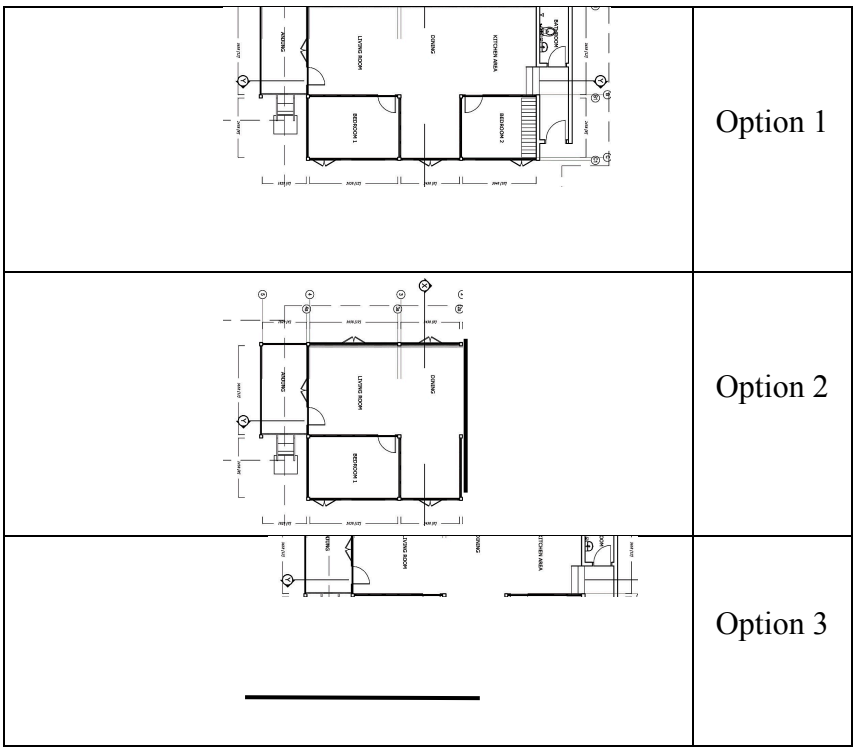


Figure 5.32: Possible Spatial Layout That Meet the Needs of Each Family and Their Budget

Figure 5.33: Possible Elevations that Provide Flexibilities and Varieties in Design.

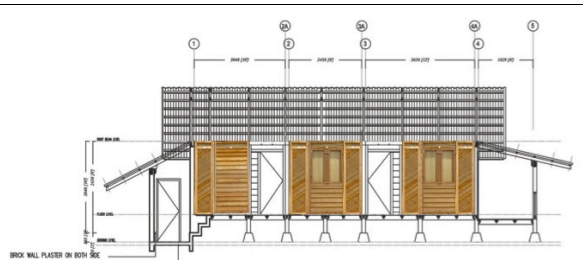
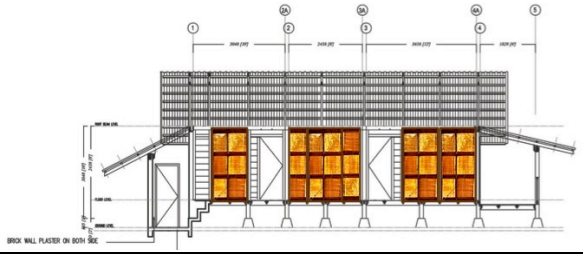
	Option 1
	Option 2

Figure 5.34: Possible Materials That Can Be Used to Produce Varieties of Preferences.

5.7.3 Affordability

It is possible that a saving can be sought through material optimisation, labor efficiency and individual financial capacity. The mass production of RTA modular housing system is already a saving in terms of economies of scale. When investment is made to obtain the system, there will be mass customisation that takes advantage of the cost benefits. The repetition of order would consequently reduce any construction wastage as well as redundancy of designs.

Over and above, self build approach takes advantage of the fact that manual labour is easy to come, ergo there is the option to eliminate using contractors during the assembly of the RTA self build system. Moreover, individuals are able to financially plan vigilantly on their expenditure based on their designs. This combination of self build approach using mass produced modular components give the freedom to potential self builders to build what they can afford since the house plan can be an incremental approach. Self builders are able to identify most important spaces for their family requirements and initially invest in that particular space. Later on when financial allows, other spaces can be multiplied.

5.7.4 Accessibility

Mass production is about repetition. It promotes volume building using identical processes to increase labor productivity and the cost effectiveness of construction. Modular construction does, however, provide the opportunity for economies of scale to be introduced into design so that isolated elements of a building can be produced in volume (Schoebern, 2012). RTA self build system are produced in a mass quantity where people are interested to become self builders. Identifying the quantity of panels and the designs becomes easy since individual dictates the design of the house, hence nothing will be over produced. These panels are then easily stacked as storage once ready to be delivered for a unit of a house. Due to standard size and design, any local carpenters that manufacture these panels are able to offer their goods to any interested self builders. The ease of storage for this system, would allow manufacturers to plan a basic housing unit and be sold as a package. The ease of transporting these panels are also one of the strength in RTA Self Build Housing system. A 5-tonne lorry or one 20 footer container would easily load a full assembly of 3-bedroom RTA unit to be delivered to site.

Figure 5.35: Stacking the Panels as Means of Storing and Delivering

This combination of using imperial dimensions in the modular components accommodates the open system of prefabrication for low technology in the rural area. Standardised sizes of door and window frames are easily fitted into the wall module. This encourages local carpenters to use what is already available in the market, reducing the need to custom-made unnecessary panels.

5.7.5 Ease Of Construction:

The lightweight nature of construction enables people of all ages and abilities to build easily. They can decide to either work in a group or individually. In addition, usage of timber is associated with dry-trade construction, hence minimising the delay for self builders to move-in into their homes. This RTA self build housing system allows instant occupancy for the families to settle-down. Dry-trade construction also reduces the types of site works required during the assembly of the system.

The combination of the modular components using brackets, bolts and nuts and screws strengthen the basic principles listed in localising the construction process to certain area/context. It reduces the duration of assembly process of the house, making it fast in supplying the finished product. The sizes of these modular panels (walls, floors and structural members) has made it easier for the self builders to handle without having to rent heavy machineries. Involvement of machineries such as cranes and lifters could incur more cost in the assembly task.

There is also a provision of an illustrated manual or guideline for assembly of the system. All posts and beams are coded to make certain that anyone is able understand and erect the module. The step-by-step guide is supplied during the installation of the

module. Coding of the structural members and modular panels was observed to expedite the assembly process. Refer Figure 5.37.

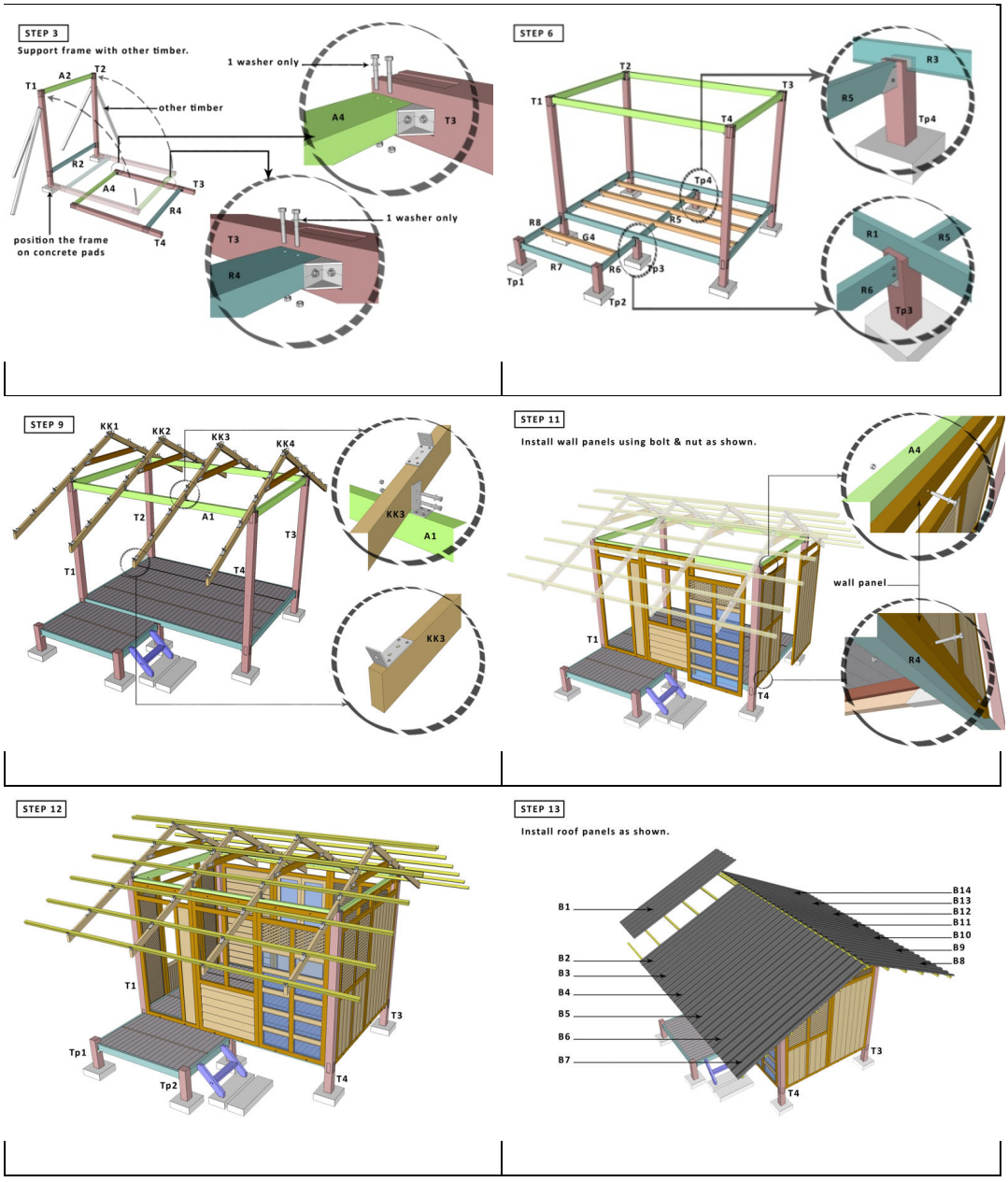


Figure 5.36: Series of Illustrated Manual as a Guideline to Assemble a Module Using RTA Self Build System (Refer To Appendix F)

5.8 Chapter Summary

Policies and planning are not discussed in detail since this chapter revolves around the design development of RTA self build system. Nevertheless the researcher

acknowledges that self build housing needs to have a greater flexibility in planning practice whereby the procedure for obtaining planning consent is to be simplified and expedite. A further study on planning policies that involved self build housing needs to be reviewed as at this moment, no such guidelines are spelled out or existed for organised self builders to establish themselves.

The compact designs of living units are nothing new in the current market and have been developing in the industry with new technologies, which made it interchangeable between stationary and mobile. The level of modularity is comparatively modern. It provides the opportunity to design prefabricated homes to meet the requirement of various range of demands from consumers. One of the ultimate goals in RTA self build housing system is to be able to satisfy any self builder's necessities through modularity, expediency, precision and efficiency.

Self builders are not necessarily prompted by traditional reasons to venture. Many are cautious about their housing choices. Chapter 4 analysis showed that 77.7 percent owned their existing house and 98.2 percent are *kampong* houses. This figure encourages self build housing to be introduced in the housing market as an option and seen as a way of obtaining a larger or 'better' house as compared to the mainstream property market. JRF (2001) surveyed that in the United Kingdom has had a social structure shift of self builders substantially, not only because they cannot afford mainstream housing, or are not eligible for social housing, but also those who are not satisfied with the existing supply of houses and desire an individual property or a particular location. Recognising the capabilities, lifestyle, culture of the local people is pivotal in this research to prevent from forcing a technology that could seem too complex to comprehend or too expensive to obtain.

Access to emerging building technologies, especially for low technology in the rural area, may become easier. Mainstream house builders may seek additional outlets for their recent investment in self build housing industry using prefabricated approach. In order to validate the strengths discussed in the previously, a series of site experimentation was conducted using the RTA self build system prototype. The next chapter documented the field testing of this system.