AN ARCHITECT'S VIEWS ON PRE-FABRICATED HOUSING SYSTEM — AN ALTERNATIVE APPROACH

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In Malaysia, present efforts to solve the housing shortage are directed primarily towards the problem of increasing production and improving means by which the poor can afford to buy houses. Measures taken to increase production include the release of more land for housing, better bank rates, more efficient machinery for approval of housing projects and the use of new technology to speed up production.

Concern about the delays in the completion of many Third Malaysia Plan projects, for example, as shown by the backlog of the housing construction, has led to an urgent search for a more effective method of implementation — including various methods of construction. In the housing sector, one of the ideas being tried is the use of prefabricated methods of construction.

In spite of its logical premise and its theoretical advantages in terms of cost, quality control, and speed of construction, and in many instances, in spite of strong government support, the development and acceptance of the prefabricated system of construction, since its emergence more than half a century ago has not been widesperead. It has yet to replace the conventional system as the principal method of construction.

This inability of prefabricated system to develop lies not in the weakness of the concept or the implementation of the system but rather in the inherent weakness of the housing industry. In most countries, the large size and the very fragmented nature of the construction industry makes it extremely difficult to get the industry to work in unison. Faced with this problem organisations and companies searching for new ideas in construction find it necessary to create entirely new system and support infractructure. Thus the systems which developed are complete systems. They are self-contained and independent of other systems and the industry as a whole. While this situation allows the privilege of independence of ideas, decisions and control, its individualistic nature limits the options which it can offer. The system operated as a closed system. This is perhaps the single biggest obstacle to the development and general acceptance of the system. To overcome this, and in order for the housing industry to get the benefits of the prefabricated system it is necessary to restructure the industry towards a more comprehensive and coordinated development.

Recognising the logic of the prefabricated approach to building construction, it is proposed that the building industry mobilises all its resources; managerial, finance and technical towards the development and production of materials and components which are more coordinated in size and compatible in use. Given the willingness of the industry to do this, it is possible to achieve a high degree of component compatibility through the use of the modular system. In Malaysia the time is ripe for this.

The contention here is that the prefabricated system of construction has a sound theoretical basis for wider application in the building industry. Prefabricated as an idea, where materials are pre-prepared into building components or individual parts, ready for assembly on site, is not a new idea neither is it a product of modern architecture. Pre-fabrication techniques have been in use for many centuries in the construction of traditional buildings such as the Japanese houses and temples and even in the little known kampong houses in Malaysia. In the construction of the Malay house for example, the master craftsman prepares all the timber posts, beams rafters etc; ready for assembly on site. On the appointed date the villagers would help to assemble the various components. Thus within a day it is possible to complete all the framings, roofs and floors of an average size house.

In modern architecture, perhaps the earliest examples of pre-fabrication is the Crystal Palace by Joseph Paxton in 1851. With the establishment of the Bauhous by Walter Gropius in Weimar in 1919 there developed a profound apprecication of the relationship between industrial production techiques and architecture.

Ideas based on the greater use of industrial production techniques and pre-fabrication were from then on being continually explored by architects, in particular in the field of housing. The period between the Two World Wars and the period immediately after, saw tremendous interest and development in pre-fabricated housing. In Britain and Europe in general where as a result of the bombing and destruction by war, there was a serious housing shortage. The shortage of skilled manpower for the construction industry due to the war effects have caused the British Government for example to base its housing efforts solely on the use of pre-fabricated housing system.

Although the claimed advantages of pre-fabricated housing are many and attractive, its achievement after half a century of development is still limited. In Britain for example pre-fabricated housing system was given every opportunity and encouragement to develop since the second World War and yet it has not had the impact that is expected from such a committment. In an effort to exploit the potential of pre-fabricated housing, the Ministry of Works in Britain invited the nation to contribute ideas. When this move was made in 1945 nearly 1, 4000 proposals were received, exploring a variety of construction techniques, including thoses which follow the principles of and line mass assembly used in the motorcar industry. Many of these ideas were tried and yet there have not had the impact. At about the same time Germany which was totally razed to the ground by war, managed to build 2.5 million houses between 1946 and 1950 relying entirely on conventional modes of construction. Viewed against the background of a post war condition where was a shortage of just about everything, the achievement is incredible. Certainly it is more impressive than the achievement in Britain, which uses the pre-fabricated system. Similarly, in Poland where housing is a state matter, the government has developed and planned a comprehensive infrastructure for the implementation of a single pre-fabricated system. This means that all government housing schemes in the country use only one system of construction. Production plants are strategically located to serve the various regions. In short the system has been very omprehensively developed. However, in spite of this, neither the architecture nor the cost has been able to compete with the small time private builders using conventional methods of construction. In Malaysia the real contribution of pre-fabricated system is yet to be seen. When the system was first introduced in the 60's, several blocks of flats were constructed. The initial interest however died out and it was not until recently that it is being re-introduced.

It seem strange that the pre-fabricated system, which seems such a logical method to housing construction, has never after 50 years of development been able to completely overtake the much slower and more cumbersome conventional method of construction, say in the way that ready-made clothing has been able to take over the market from the individually tailored system. I suspect the problem lies not so much with the system but rather with the construction industry as a whole, in particular to the free for all approach that is currently in existence.

In order to understand the problems faced by conventional construction, it is necessary to look at the construction operations and the building industry as a whole. The construction of any building involves four basic operations; design, materials manufacture, components manufacture and assembly of components and materials.

In the material manufacturing operation, the materials produced are either in a free-form or ready formed. Both free-formed materials (cement, sand, bitument, glues etc;) and formed materials (pipes, plywood, timber, sheet metal etc) required further factory or site processing in order to fabricate them into components or cast on site before they can become components ready for assembly or form part of the building.

The components manufacturing operation uses either free-form or formed materials to manufacture of fabricate them into components ready for assemble on site. This include windows, doors, roof tiles etc.

The construction or component assembly operation is the putting together of components and materials which can be either free-form or formed on site.

The design operation is the point where all decisions are made on the building form, the type of materials to be used and the sizes and the manner in which they are to be used.

In any building operation the three constructional operations can be undertaken either in factories and workshop or on the construction site. At one extreme, and where the construction needs are extremely basic, all the four operations are done in process on the site. The construction of traditional oboriginal bamboo house in Kuala Kubu Bahru for example requires the cutting, cleaning, splitting and fixing of the bamboo roofs, walls, floors, posts and staircases to be done from materials obtained from the construction site. Similary, traditional mud houses of Africa also use materials and process them on the site. While these methods of construction are adequate for their purpose, they would not be able to meet the constructional needs of contemporary housing.

Contemporary housing needs are more complex, demanding a greater variety of materials and component types and sizes and therefore do not allow the simplistic approach of preparing the materials and components on site. In this instance some of the operations are done in factories and workshop and some on site. Windows and doors frames for example are done in workshops and factories and then assembled on site. However, the casting of concrete columns and beams are still done on site.

At the other extreme, in the pre-fabricated system, almost all the manufacturing and fabricating works are done at the factories and workshop, thus leaving the minimum work, of site preparation, foundation works and components assembly to be completed on site.

This means that, as much of the materials and smaller components as possible are fabricated in the factories. In the most extreme case, the completed house is rolled off the assembly line to be transported and placed on the site.

In essence, the difference between pre-fabricated system and conventional methods of construction in terms of operation, is the degree of site operation required. In the pre-fabricated system this has been reduced to the minimum and usually confined to the assembly of components, site preparation and foundation work.

However, to achieve these advantages it has been necessary to rationalise the construction operation and component design and manufacture, in terms of the number of components, types, variety, size of components, joints, flexibility in use etc. Each of these factors are vital to the system.

Size of components determine transportability and mode of site handling. Component which are too big may not be able to be transported to the site. If too big, it may require the use of expensive, large cranes on site. On the other hand if the components are in too small a piece, the volume of site work increases, thus increasing construction time and cost. Ideally there should be only one variety for each type of component; e.g. one door size and design. An increase in the component type or variety will substantially increase the plant cost and slow down construction time.

The development of each component and system is very expensive. Hence it is vital that the components and system are flexible enough to be used in as many building design situations as possible.

Dimensional tolerance and quality of workmanship of the individual components must be exact. Without this there cannot be pre-fabrication.

The second characteristic of pre-fabricated system is that they are centrally planned i.e. by a single organisation although they may use products from other companies. This allow the system to be developed comprehensively in an intergrated manner, where the buildings are designed with respect to materials and components, and takes into consideration the entire construction process.

On the other hand, this same process handicaps the system. Pre-fabricated system developed originally as a reaction against the inability of the conventional system to supply the complete range of components and materials which are compatible dimensionally and in use. Hence it becames necessary for companies to develop their own system.

To develop a system requires large investments in research and development and plant installation. A system once developed, therefore cannot be easily changed as it will require further research, testing and plant modification. The system therefore becomes fixed. Because the system is an independent system, it is necessary to set up plants which are very expensive. This ties up the company's capital and limits their range of operation.

The construction process, particularly where large components are used, requires expensive on site plant installations. To recover the installation cost, the system has to have a large number of units to be fabricated. It therefore cannot handle small odd-lot development. Reducing the component sizes to easily transportable and easily handled units can help to reduce on site plant cost. It however increase construction time, since there will be more components to assemble. To transport all the components from the factory to the site may be prohibitively expensive or uneconomical particularly if there is abundant supply of materials nearby for on side manufacture.

The system is a closed system, hence components are not interchangeable for repair or substitute. This can be compared to the motocar industry where to replace a door it is necessary to find the door from the same company and model.

The conventional system on the other hand suffers from lack of any coherent system. Each component has an independent dimension and mode of fixing. The industry is highly fragmented, with no central organisation or force to direct it towards any type of development.

The four operations of material and component manufacture, building construction and design are independent sectors operating through a multitude of small companies and organisations, each producing its own product, service and system. In Malaysia, where the industry is new and still open for development the range of products produced are small. For example, there are no ready made structural system, floor or wall system which can be purchased off the shelves. In the more developed countries for example it is possible to select a reinforced concrete structural system for medium and high rise constructions. Even for components such as doors, it is only quite recently that there have been companies producing standard doors. These however are mainly for the export market and consists of only luxury class decorative doors. For instance, there is no good quality flush door for the kitchen.

This lack of range of material and component has also allowed a wide variety of foreign "system" to invade the domestic market. Although this process helped to increase that product range, they have also created more variations with their "newly introduced system".

In the system which developed therefore, both materials and components are unrelated in size and use. For example corrugated asbestos sheet sizes are not related to other sheet materials. It is therefore extremely difficult to develop an economical wall framing system which combines the corrugated sheets with interior plywood sheets. Similarly, it is difficult to construct a root framing which can double up the use of the roof purlin as ceilling frame. The recommended purlin spacing is not related to asbestos sheet dimensions.

The some applies to the timber industry. Timber stated as 4" x 2" (100 x 50 mm) are smaller than stated., and not all 4" x 2" are the same size. Similarly two piecess of 2" x 2" (50 x 50 mm) do not make 4" x 2". In carpentry work therefore it is not possible to confidently dimension timber tolerances. In most cases the contractor has to check the actual dimension on site or suffer fabricating components which would not fit.

Even for components such as doors which can be easily standardised, they are manufactured in a variety of sizes such as 864 x 2082 mm and 762 x 829 mm. Changing door which is acceptable but to change the height as well would create problems in the wall framing system.

The search for design expression is a universal preoccupation among Architects. In some countries, such as Scandinavia, factors such as severe climatic condition, high cost of construction and cultural values have tended to focus this effort towards better interiors and better finishes. In Malaysia, on the other hand, where the climatic conditions favours open planning, and since the design profession is comparatively young, house designs compete for external expression of forms, and uniqueness of design. As a result, it can be said that each and every house is one — off design. To achieve this, Architects avoid standardised components like the plague and strive almost at any cost for special components. This attitude is further justified by the lack of choise of standard range components. Further it provided the excuse for a wider use of imported components and materials. Place this against the background of poor detailing, bad workmanship and poorly produced components, it provides a never ending woes to the house buyers.

In many, fairly standard, developer-built houses for example, there could be as many as four or five different door and window sizes and bathroom fixtures which do not work, and odd shaped roof which leak. In a typical two-storey terrace house it is possible to find a variety door of sizes, ranging from 3' 6'' to 2' 8''. Personally, I have never appreciated the significance of the differences. I have however found them a nuisance to replace because they have to be specially ordered to fit. Similarly the design of round windows may be aesthetically satisfying but they are difficult and expensive to build and impossible to fix curtains.

It is strange that Architects who have developed and accepted standard layouts such as the typical hotel bathroom layout have never developed nor accepted a typical layout for bathroom in fairly standard terrace-housing, where the demands are actually less demanding. Instead I keep coming across designs where some of the fixtures are not usable.

Considering that bathrooms in typical housing schemes are fairly standard and have only two or three major fixtures (longbath, or water container, sink and water closet) and between two to five small fixtures (shower, tower rail, soap holder, light and toilet paper holder), it is amazing that no one has attempted to rationalise and standardise the design. This I believe can make the design more compact and more economical. In fact there are many other elements in terrace houses which can be easily standardised without sacrificing the architectural expression.

These problems which can originate from building design or component and material design, serve only to compound the contractors problem. The contractor has to deal with assembly of component, fabricating himself and insitu construction. The problem of coordinating the material handling and installation by the various trades is by itself a major management problem. This happens because both the design profession and material and component manufacturing sector exists independently from the contractor.

This impression may not be true of the whole of the building industry or even the housing industry but it is certianly true of most of the schemes that I have visited.

Comparing the two systems, therefore it may be concluded that the conventional system suffers from lack of any consistent approach to component, material or housing design. The prefabricated system however suffers from its closed nature. Yet, it has many potentially excellent ideas. As each system stands, neither is making much headway. The pre-fabricated system, after half a century of development is still being questioned. The conventional system will probably continue to plod on.

Recognising the potential of the ideas used in pre-fabricated housing, it is proposed that conventional housing system should seriously consider the use of some of these ideas particularly on standardisation of components. Standardisation as an idea is often associated with boring, uninspired, repetitive designs. Since the idea was first proposed, Architects have expressed strong objections. The very idea of being allowed to designwith a few standard components is against all principle of creativity. However, this is not the intention of standardisation.

The proposed system recognises that the existing free for all approach is not to anyone's benefit. The idea therefore is to rationalise component sizes to a meaningful range, sufficient to allow choice but few enough to allow the use of mass production techniques. At present, there is no agreed range of door sizes for example. In the proposed standardisation, the range of door sizes would be rationalised and reduced to a few meaningful sizes. The same can be done to other components such as windows, and even bathrooms. To make full use of the system it is necessary to extend the present available range of the standardised components, to wall panels, structural system, staircase, and floor system. For the system to be workable component dimensions have to be coordinated using an agreed module.

A module is a unit of measure. It could be of any agreed dimension; 50, 100, 120, 200, 230, 300, or 500 mm etc. Once a dimension is accepted as the module, all components are manufactured in dimension which are multiple of the module. Using 100 mm module, for example, door width will be 800, 900 or 1,000 mm. The choice of the module is therefore critical, because by its very concept, the basic module does not support any other dimesion smaller or larger than itself. Debates which take place about the module usually follow a fairly set line of argument. Architects usually insist that the module be kept as small as possible to allow greater design flexibility. Manufacturer of building components however prefer the module to be as large as possible as this helps to reduce the multiples of component sizes required.

The idea of using a module and modular coordination is not new. The traditional Japanese house have been using the tatami as a design and construction module for a few hundred years. In modern architecture, the idea came in together with the pre-fabricated system of construction and the modern movement in architecture. The debate as to the best module has therefore been going on for also quite sometime. Interestingly enough by 1960 the 20 or so countries, such as the United States, Britain and France which individually have set out to debate on the most acceptable module, have all chosen either 4" for countries using then imperial method of measurement, or 100 mm for countries using the metric system.

The benefits of the system are many. For the Architect it could mean a more disciplined design and less search time and verification time for exact catalogue dimensions. For some of the components it would mean less detailing required. Construction wise it means less messy details. Precious drawing office time could be used in more judicious selection of component or properly detailing one off components. The assumption here is that no matter how much standardisation is forced on, there will always be one-off designs for those who can afford. For the general public however, it will be designs using standardised components. Just like the motorcar industry, while the public in general buys off-the shelves, Fords, Toyotas and Fiat, there will always be some who insist on th Rolls Royce and Ferrari.

To the component manufacture it means a smaller range of components to manufacture or fabricate. This means there is less types of stocks to be stored and organised and less shortage space needed. There should also be less time spent setting the machine and organising production. Equally important manufacturers can produce and stockpile components during slack time rather than wait for the offers to come in.

To the contractor, standardisation of components can speed up construction. At the tender stage it would be easier and quicker to preprare estimates. The process of insitu fabrication of components and fabricating of special components would be greatly reduced to mainly handling and assembling of ready made components. Constant handling of standardised components can familiarise the workers with the system and help speed up construction. Even in cases where components are not available it would be much simpler to decide on alternatives.

Under the system it is possible to manufacture combinations of components such as a complete bathroom units and kitchen units; thus allowing faster on site assembly and better quality components.

Like the prefabricated system, to get the most out of the standardised components, greater attention has to be given to component detail and dimensions, thus forcing the industry as a whole to focus its attention to a much neglected aspect of construction.

In essence, standardisation and the consequent reduction of component range bring the industry towards fuller industralisation, the use of industrial production techniques. As concept industrialisation and standardisation are mutually dependent. Although it can be argued whether standardisation makes industrial production technique possible or industrial production techniquen forces products to be standardised, the two are closely linked. With a smaller range of each type of component to be produced, it is possible for manufacturers to streamline and improve productions.

The standardisation of components such as doors and windows can have a chain reaction on other components such as door and window frames, metal grill and curtain rails, timber sizes and glass panels. The benefits therefore extend beyong the specific component manufactured, into a variety of trades.

In a developed system, the effect is similar to having an open instead of a closed system of pre-fabrication. It allows enterprising developers and individuals to select and combine components to form a variety of semi-pre-fabricated system. The difference with the present pre-fabricated system is that the system is open, allowing components to be interchanged, either for repair and maintenance or extensions. This idea has been in use in many industries and in many countries. In the motorcar industry for example a large part of the components are supplied from a variety of independent components manufacturers. There is not a single car manufacturer which makes all its own component. The range is too big. In many European countries and the United States, it is already possible to select a wide range of compatible structural, floor, wall panel and bathroom units and kitchen units ready for assembly. Charles Eames a famous designer, for example, has designed his home at Pacific Palisade, California, entirely through a judisious selection and integration of standard building components available in the market.

In essence the system enjoys the advantages of the pre-fabricated system but without having to pay the penalty of expensive research and development. Futher, the system is an open system, thus avoiding the restrictiveness of the pre-fabricated system. In short it makes pre-fabrication as it exists today, absolute.

Three factors makes this change inevitable; the current government push towards industrial development, metrication and technological development.

The present push towards industrial development includes the construction industry. This can be seen in the reintroduction of the pre-fabricated system, and the push toward the development of fast tracking techniques, The climate is therefore ripe for the building industry to further industrialise.

The current metrication exercise can be viewed either as a process of paper exercise to convert imperial measurements into metric or as a process which involve actual adjustment of component sizes. The 4'' x 2'' timber of example can be either dimensionally converted to 101.6 x 50.8 mm without any change in the timber size or to convert and change the timber size to a more meaningful dimension of 100 x 50 mm. Similarly in the case of doors, the option is either to use the convreted figure of 2082x 864 mm (6' 10'' x 2' 10'') or a more meaningful dimension such 2100 x 950 mm (6' 105/8'' x 2' 93/8''). The problem with the odd dimension is that it is extremely difficult to cut timber to exactly 101.6 mm or to make an exact door width of 864 mm. For metrication to be meaningful it is necessary to rationalise existing dimensions to a set of meaningful metric dimensions. Metric dimensions arrived at directly from imperial measurements are not convenient dimensions to use and can give rise to serious miscalculations.

More significantly, the whole idea of changing to metric dimension is to get rid of all the odd numbers governing all sorts of measurements, into a series of decimal divisions which are more convenient to calculate and work. Metrication therefore is not paperconversion of components but involve the actual adjustment of components to make them easier to work. This means that machines have to be adjusted in order to produce metric components. Since changes is inevitable, it would be a great advantage to adjust these components to a modular dimension. It would be killing two birds with one stone.

Since the industrial revolution, technological development have all pushed for a greater use of industrial production technique. This has taken place in all industrial sectors including the housing industry. The question therefore is not whether we should or we should not change but rather whether we plan the change or allow the change to occur unplanned. It is the contention of this paper that Malaysia which has the opportunity for change should do so, now.