Northumbria University Architecture Portfolios

BOKLOK MASS CUSTOMISATION
HOUSING TYPOLOGY FOR WORLD MARKET

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Fig 1 Front cover

View of Boklok Housing Gateshead

1.Project Details

Principal Researcher	**David Morton**
Title	**Boklok Mass Customisation Housing**
Output type	**Housing System**
Curator	**David Morton**
Function	**Homes**
Location	**Various**
Practical Completion	**10,000 + units in multiple completions**
Client	**Ikea**
Co-exhibitors	**None**
Budget	**Estimated Market Value £732 400 000**
Support/acknowledgements	**Ikea and Skanska via joint venture BoKlok AB**
URL	**www. northumbriaarchitecture/research.com**

2. Description

Description

The BoKlok housetypes are an architectural approach to resolve the issue of affordable housing typologies that can be universally constructed in any location around Europe. The approach aims to ensure the advantages of mass customisation but allowing for the additional benefit of user customisation. The products designed, produced and delivered to IKEA stores is based on needs, demands and selection criteria of their customer base. The products sold within the stores are developed from the initial idea to product launch in house involving economic, technical and market driven factors derived from analysis of the companies' clients and customer base. This approach allows the company to learn from its customers' needs and buying behaviour and predicting to some extent, the potential needs and requirements that may well occur in the future. This is analysed and structured through use of both the Manufacturer-Active and Customer-Active Paradigm. The Manufacturer-Active paradigm (MAP) and the Customer-Active Paradigm (CAP) were originally defined by Eric von Hippel in 1978. These paradigms explain a structure of opportunities that could be utilised by an organisation that arise from the market the company supply, for generating new ideas with the customers input and feedback from the initial stages of development. Customer feedback can create better market intelligence that can increase market strength in the short term, followed by market predictions in the long term.
This study sought to deliver a mass produced housing system that could also deliver a high level of customisation. Historically housing that has been mass produced to ensure affordability, has removed a high level of customisation to ensure that the final costs were controlled.. The move away from traditional methods of delivery and a shift in the procurement of the design for such housing typologies.

3. Statement of Significance

Fig. 2 Boklok Units in Gateshead Tyne and Wear

(i) The BoKlok housetype has been seen my over 10million people across Europe, with over 10,000 completed housing units sold and occupied to date, having a current market value of over £732M.

(ii) Research from this housing typology has been dissemination across Europe including Keynote Opening Speech from the PI on the project, at the Inaugural European BIM Summit in Barcelona, Spain in 2015.

(III) Further dissemination has occurred through Magazine and Journal Articles Morton, D (2014) Sum of the Parts: Leveraging BIM to achieve effective delivery of mass customised housing. International Journal of 3-D Information Modelling, 3 (4). pp. 36-55. ISSN 2156-1710 Published by: IGI Global.

5. Statement of Originality

Fig.3. The BoKlok house type is sold to the public via IKEA stores allowing for a different approach to purchasing. All developments hold an event at the nearest IKEA store. All prospective buyers then attend and all names are put into a 'draw' these are selected and those drawn then have the option of purchasing a BoKlok house. This is to ensure fairness throughout the process, from purchase to completion.

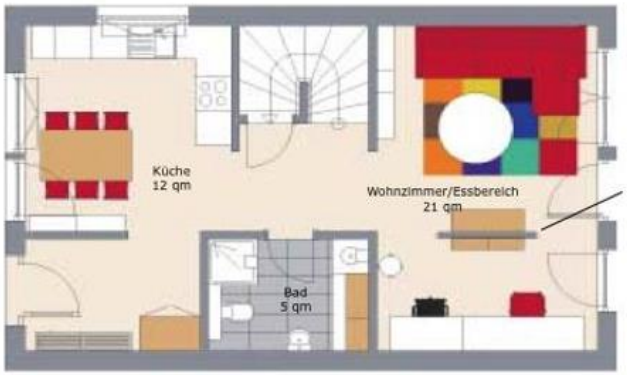


Fig 4. The BoKlok house type at ground floor has a plan form that minimizes the circulation floor area allowing for greater usable floor area for 'living' spaces. The relationship of living space to circulation space is improved by 22% over similar house types of comparable floor area. The wet spaces are retained in one define 'room'. This room affords the dwelling a ground floor wc and shower room, combined with a utility area.

(i) The systems proposed by this research are limited but provide a platform from which future mass customisation via a panelised system approach to the external and internal structural elements could be used to realise a cost effective and rapid build approach to housing design and construction. The current delivery system of affordable housing does not involve the end user at an early enough stage, with very little input and option for customisation. Therefore to capture potential market share, panelised approach to design and build was explored. The use of greater standardisation will allow the end user to directly assess and select each element of the home. This creates a true mass custom model, in a market that currently dictates a set design with very little option for modification other than fixtures and fittings. The aim of the research project was to develop a constructional approach that vastly reduced the number of components in any single housetype within the range offered by BoKlok. It well documented that a standard house contains on average 3000 components.

The originality and value of this research stems from the adoption of panelised approach in the design process and the systematic approach in the details that is possible to reduce the number of components in the BoKlok house type by 70%. In addition to this, the use of a semi-open system reduces the concern over dependence on one supplier or manufacturer of parts in the future. The drawback of this flexibility was the high levels of co-ordination to integrate all of the possible elements seamlessly. The extra overall costs of this flexibility was countered in the final design by the use of service walls and shared service routes throughout the dwelling, that could be shared and utilised with all variations of internal layout and external form. Such design framework follows the work of Alvaro Siza, who in 1977 foresaw the need for mass produced customisable housing. Siza developed the SAAL system, which followed a set of design rules allowing the house design to be extended and modified within a set of rules.

Image.6. The BoKlok house type at first floor has a plan form that follows the minmised circulation format of the ground floor. Depending on the house type, the upper floor contains either two or three bedroom spaces (Molna and Alsten – 2bedspaces, Jarnbro – 3bedspaces). The location of the main bathroom is directly over the wet room on the ground floor. This allows both floors to share a common service wall. This contains all vertical services for the dwellings.

4. Statement of Rigour

(i) Rigorous research undertaken across varied fields of knowledge, disciplines and architectural methods (Groat and Wang 2002); its synthesis and assimilation of the given academic field into specific drawn and modelled interpretations and influence upon the broader design process. These methods include extensive prototyping of component parts, surveying or individual sites and mock-up of house interiors.

(ii) Extensive computer-based research and 3D modelling, through drawing, and making that worked alongside the manufacturing process.

iii) Extensive research into IKEA's product lines in terms of their size, weight, assembly and how these products and the Boklok housing range worked together to provide the market with a compatible and workable product

6. Research Context

Description

The BoKlok housetypes are an architectural approach to resolve the issue of affordable housing typologies that can be universally constructed in any location around Europe. The approach aims to ensure the advantages of mass customisation but allowing for the additional benefit of user customisation. The products designed, produced and delivered to IKEA stores is based on needs, demands and selection criteria of their customer base. The products sold within the stores are developed from the initial idea to product launch in house involving economic, technical and market driven factors derived from analysis of the companies' clients and customer base. This approach allows the company to learn from its customers' needs and buying behaviour and predicting to some extent, the potential needs and requirements that may well occur in the future. This is analysed and structured through use of both the Manufacturer-Active and Customer-Active Paradigm. The Manufacturer-Active paradigm (MAP) and the Customer-Active Paradigm (CAP) were originally defined by Eric von Hippel in 1978. These paradigms explain a structure of opportunities that could be utilised by an organisation that arise from the market the company supply, for generating new ideas with the customers input and feedback from the initial stages of development. Customer feedback can create better market intelligence that can increase market strength in the short term, followed by market predictions in the long term.

Aims and Objectives

The research aims to examine the implications of designing constructional systems using open and closed panel approach for the structural envelope of building. The principles are described in figure 2. These principles follow commonly accepted ideas about spatial requirements for dwellings, beneficial combined use of spaces, the minimising of circulation space to ensure maximisation of living area and increased use of core servicing strategy that ensure fast and cost effective solutions during the construction process. The only two conceptual additions to these ideas is the concept of dynamic, and interchangeable panelised system that uses smart joints that allow for configurable internal and external walls and partitions that allow for speed of construction, affordable material and constructional costs but also allowing for user led customisation. The second concept is that of servicing cores that follow the automotive approach to 'loom and core' plug and play services both in terms of location(s) in the dwellings and the physical manifestation of these within the building fabric.

The objective is to build prototypes that examine the feasibility of applying these principles to the design and occupation of the housetypes. The investigations address this objective in the context of new construction. It is possible to imagine applications of mass customisation to housing typologies where panelised systems afford increased affordable approaches to housing design that also offers maximum customisation. The result of this research project into panelisation approach has resulted in the development of an advanced housing system now used by IKEA and Skanska in a joint venture called 'BoKlok' with over 10,000 completed dwellings to date.

Modularisation of panel system creates internal fit out options for customer customisation whilst retaining speed of build in factory controlled conditions.

7. Research Questions

Image.5 Skanska and IKEA together

The project aims to solve

1. What are the aesthetic, spatial and typological consequences of producing a mass customisation approach to affordable housing,

2. How can this typology afford fast construction times on site, with the aim of a 24 hour initial construction sequence.

3. How can the technical challenges of the project be overcome and what exemplar technical strategies can be generated for the broader use of deployable in other housing typologies?

Questions

The following questions have led the investigation: What are the aesthetic, spatial and typological consequences of producing a mass customisation approach to a panelised system build for affordable housing?
The underlying paradigm that architects have persistently endeavoured to solve is the standardisation of components and the systemisation of the construction process, the combination of which was seen as the panacea to affordable housing. The primary issue with this paradigm in past endeavours was that it created minimal customisation. Mass production is not new in many not construction industries, such as motor vehicle manufacturing. Historically, the concept of mass production in this industry was created by Henry Ford, who mass produced the Model T in 1910. The famed quote of Ford at this time was that you could purchase a Model T in any colour as long as it was black. Many researchers' have taken this as to offer one colour was inherently cheaper to produce. The actual reasoning behind this choice was the fact that black paint was faster drying, so the production line could be operated at faster rates.

Fig.6 Ingvar Kamprad (IKEA) and Melker Schorling (Skanska) together in 1996 at the forming of the BoKlok Company in Malmo, Sweden.

The original BoKlok logo presented in Malmo, Sweden in 1996. Bo meaning 'Live' and klok meaning 'Smart' BoKlok meaning Live Smart.

Fig 7 The BoKlok house type is sold to the public via IKEA stores around Europe. Potential customers going to a local store and viewing the dwelling prior to purchase. The 'show homes' are constructed in the carparks of the stores and moved between stores once the local schemes are sold out. (This example depicts the IKEA approach to showing customers what spatial and storage options you could achieve in the dwelling).

Origin of Study: The Panelisation Concept

This study has its origin in the concept of mass production for the affordable housing market. The concept on mass production has been discussed earlier in this paper, with the concept of the production line from Henry Ford in 1910. During the 1970s the new wave of production began with Toyota using the concept of so called lean production. This concept took the original production line methodology and removed the waste from the process. This so called waste was a combination of time and cost in the processes that serially followed on to each next stage. The solution in the main was to develop just in time delivery procedure. These procedures minimised storage and the need to collect materials and deliver them to the production line. Instead, the materials or components would be delivered directly to the factory and taken straight to the location needed to build the final product. This process was developed further to optimise the time and cost, via the removal of element of the production process as a pure linear process. The product was now delivered using smaller teams gather around the product to complete smaller combined tasks. The repetition and variation of tasks created higher productivity amongst the workers.

The Study and Methodology

This research is undertaken through design in the form of iterative studies of 1:1 prototype fabrications of components and whole buildings. Purpose and Scope of this research was to capture how the use of off site manufacturing allows for higher quality and faster construction via mass customisation producing high quality affordable housing typologies. The justification behind this research originates from the need for architectural industry to face the current challenges that off site manufacturing and panelized system approach to housing provision. The adoption of off site imanufacturing in lieu of on site construction is seen as a panacea to lean productivity and efficiency in the housing ndustry and has many advantages that should be embraced in order to achieve advantages in building design and the processes that are needed to create those designs. From such an approach and embracing off site methods of manufacturing, the aims of creating more affordable housing typologies is exponentially achievable. This research aims to detail and explain the systematic evaluation of the 'BoKlok Housing typology'. Allowing for

'...the materials or components would be delivered directly to the factory and taken straight to the location needed to build the final product. This process was developed further to optimise the time and cost, via the removal of element of the production process as a pure linear process.'

Fig.7a. Citrohan House (1929) Le Corbusier – Commonality of components

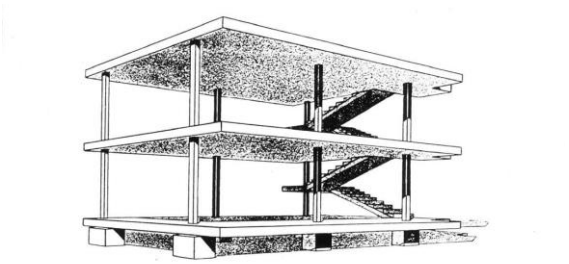


Fig 7b. Domino House (1914-15) Le Corbusier

Fig.7c Citrohan House (1929) Le Corbusier – repetition of singular elements

Image 7a and 7c (top and bottom) The systematic approach of design and component and panel of construction first appeared in 1929 with the Citrohan House by Le Corbusier. Using a rigid format of construction that afforded fast and cost effective construction techniques

What is affordable housing archetype?

The housing market in the UK today delivers very little choice at the lower price ranges. This occurs from a number of factors. Many house builders wishing to construct a development of 25 or more dwellings would employ the standard convention of utilising a small number of house types that would be repeated around the development. Such an approach is commonplace and allows for cost efficiencies at all stages of the design process. From the initial design stage, the convention of designing a small number of dwellings that can be repeated throughout the site reduces the potential of large amounts of information for the individual dwellings. Focusing on a small series of dwellings allows for this information to be vastly reduced. This reduction brings with it efficiencies in both time and cost. The construction phases also benefit from this reduction in variation, as the purchasing of components, fixtures, fittings and general materials are often replicated throughout the small series of dwelling designs to optimise cost efficiencies. The repetition of both design elements and material choices allow for lower overall construction costs and therefore more affordable housing for the market. However, all of these efficiencies stem from the reduction of choice and the repetition that remove the individuality and customisation of the final product. The result is housing that is mass produced and therefore deficient in the required levels of individuality frequently sought from potential buyers in this market. The aim of this project was to test the accepted norm that mass production in housing cannot also achieve levels of customisation that limited today's affordable housing market. Secondly, it aims to explore how a panelised system approach can be used to increase levels of affordability and rapid construction times by moving from construction to a manufacturing format that move from the considerations and issues that are directly controlled by the site conditions As the market segment for low cost housing increases, the clients of these housing types are becoming more accustomed to dealing with an increasing number of the tasks once deemed the role of the professional. Although this trend stems from the reoccurring need to retain a low initial costs ceiling in relation to the need to retain overall control on the smaller budgets such projects are constructed within.

The paradox of mass customising has considerable potential impact on the affordable housing market. Customisation with only minimum component options is somewhat of an architectural panacea but also a paradigm. The level of customisation adds to the richness of possibilities for the home owner, whilst the increasing levels of customisation require increased levels of complexity. These are common constraints of a mass custom approach. The system takes its name BoKlok which literally translated means 'live smart' from its ability to be changeable and react to changing needs. It is a system that allows for a complete structural envelope for dwellings to be created from a timber panel system that can be constructed in either open or closed format. Timber panel systems on the market today are of these two derivatives 'open' or 'closed'. As the names suggest, they differ in the fact that one of the panel systems is manufacturer without an internal closing element (usually plasterboard or similar). This allows the dwelling to be constructed from the panels whilst retaining the flexibility of changes being made during this programmed construction period. Such changes may be altering plug socket positions, heating pipes or other services. Whereas the closed panel, as the name suggests is fully completed in the factory, with all socket and switches located in position on the internal board of each wall panel. The latter system creates a faster mode of construction, whilst the former creates maximum customisation.

Image.8a (top left and bottom left). The BoKlok standardised elevational panels have been located in external locations that afford ease of removal for access to swap out 'podularisation' or wetrooms and kitchen areas (the areas most likely to require refurbishment

Most timber panel systems have a large variety of panel widths, and a small number of panel height variants. Thisnumber of options is controlled in the BoKlok system, never the less the system is very versatile and can accommodate a large variety of dimensional tolerance in variations from the panelised approach. The overall build up of each panel has been design to allow for the need to adapt to a variety of external cladding options. This has been achieved by coordinating all of the panel widths to brick sizes as a base dimensional size. This allows the system to co-ordinate with a large array of external materials, from brickwork, rendered block, timber cladding and rain screen systems. The system allows for eight external panel types. Three of these are full height wall panels, the remaining five are variations of infill panels the accommodate options for window positions and arrangements within the façade.

Image.8b. The BoKlok house type shares a standardised format for elevational treatments across all house types. These areas of the façades allow for customized material changes dependent on location of the proposed scheme. The material choice can then be amended to suit local planning requirements, but retain set areas for 'change' that have be detailed to allow for flexibility of fixings for different material choices of rain screen.

The panelised system approach: An envelope design methodology that is established via interior spatial conditions.

The concept of the panelised system approach to the BoKlok housetypes focused on the cost effective balance between the external surfaces of the interior spaces to yield the most flexible spatial core with the minimum exterior surface area.
The affordable housing market has a number of key drivers that dictate size, layout proportion and types of materials used in the delivery of housing in this sector. The methodology for BoKlok Project was to create systems for internal layout and exterior construction that achieved both Code for Sustainable Homes and Life Time Homes accreditation. The design approach for the BoKlok Project does not align itself with the recognised approaches of panels system in general, that of production, semi-custom and custom. The concept of the panels interconnectivity and flexibility affording the system alignment with the mass-customisation approach or mass custom design. This is the result of three basic design elements for housing; the overall volume, exterior and interior as stated by Noguchi (2001).

The utilisation of daylight was a important consideration for the design. The concept originated from the Scandinavian housing market, where the internal spaces are design to maximise the extent that daylight penetrates the internal volume of each room. The term 'leading to light', which also originates from Scandinavian home design, is given when the architect positions the internal doors and fenestration on the external envelope to align directly. This alignment affords the end user the view of external spaces surrounding the home and emotional connection with the surroundings whilst still remaining inside the home as they open the door and enter a room. This direct visual reference with external space is further enhanced by utilising higher ceiling heights for all internal spaces. In the UK the standard ceiling height is 2400mm, whereas the

ceiling height in many Scandinavian homes is 2700mm (+/- 50mm). The use of prefabrication was exploited to minimise onsite waste and improve overall quality of the final product. When logistics, planning and design drawings have been completed and agreed prior to commencement, then construction times can be reduced by 20-30%. The research project is to be commercialised in 2014 and once the construction team have become more familiar with the processes of the Chameleon House system is is envisaged that the team will complete the timber frame shell of 2.5 houses per day, with completion of the roof elements within 8 days. Standardisation of the building components (notably the windows and doors) have been exploited to minimise overall cost per dwelling. Research carried out within the Chameleon House Project suggests that development of over 100 homes, using this off site manufacturing method, can achieve cost savings in excess of 8.5%, and reduce the overall construction programme for traditional UK building techniques from 21 months down to nearer 12 months, whilst also increasing the useable area of the site by 33%.

The project's findings and future considerations

'Quantitative advances of this magnitude create qualitative shifts', Davis (1987). These shifts are currently being used to engage with problems of leaner and more cost effective segmentation of the design components, in order to deliver better results. However, such advances have and will lead to better constructional detailing, increased quality at a level of affordability not previously achieved. 'Quantitative advances of this magnitude create qualitative shifts', Davis (1987). These shifts are currently being used to engage with problems of leaner and more cost effective segmentation of the design components, in order to deliver better results. However, such advances have and will lead to better constructional detailing, increased quality at a level of affordability not previously achieved.

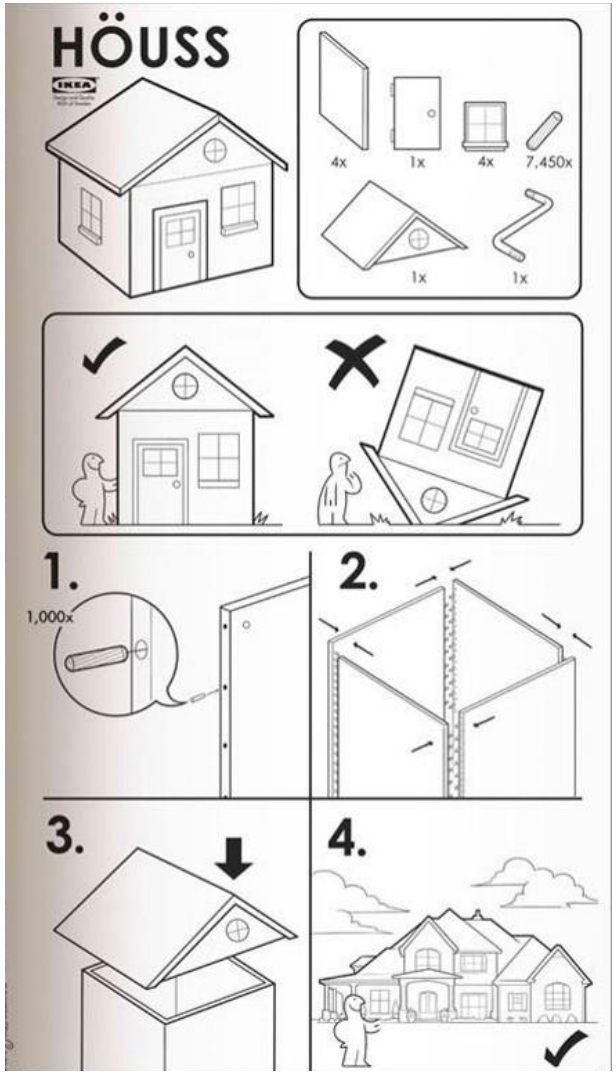


Fig 9. The BoKlok house type was launched via IKEA stores across Europe. The idea of a panelised house was captured in the image above, which replicates the IKEA flat pack instructions. The initial adverts also stated that 'no allen key is required' another well known constructional icon of the IKEA flat pack furniture.

Comments and future implications:

The research has also indicated that such a system can be readily implemented to create mass customisation, however the drawback being the requirement of the designer to create the system and sub-systems from which the design will evolve. These systems have many layers of sub-systems which all require testing to ensure they yield varied solutions that are compatible. The BoKlok house types have variations, but these are currently limited. Considerable investment would be required to create a greater number of rules to enlarge the framework of differentiated solutions. The systems proposed by this system are limited but provide a platform from which future mass customisation could be used to realise the desires and expectations of home buyers or prospective self builders. The current delivery system of affordable housing does not involve the end user at an early enough stage.

Therefore to capture potential market share, mass custom approach to design and build should be introduced. The use of greater standardisation will allow the end user to directly assess and select each element of the home. This creates a true mass custom model, in a market that currently dictates a set design with very little option for modification other than fixtures and fittings. The future markets may demand far greater customisation, lifestyle.

Project Stages:

Key Stage 1: The initial development stage will require the assessment of current manufacturers panelising systems to ensure BoKlok House is able to use standardised components throughout. This will include the often overlooked problem in MMC (Modern Methods of Construction) that of cutting waste and wastage.

Key Stage 2: The design stage will require the development of the system for the BoKlok House via CAD and BIM (Building Information Modelling). Using Revit will allow the construction complexities of the panels within the system and their componentry to be assessed and refined.

Key Stage 3: The design testing stage will require the

BIM model of the BoKlok House to be developed further in terms of assessing its sustainability credentials. The model was tested via the BIM model by internal team members for the project. This will enable enhancement of the design to ensure Code Level 5 and working towards level 6 to be 'achieved' and assessed prior to any actual dwellings being constructed on site.

Key Stage 4: The commercialisation stage will use the model of the BoKlok House to test interchangabliity of the panels and construction sequencing of the proposed system. The model will enable testing before the project / system is externally released.

Design: The utilisation of day lighting has been a focus for the design. Space standards have been developed with regard to Life Time Homes criteria.

Cost: The design team is mindful that for costs to be truly optimised outcomes have to be scalable. A one-off house on a site can be delivered affordably, this is very different to delivering fifty similar units. For a bespoke one off house our research suggests that rainscreen/ external thermal wall insulation system may offer the most cost effective result, however, once a development reaches the size of roughly 35-40 homes then prefabrication becomes the most cost effective construction route. Studies have shown that developments of over 100 homes can achieve cost savings of over 8.5%, and reduce the construction programme for traditional UK building techniques from 21months down to nearer 12 months. Studies have shown that developments of over 100 homes can achieve cost savings of over 8.5%..

One site of about 100 homes the first home may be ready within 100 days after which point the hand over rate is four to six houses per week. reduce the construction programme for traditional UK building techniques from 21months down to nearer 12 months, whilst also increasing the usable area by up to 33%.

Commercial realisation is also worthy of consideration. One site of about 100 homes the first home may be ready within 100 days after which point the hand over rate is four to six houses per week.

Therefore to capture potential market share, mass custom approach to design and build should be introduced. The use of greater standardisation will allow the end user to directly assess and select each element of the home. This creates a true mass custom model, in a market that currently dictates a set design with very little option for modification other than fixtures and fittings. The future markets may demand far greater customisation, lifestyle.

BoKlok House Types: Pragmatic spatial and construction approach: allowing affordable housing designed for the many people

The planning and special concepts for the BoKlok housetypes follow traditional aspects of locating the building by allowing the user(s) to continually relate to the external context. This is controlled via location of windows in the external envelope and how each space internally is entered affording an immediate view of the external environment. These concepts are outlined below.

Flexibility of internal space

The need to create affordable house types tend to result in low overall room square-metre rates per room as often design is secondary to the strict conventions of many housing providers. The development of the floor plan to allow for the complexity of services and spatial needs within a restricted footprint per dwelling was the focus of the BoKlok House project.

Open plan environment – inclusive interactive living space

The initial development of the circulation and occupation of each room in terms of function was considered in detail within this research and the BoKlok housetype. This research resisted the tendency to create an open plan format, but one that would afford definition of spatial use and an overall clarity of the dwelling without compromising its aesthetic and spatial qualities.

Leading to Light

The Swedish tradition to 'lead to light' is embedded within the BoKlok housetypes and is used in both the plan format and the elevational treatment and fenestration locations. As the user enters each room a view of the external landscape is viewable. This is achieved by locating the doorways to each internal space opposite a window in the external envelope.

Internal dimensional Co-ordination

The spatial co-ordination of the dwellings is related to the standard unit size used for all IKEA furniture, that is the dimensions of a 'Billy' bookshelf. Therefore allowing a co-ordinated internal layout for each room to afford the fitting of any IKEA item from the storage and furniture range.

Maximum storage per square metre of floor space

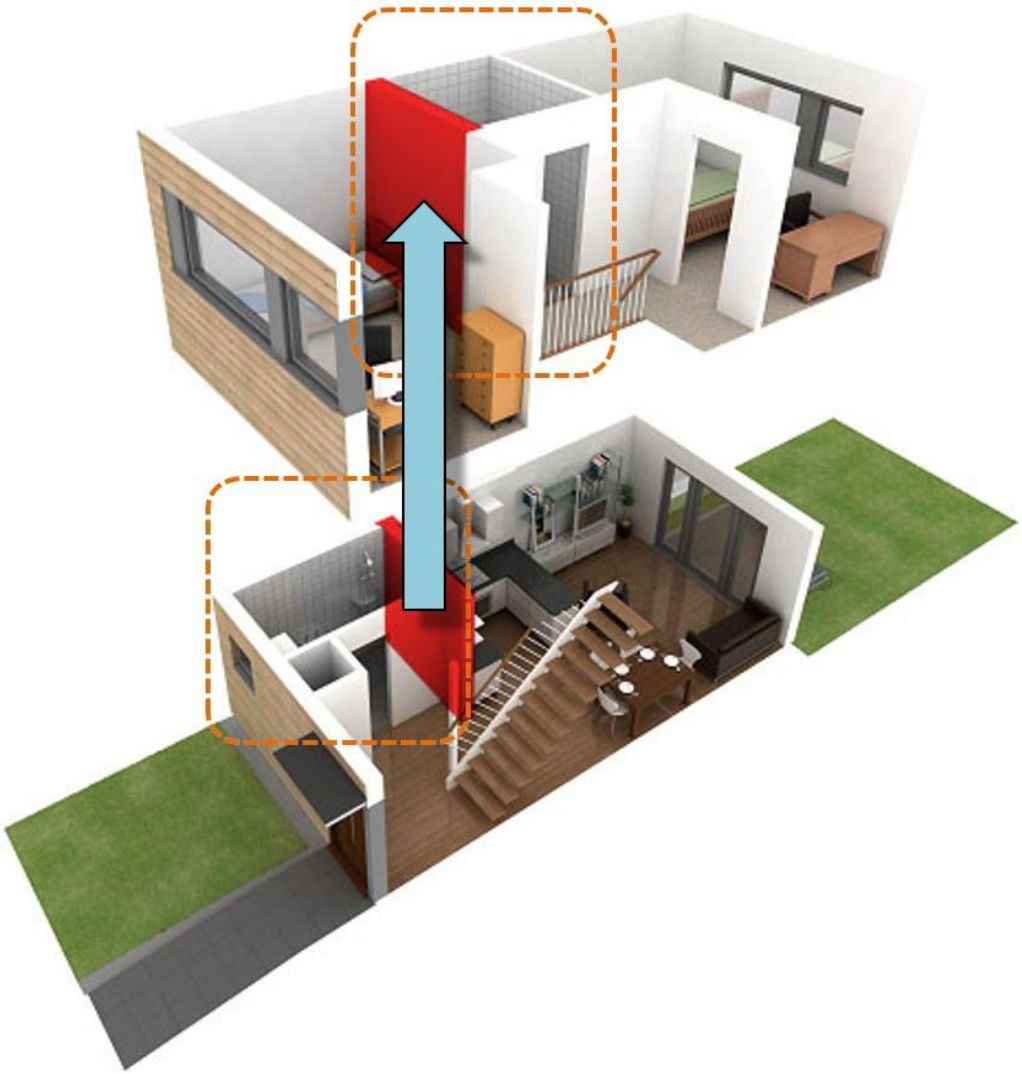
The zones between rooms, below the straight flight stairs and above internal doors are all located and of a size that affords maximum storage potential for each square metre floor area. Reveals to external doors and behind internal doors has been dimensioned and sized in terms of depth to allow maximum area for storage units.

Fig 10 The BoKlok house 'Service Wall' concept indicated in red in the above diagram is shared by all of the BoKlok house types. This sharing of the service wall ensures that all plots and site works relating to foundation slabs is completed with minimal error. As there is only one location for the same element there is a vastly reduced potential for error. This repetition also allows for rapid on site programming of repeated construction work.

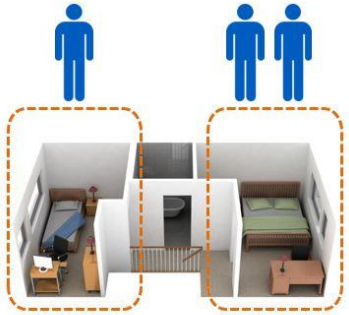
Shared internal spatial platform for BoKlok housetypes – Molna-Alsten-Jarnbro allowing Unit-isation of internal planning for each dwelling typology to maximise living space and minimise circulation space.

Fig 11 The BoKlok house type has been designed for a single point of entry for all services with only one 'pop up' location for all services. This reduces the average number of service locations for a comparable dwelling by 75%.
A single short run of ducting within the slab directly connects all services to the shared service wall.

BoKlok Concept: Single Point Service and Circulation



BoKlok Service Wall Concept



BO KLOK Molna

BO KLOK Alsten

Construction:

The use of prefabrication was exploited to minimise onsite waste, improve quality. When logistics, planning and drawings have to be done up front then construction times can be reduced by 20-30%. Once a construction team is familiar with the processes the use of prefabrication means that a construction team may be complete the shell of 2.5 houses/day and the roof complete within eight days per house, Standardisation of building components (notably the windows and doors) has been exploited to minimise costs.

External walls:

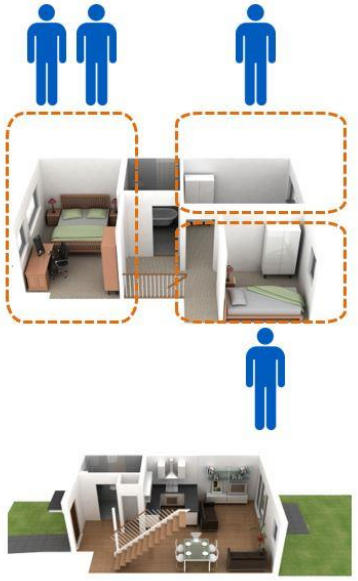
Timber frame to have plaster board pre-applied (Fermacell type as this is more robust and resistant to site damage whilst offering better acoustic properties), all air barrier membranes are to be factory sealed off site. At capacity, in terraced format, based upon case study documentation, it would be possible to complete the shell of the façade for 12 number, 2 storey houses per day (front and rear.)

Services: The design intent was that only gable wall was to receive a service void. All other electrical services penetrations to the thermal envelope are to be avoided. Window and door frames pre-installed within the timber frame cassette unit. To avoid the risk of transport damage and cracking the triple glazing is to be installed at a later date.

If prefabricating allow for movement and racking during transit 4 person team can install 24 wall elements in four hours

Internal walls: Non-load bearing internal walls are to be utilised as this i) minimises the critical path for the construction process ii) aids future flexibility

Internal walls: Fabricated from timber cassettes, as they reduce construction time and offer good acoustic qualities (32dB to 36dB), fire protection, whilst avoiding the need for wet plastering; thus reducing the construction programme even further. One operative can install up to 50m2/day.



BO KLOK Jarnbro

Fig 12 The BoKlok house type shares 'cross platform' servicing walls and minimizes the vertical and horizontal routing of all cables and pipework. These are located within the closed panel system prior to delivery to site. An example of this plug and play type approach is the time taken for wiring on site for the BoKlok house types, which is 70% faster to completion when compared to to similar house types.

BoKlok Concept Common Panel Platform and minimal Overall Components (70% reduction to comparable systems)

Fig 12a. The BoKlok house type shown above is the Molna, this is the 'base unit' for the larger dwellings within the BoKlok house type range. The planning and location of primary walls are shared with the larger house types. The minimal changes to this base format affords the option of larger dwellings with minimal constructional and manufacturing stages, reducing costs and time to build different house types for a proposed site.

IFig 13 The BoKlok house type shown above is the Alsten, this is the mid sized dwelling with a 2b3p (two bed three person) format. The bedrooms are larger in this particular house type. The ground floor living and dining spaces are also larger and allow for greater storage options and flexibility of space.

Fully engineered roof cassette system is to be utilised. Our research suggests that 4 operatives and a crane to install the roof structure in just one hour; compared to some 26 hours for erecting a traditional trussed rafter. The structure of the roof shall be optimised by having the battens and counter battens preinstalled. Concrete roof tiles and dry ridge construction is to be adopted. Sills, skirting and glazing installed on site A dimensional framework is essential to ensure that the various systems are compatible. The size of a given cassette unit is dependent upon the implications of transportation and craneage The dynamic stresses induced within large units, when transporting and lifting, will need to be considered and suitable "over engineering" will be required. The timber fraction has been adjusted to accord for this consideration. Sequencing and operational issues are of greater concern due to the modular nature of the design. This could result in limiting the size of cassette units so as to allow changes to the installation sequence should this prove necessary

Door sets shall include ironmongery: Using prefabricated door sets is it possible for a two man team to install 80 to 100 per day. Sprayed plaster finish as quick to apply.

In Use: A user guide will be prepared to explain the property to the building owner. During the specification of appliances and equipment attention will be given to the affordances of each item.

3B4P:
Building maintenance has received careful attention. For this reason the MVHR unit has been placed outside of the building envelope. The benefit arising from this is that a social landlord will be able to change the filters without compromising the privacy of the building occupant furthermore a compact floor plan is afforded.

2B3P:
Building maintenance has received careful attention. The MVHR unit has been placed inside of the building envelope in a discrete location at the first floor level. The benefit arising from this is that the home owners will be able to change the filters without incurring health and safety issues that can arise from the use of loft ladders furthermore a compact floor plan is afforded.

Standard Circulation and flexible cores that can be 'pod-ularised' in future developments. Increasing ease of renewing spaces that have heavy use (Kitchen and wet rooms).

Fig 14. The BoKlok house type has created a considerable impact on the affordable housing market, with coverage in the national and international press, radio and TV. See 'dissemination' on page 3.

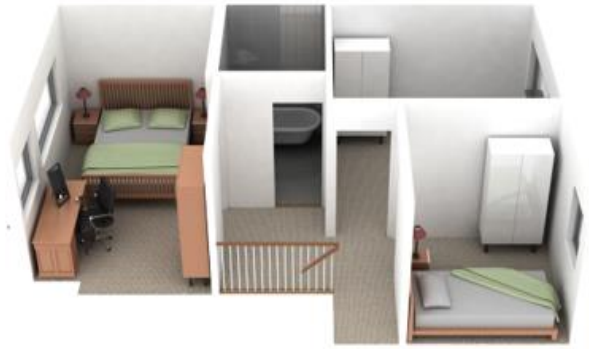


Fig 15 The BoKlok house type shown above is the Jarnbro, this is the larger of the three house types. On the ground floor the living and dining spaces are very generous in comparison to similar house types available. The first floor now allows for the planning of three bedroom spaces. This format is a 3b4p (three bed, four person) layout.

Compliance:

BoKlok housetypes and their associated developments would be required to be designed to conform to:

- UK Building Regulations
- The Passivhaus Standard (utilising the peak load as the design standard)
- The Code for Sustainable Homes (Level 4, towards Level6)

Compliance:BoKlok housetypes and their associated developments would be required to be designed to conform to:

- UK Building Regulations
- The Passivhaus Standard (utilising the peak load as the design standard)
- The Code for Sustainable Homes (Level 4, towards Level6) Biodiversity will be enhanced by:
- Provision of bat and bird boxes
- Utilisation of native flora and fauna

Assumptions:

The over shadowing of adjacent properties will impact upon the design. Based upon the information provided to date.

Fabric

FOUNDATIONS

The 200mm insitu reinforced concrete floor slab, with power float finish, shall form a raft structure using a uniformly distributed load and shall bear upon DPM on EPS insulation (thickness confirmed in PHPP), on 50mm sand blinding, on 300mm hardcore. Recycled aggregates to be from local sources.

EXTERNAL WALLS

Rainscreen on battens and counter battens to form 50mm clear cavity. Central cassette to be formed using two layers 8mm OSB for racking. Larsen truss arrangement to form cavity for insulation (thickness confirmed in PHPP). Fermacell type plasterboard on OSB substrate. Intelligent air barrier membrane behind plasterboard for protection during construction processes. All joints to be taped and sealed (continuous rigid support offered by OSB). Rainscreen to be render finish on cementicious board and Western Red Ceddar.

TIMBER PRODUCTS

CAD and BIM (Building Information Modelling). Using Revit will allow the construction complexities of the panels within the system and their componentry to be assessed and refined.

Either 70% of all timber is to be FSC accredited, or 85% of all timber is to be PEFC accredited. This percentage based claim applies to all timber and composite timber products by volume, specified for key building elements including formwork, structural timber, cladding, carcasing, windows (if timber windows are specified) internal joinery

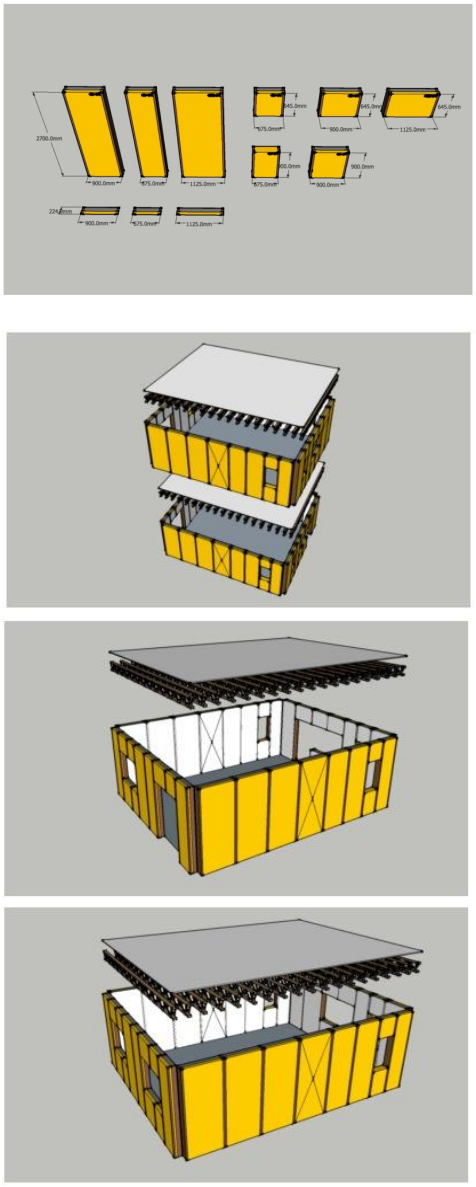


Fig .16 The BoKlok house type panelised system has been considered in terms of unit sizes and location of both doors and windows. There are only two window types used for the external fabric (a 50% reduction against comparable housing systems). There are two external door types (a single and double leaf design). The internal doors share the same single design format. All of these design decisions equate to a considerable reduction in overall manufacturing costs of the dwellings.

(inc. doors, skirtings etc.) Only preservatives with KOMO accreditation should be used. All weathering timber to be vacuum pressure treated where it is structural it is to be Protimised, elsewhere it is to be Tanalised. All timber studwork, joists and rafters are to be formed from low moisture content (<20%) kiln dried timber and is to be made available in regularised sections. The site treatment of timber is to be minimized. The type of preservatives used should be appropriate for the intended function. Non-structural timber to be treated using ProBor Boratic salt preservatives using diffusion treatment. When site treatment is necessary safer preservative treatment methods based on borax salts, acypetacs zinc and peremethrin will be used. Volatile Organic Compounds (VOC) in timber preservatives are to be avoided. Structural timber is industrially pretreated with non-volatile preservatives (copper, arsenic or tin) ready for finishing on site. Timber treatment to be avoided wherever possible CCA, Tanalith-E to be avoided as are vac-vac treatments using Cuprinol and copper based TBTO (Tributylin Oxide).

FIRST FLOOR SPECIFICATION

Min. 300mm engineered timber joists by JJI joists 'I' beams by James Jones and Sons or Masonite, to BS EN 1995-1-1:2004 (TO STRUCT ENG APPROVAL/ SPECIFICATION) at 400mm centres max. Low formaldehyde, FSC approved, 22mm thick Weyrock P5 chipboard flooring to EN300 should be screwed on engineered timber joists. All joints to be glued with as adhesive recommended by the flooring manufacturer.

Alternatively 19mm t&g flooring, or 22mm thick OSB/3 decking screwed and glued to the engineered timber joists

FLOOR FINISH (GENERALLY)

Hardwood strip floor 18mm. Forest Stewardship Council Chain of Custody certification should be sought from timber manufacturer/ supplier.

WALL / CEILING FINISH Water based white paint

WINDOWS

Frame width 130mm max., Sill 140mm g-value: 0.5 Ug: 0.6 W/m2K; Uf: 0.9 W/m2K; Psi-g: 0.03 W/mK

DOORS

Frame width 180mm max. , Sill 270mmg -value:

0.5 Ug 0.6W/m2K Uf: 0.9 W/m2K Psi-g: 0.03 W/mK

BoKlok Concept: family of external panel system for exterior envelope aligns with internal panel system (Kitchen and wet rooms).

Fig 17. The BoKlok house type has been designed with many elements of the design allowing for repetition of service locations and routes. All socket locations have been fixed at agreed locations. These locations can be altered when the open panel system is used. The open panel system leaves the internal element (plasterboard) to be completed on site, allowing for maximized option for change.

Fig 18. The BoKlok Service Wall being manufactured off site in factory controlled conditions. Each service wall uses continuous pipework to primary locations for fittings, such as basins. This a=ensures that only one connection is used per fitting minimising the potential for leaks within the dwelling(s).

STAIRCASE

Prefabricated oak timber staircase by Jeldwen, or similar approved, with closed risers, square newel post and cap, handrail. min 900mm clear width (This clear width should be measured 450mm above the pitch height.) 225mm min going 215mm max rise Where appropriate min 50mm going to tapered treads. Max pitch 42 deg. min 2000mm clear headroom to full length and width of stair. The requirements will be satisfied if in a flight the steps have the same rise and the same going to the dimensions shown in B.Regs Part K Section 1.3 or comply with parts 1.4 & 1.5. Manufacturers/ suppliers of all timber products are to provide Forest Stewardship Council Chain of Custody Certification upon delivery to site. Landings shall be provided at the top and bottom of every flight (min 900mm clear). The width and length of every landing shall be at least as great as the smallest width of the flight (min 900mm clear). Landings adjacent doors should be min. 400mm clear between door and edge of step across the full width of the flight. Proprietary 900mm high balustrade formed using 27mm spindles, from Jeldwen or similar approved, and 100mm dia handrail. Single handrail to be provided to stairs less than 1000mm wide, where a stair is in excess of 1000mm wide handrails are to be provided to both sides. 99mm max gap between balusters. Guardings and balustrade to resist a horizontal force of 0.36 kN/m. Guarding to be designed so as not to be easily climbed. All heights must be checked on site.

Concealed steel brackets, dowelled sections. Where necessary units are to be supplied with panelled sides to form return laminate head and skirting rails. 19mm thick melamine faced moisture resistant chipboard to form 16mm flashgap. 18mm plywood subframe, 17mm moisture resistant chipboard faced high pressure laminate vanity top.

CABINETS & VANITY UNITS

Cabinets and vanities shall be solid wood or, if made frommanufactured wood products, shall be made from formaldehyde-free fibre board; or particleboard meeting the E-1 European standard; or have all exposed surfaces sealed with an Environmental Choice-approved sealer or a low toxicity sealer. Manufacturers/ suppliers of all timber doors are to provide Forest Stewardship Council Chain of Custody Certification upon delivery to site.

BoKlok Concept: Mass production of main components in factory controlled conditions minimizing

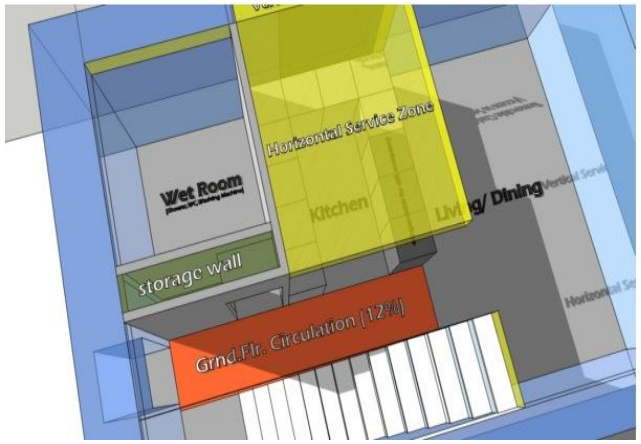


Fig.19 showing compartmentalized stair and wet-room

Vanity unit to consist 19mm panel with melamine faced high pressure laminate moisture resistant chipboard core. Concealed steel brackets, dowelled sections. Where necessary units are to be supplied with panelled sides to form return laminate head and skirting rails. 19mm thick melamine faced moisture resistant chipboard to form 16mm flashgap. 18mm plywood subframe, 17mm moisture resistant chipboard faced high-pressure laminate moisture resistant chipboard core. Rolled metal section subframes with click fit fixings. Aluminium base, head rail and jamb sections. To be installed using manufacturers components and in accordance with manufacturer's instructions.

COMPARTMENTALISED STORAGE

Compartmentalised storage for waste compost, paper, plastic, tins/metals capacity each 8ltr. To be integral with kitchen units.
exceed 30dB(A) in the installation room and 22-25dB(A) for the supply zone i.e. inhabitable rooms.

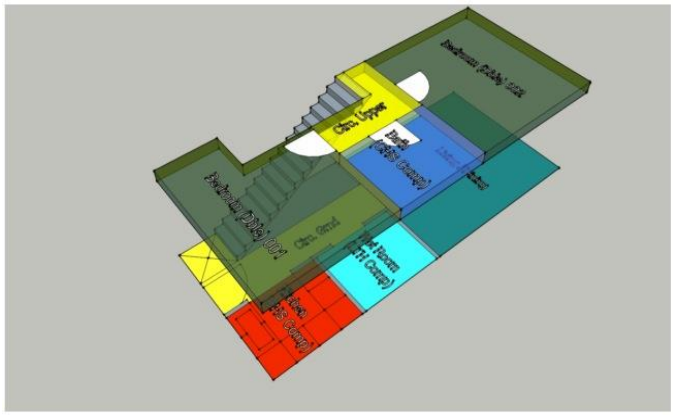
WC to have 4.5 litre siphon-flush concealed cistern Panelled bath to have 140 litre capacity Offset tap to hand basins Hand basins to have max7 litre capacity. Microbore plumbing (pipe lengths have been minimised via design). Showerheads to limit flow rate to be less than 6 lt/min flow at 4 bar. Stainless steel sink to have max 10 litre capacity

OUTLINE SPECIFICATION & SERVICES MVHR

Heat recovery efficiency to be >90% (PHI Certified). The cumulative specific fan power (efficiency) of the ventilation system is to consume < 0.35W/m3 of air conveyed. Automatic summer bypass to be integral to MVHR unit. MVHR system to be acoustically insulated so as to ensure that the sound level of the system does not exceed not.

DUCTWORK

Ductwork should be airtight (leakage < 3%) in accordance with Class C according to EN 12237.



IFig 20. The BoKlok house type is sold to the public via IKEA stores allowing for a different approach to purchasing, instead of the usual broker approach. All BoKlok housing developments hold an event at the nearest IKEA store. Allowing a BoKlok house. This approach to the product combined with the architectural design approach to ensure affordable and flexible housing has been viewed on the internet in various forms over two million times.

ATTENUATION

160mm by 1000mm acoustic attenuators to primary supply and extract branches.

TRANSFER DEVICES

Adjustable circular wide-angle air-jet diffusers. Dampers and valves are to comply with BS EN 1751:1999. Although the void of the floor cassette is to be used for the majority of the 'ducting'.

RECIRCULATORY COOKER HOOD

Recirculatory cooker hood to be located over hob.

HEATING SYSTEM

Weather compensated gas condensing boiler with controls.

HEAT DELIVERY SYSTEM

Radiators

POWER & COMMUNICATIONS

All power provision to satisfy building regulations requirements. Minimum provision of double socket electrical outlets: 4no. to working area of kitchen, 2no. to dining area, 5no. to living area, 3no. to office, 3no. to double bedrooms, 2no. to single bedrooms, 1 no. to each hall and landing, 1no. to store/workshop/garage.

FIRE PROTECTION

Smoke detectors, rising heat detectors and possible sprinkler arrangement to be provided. Dimmable compact fluorescent and fluorescent lighting. The use of LED lighting is to be used in key locations only. Generally lighting to achieve 70 lumens per circuit-watt, a colour rendering index => 85 and a colour appearance of 2750 K. < 3.0 W/100 lux.

INTERNAL LIGHTING

telehone sockets 1no. to living area, 2no. to office, 1no. to each bedroom, 1no. to hall and landing.

Image.21. The elevational treatment for each dwelling has been formatted to allow for different 'zones' of the facades to be inter-changeable in terms of materials used in differing locations. For example in the UK, the BoKlok house types are mainly constructed using a render and timber paneled appearance. This is very acceptable to many of the BoKlok sites in the UK in terms of planning conditions. However, across Europe these areas of the façade can be clad in a 'Trespa' panel system (coloured Aluminium composite panel). To add variety but reducing the number of external materials, the location and direction of the cladding is amended. The example above with a streetscape of three Alsten dwellings has variety of external appearance by mixing vertical and horizontal timber cladding.

Image.22. The elevations above show the removable external panels that allow for future podularisation of internal rooms. For example the rooms that often require refurbishment are the bathrooms and kitchens as these get high use. By removing the external panel(s) the room 'pod' can be quickly removed and a new pod fitted. The external rendered panel is then replaced.

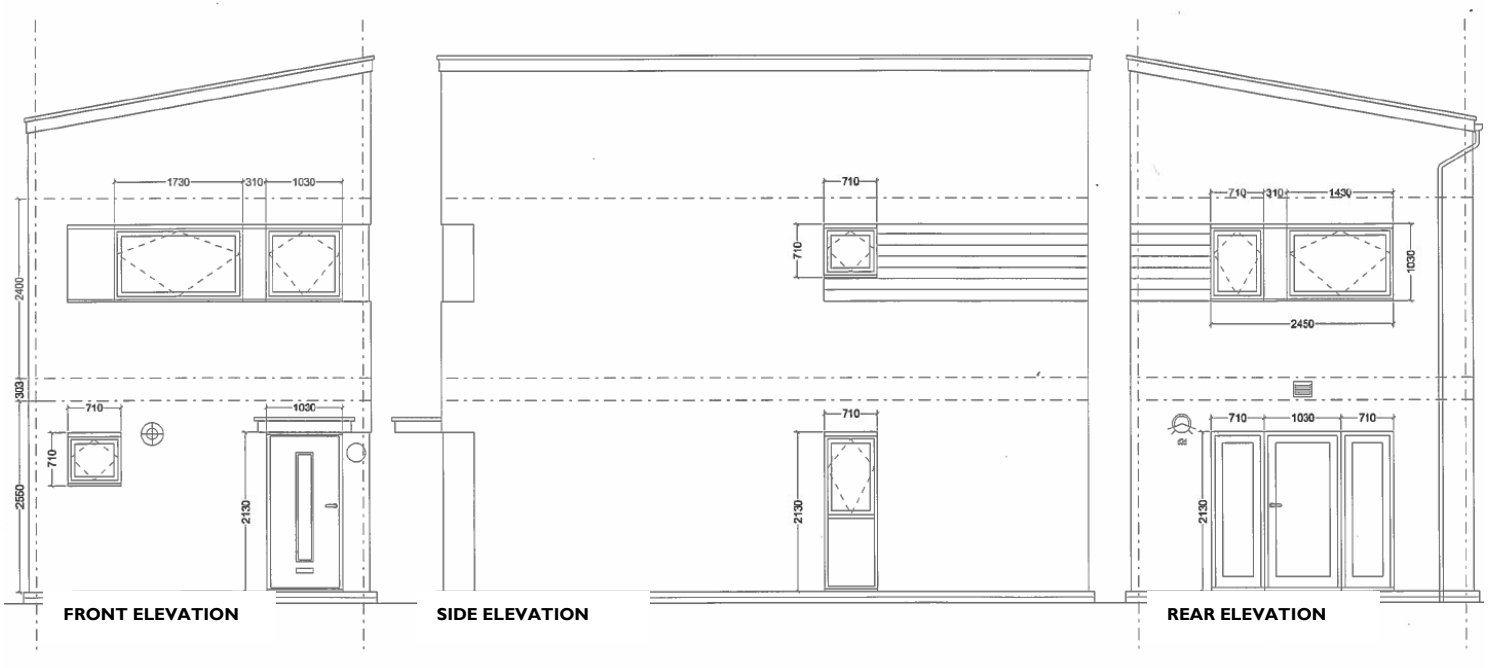
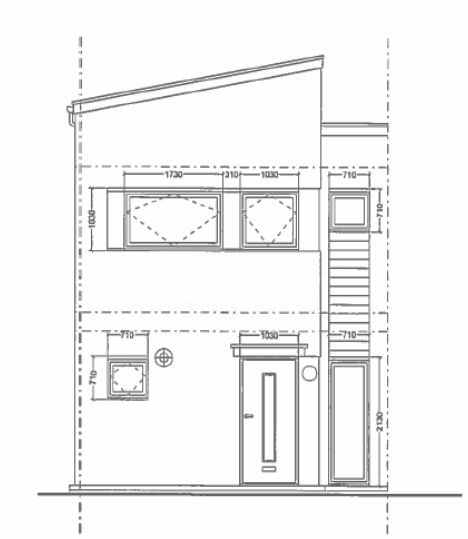
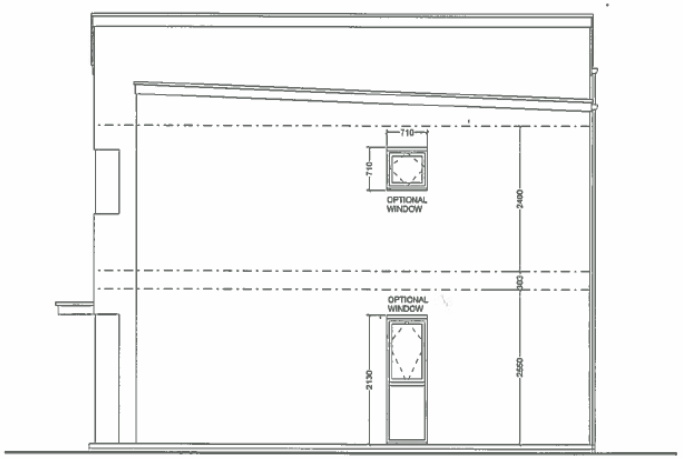


Image.23. The Molna house type elevations as shown above.

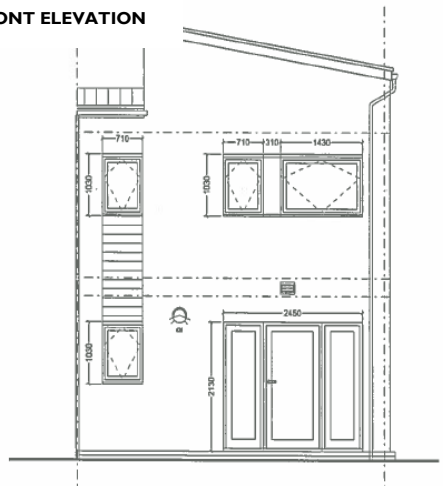
Image.24 The Alsten house type elevations as shown above.



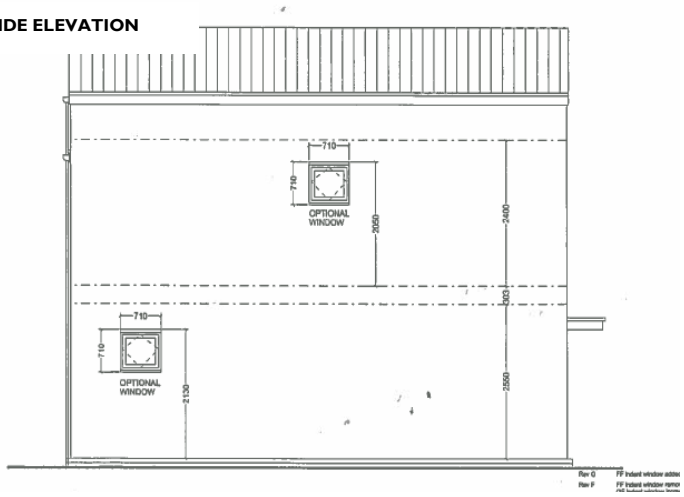
FRONT ELEVATION



SIDE ELEVATION



REAR ELEVATION



SIDE ELEVATION

Image.25. The Jarnbro house type elevations as shown above.

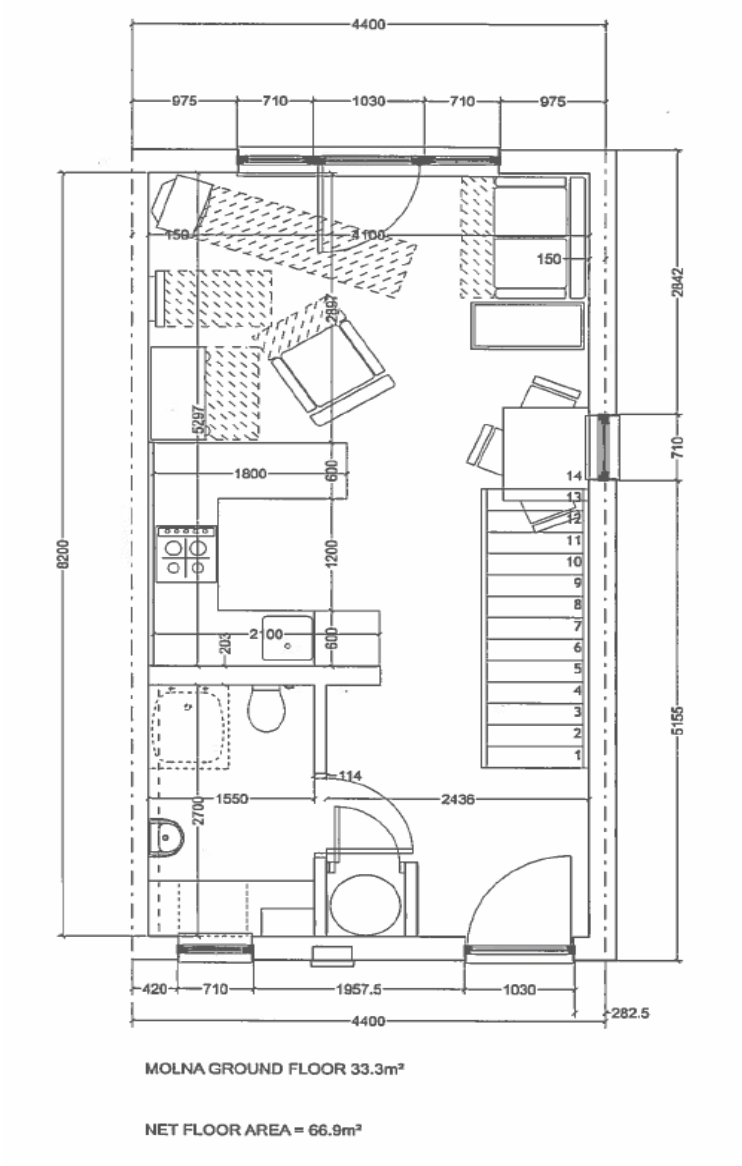


Image.26 The Molna house type dimensional ground floor plan.

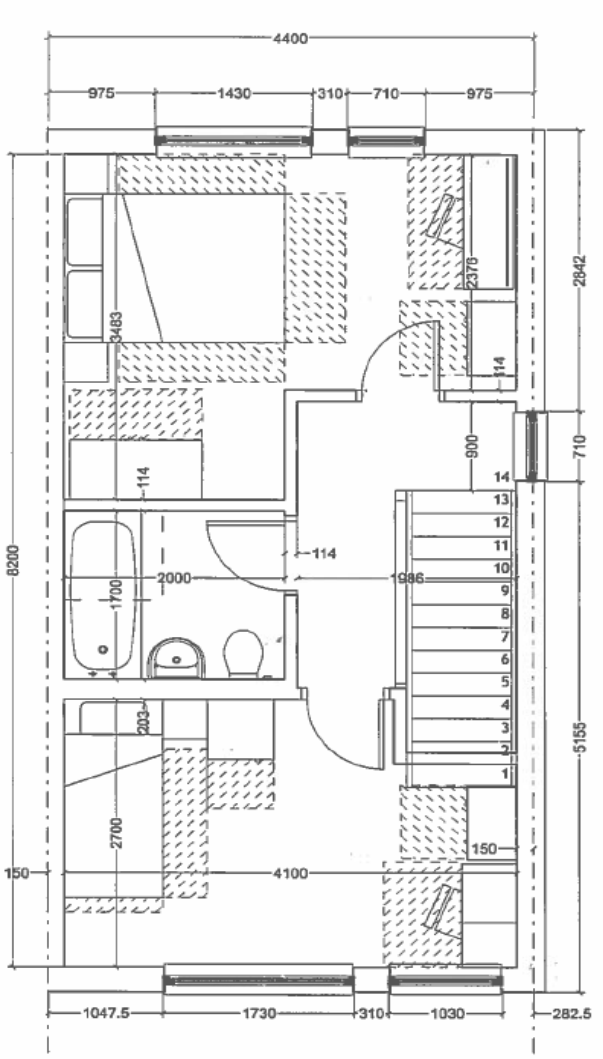
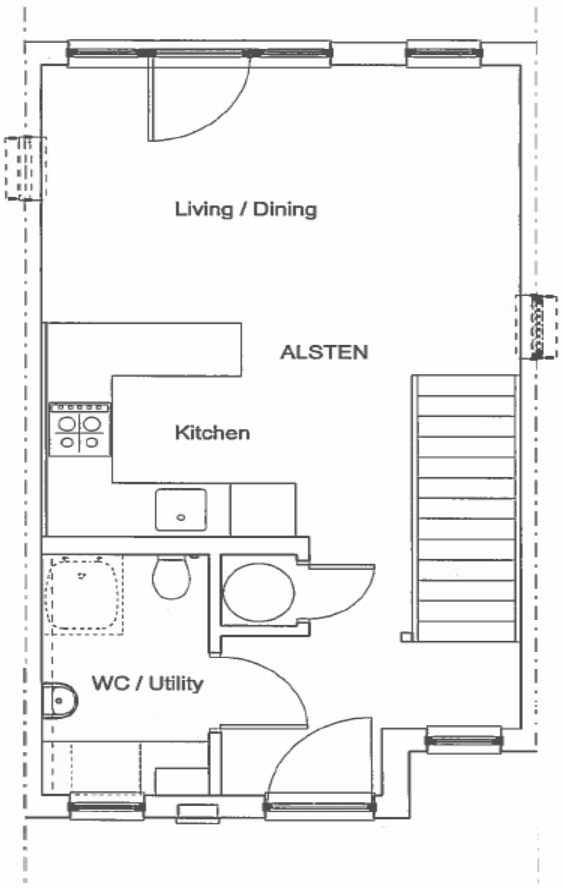
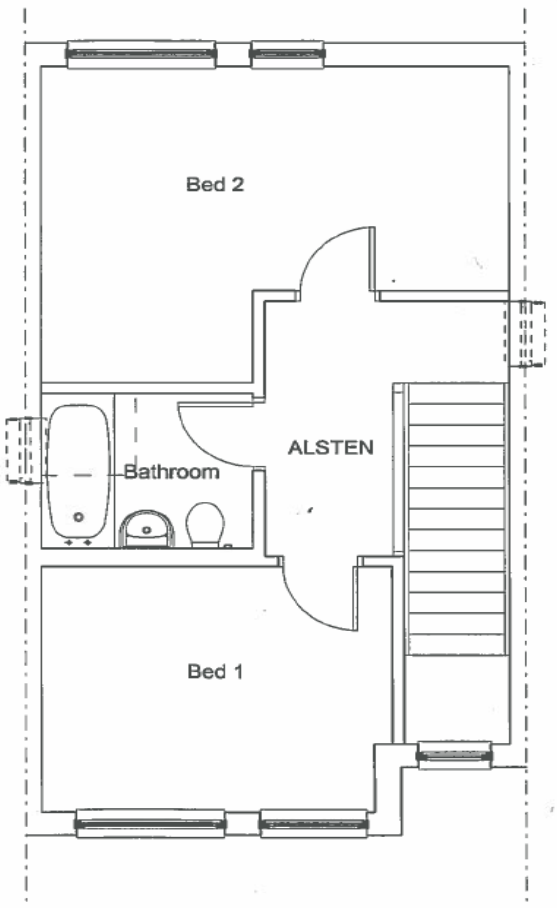


Image.27. The Molna house type dimensional first floor plan.



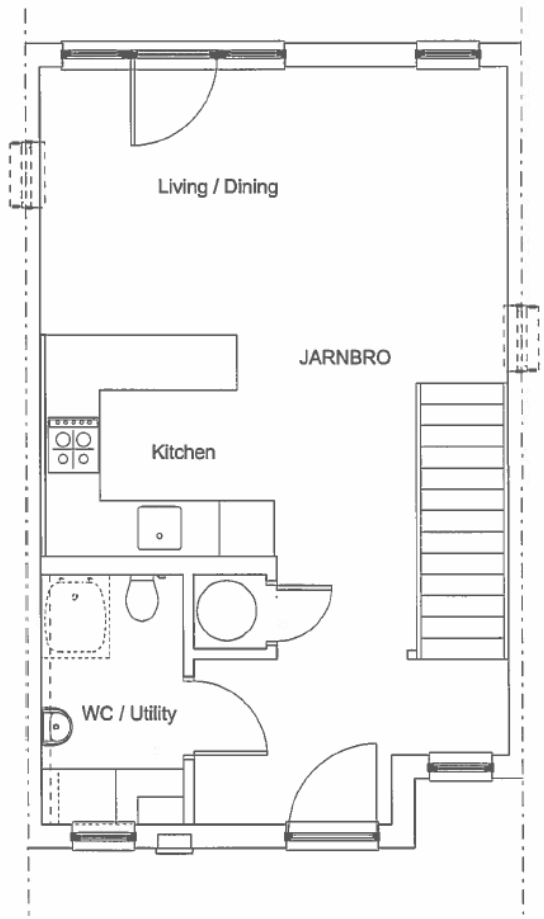
ALSTEN - GROUND FLOOR - 35m²

NET FLOOR AREA = 70.3m²



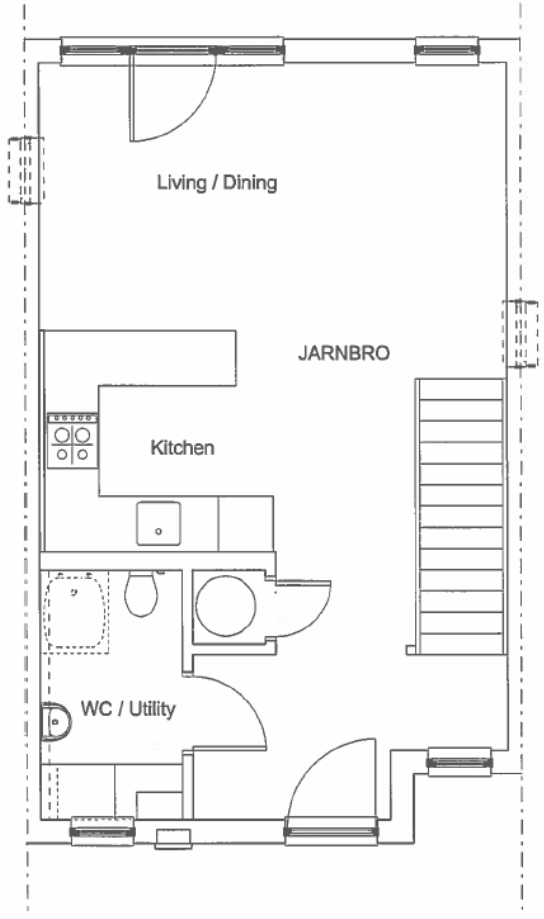
ALSTEN - FIRST FLOOR - 35.3m²

Image.28. The Alsten house type dimensional first floor plan.



JARNBRO - GROUND FLOOR - 40.5m²

NET FLOOR AREA = 81.4m²



JARNBRO - GROUND FLOOR - 40.5m²

NET FLOOR AREA = 81.4m²

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