

FINANCIAL VIABILITY

RESEARCH QUESTION:
*"HOW CAN MODULAR CONSTRUCTION
DELIVER MORE QUALITY AFFORDABLE
HOUSING"*



Fig. 1 - Modular Construction (Chapman Taylor)

CONTENTS

03 INTRODUCTION

04 LITERATURE REVIEW

06 FRAMEWORK

07 CASE STUDIES

07 SCOTLAND

09 SWEDEN

10 BARKING

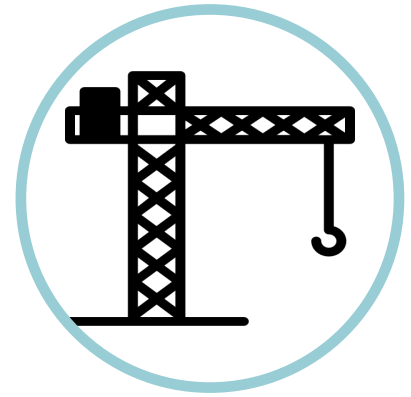
12 MANCHESTER

14 SINGAPORE

15 DESIGN PRINCIPLES

16 REFERENCES

INTRODUCTION



Research Aim:

“How can modular construction deliver more quality affordable housing ?”

The focus of this paper is to identify and understand how modular construction can be a solution to the rising need for desirable affordable housing.

To achieve this aim the following report will research a range of relevant academic literature and global case studies that provide necessary information on modular construction and affordable housing.

The findings from this research will inform a set of design principles that can deliver innovative affordable housing for low-income neighbourhoods. These principles will be applied to our Billingsgate market site.

Literature Review

Provides key background information which can be related to throughout the report and applied to relevant case studies and the design principles.

Framework

A logical framework developed for the critical analysis of case studies.

Case Studies

A analysis of 5 case studies highlighting different key advantages and achievements of housing through modular construction.

Design Principles

Principles outlined for the Billingsgate market site based on the findings and analysis of the global case studies.

LITERATURE REVIEW

Nazir, F. A. et al. (2020) "Comparison of Modular and Traditional Uk Housing Construction: A Bibliometric Analysis," *Journal of Engineering, Design and Technology*, 19(1), pp. 164–186

The need for housing in the UK is continuously rising with governments setting targets of 300,000 homes to build annually, however housing completions are falling short of these targets by about 250,000. The growing gap between the supply and demand of housing has been accelerated by several factors, including a lack of skills and workforce in the construction sector, reduced profitability, cost blowouts and extreme pressures on delivery times. All these considerations have raised concerns over the effectiveness of traditional building methods in the construction industry with professionals researching and challenging the way building is being thought about.

"Comparison of modular and traditional UK housing construction: a bibliometric analysis" is a study published in the *Journal of Engineering, Design and Technology* (Nazir, F.A. et al. (2020) comparing the traditional approach of construction to the modern method of construction (MMC), modular construction and assessing if a transformation in the construction sector could deliver on the growing demand for housing in the UK. Through this research they were able to effectively map out the advantages and disadvantages of both traditional (Appendix A) and modular construction (Appendix B) through which they concluded that modular construction outperforms the traditional approach in regard to cost, time and quality of the end projects.

In their findings the researchers of this study also acknowledge a need for further empirical research to be completed to obtain the necessary information to make informed decisions on how modular methods can be more effectively integrated into the current UK construction practises.

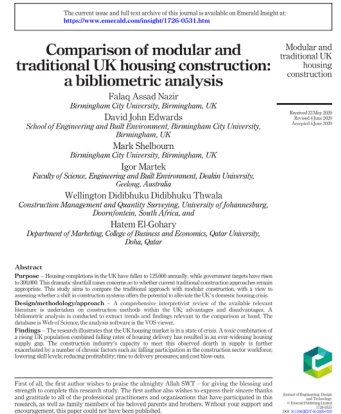


Fig. 2 Cover page (1)

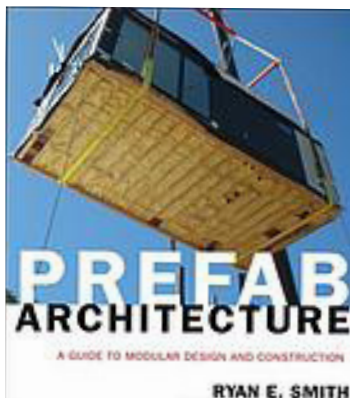


Fig. 3 Cover page (2)

Smith, R. E. (2010) *Prefab architecture : a guide to modular design and construction*. Hoboken, N.J.: John Wiley & Sons.
Available at: <https://ebookcentral-proquest-com.oxfordbrookes.idm.oclc.org/lib/brookes/reader.action?docID=698719>
(Accessed: November 17, 2022)

"Prefab architecture: a guide to modular design and construction" is a book by Ryan E. Smith published in 2010, providing a guide for practitioners of the built environment who are looking to embrace innovation in the construction sector to use pre-fabrication as a method of building.

The idea of using prefabrication or modules to build homes has retained a stigma stemming from the lack of quality in design and construction found in prefabricated homes built in an effort to recover from WWII. This has led to hesitation from architects and construction professionals to advance their way of thinking about building and design and favour traditional methods over the opportunities and benefits prefabricated and modular building processes can deliver. However, there is an increasing need for affordable housing across the UK and modular construction is a forward way of thinking about delivering on the demand. Prefabricated homes can offer greater quality, precision, shorter construction periods and lower project costs, allowing a greater number of affordable housing units to be built whilst permitting financial viability of developments. These advantages are important to consider when designing for affordable housing.

In this guide, Smith sets out to provide necessary information for professionals to integrate prefabricated processes in their projects and find a greater balance between economy, efficiency, and aesthetics. Furthermore, Smith highlights the importance of cross-disciplinary education to allow the fragmentation in the building industry to be mended and empower future professionals to further advance the building industry.

LITERATURE REVIEW

Wallance, D. and Szenasy, S. S. (2021) *The future of modular architecture*. New York: Routledge, Taylor & Francis Group.

Global cities today require developments to maximise the limited space available in addition to delivering high density. Building vertically through high-rise buildings is the most effective building typology to achieve high density but with current traditional construction methods and at desirable quality their cost is too high to build for equitable multi-story housing for people of all incomes as argued in the book "The Future of Modular Architecture" by David Wallance and Susan S. Szenasy (2021). This book sets forward a proposal for mass-fabricated mid- and high-rise modular housing on a global scale based on twelve interrelated principles of modular architecture defined throughout the book.

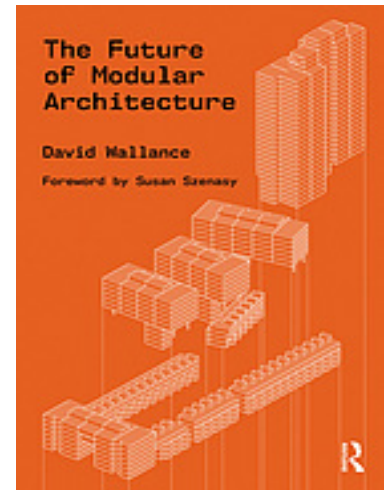


Fig. 4 Cover page (3)

Growing concerns over all aspects of sustainability, have pushed innovation to consider and explore different building methods and delivery systems. Guided by the idea that modular architecture, architectural practice, urbanism, sustainability, and globalization are intertwined areas author David Wallance seeks to show how modular construction (also referred to in text as Volumetric Unit of Construction (VUC)) and the use of existing global intermodal transport systems can be a vital tool in solving environmental, economic, and social pressures of the construction industry.

Current trends in technology across the construction industry strongly suggest a reshaping from on-site to off-site manufacturing will be assumed and the modular will effectively deliver affordable and desirable housing. Moreover, similarly to the literature of Ryan E. Smith (2010), David Wallance theorises that it is very possible for the house building industry to become an industrial or manufacturing process but requires professionals to alter their way of designing and building.

Cornell Real Estate Review

Volume 17

Article 21

April 2019

Modular Construction: A Solution to Affordable Housing Challenges
John Thompson
Cornell University

Follow this and additional works at: <https://scholarship.cornell.edu/crr>
Part of the Real Estate Commons

Recommended Citation
Thompson, J. (2019) 'Modular construction: A solution to affordable housing challenges', *Cornell Real Estate Review*, 17, 90-97. Retrieved from: <https://scholarship.cornell.edu/crr/vol17/iss1/21/>

This article is brought to you for free and open access by The Scholarly Commons. It has been accepted for inclusion in Cornell Real Estate Review by an authorized editor of The Scholarly Commons. For more information, please contact library@cornell.edu.

If you have a disability and are having trouble accessing information on this website or need materials in an alternative format, contact library@cornell.edu for assistance.

Thompson, J. (2019) 'Modular Construction: A Solution to Affordable Housing Challenges', *Cornell Real Estate Review*, Volume 17 Article 21, 90 -97.

"Modular Construction: A Solution to Affordable Housing Challenges" is a paper by James Thompson in the *Cornell Real Estate Review* (2019) in which he highlights the connections of economic conditions, public policy, and affordable housing development in the state of Main, USA.

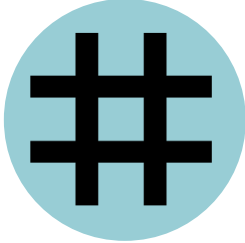
Fig. 5 Cover page (4)

Financial viability is a key requirement for any development and can be a reason developers may choose to only provide the minimum required units for affordable housing to ensure the development is feasible. When considering the financial implications affordable housing has on the viability of a development scheme it is beneficial to explore innovative opportunities to reduce project costs to allow for a higher yield of affordable units that can be provided.

Much of the literature available about modular construction agree upon the advantages of modular building, which can be both qualitative such as safer work environments and quantitative with lower costs.

James Thompson further argues, that with the willingness of both the private and public sector to engage in modular construction this method can efficiently be implemented in standardized construction and be a solution towards affordable housing. The future of the construction industry is becoming increasingly modular and will require governments to adopt measures to simply and expedite the building process and attract professionals in private practice to adopt this new building method.

FRAMEWORK



Yield (Number of Units)

High density and greater number of units are a key requirement in delivering on the rising need for affordable housing and should be maximised where possible.



Construction Time

The demand for housing is growing faster than the supply is being completed and housing needs to be delivered at a faster rate to accommodate the shortfall.



Construction Cost

Affordable housing should be delivered through cost-friendly construction methods to allow for greater provision of housing within a development.



Quality & Design

Affordable housing should be built to a high-quality standard to reduce long-term costs (maintenance, repairs) and be designed to minimize visual differentiation between affordable and market value housing.



Affordability

Affordable housing should be offered with regard to income levels, market rent or buying costs and expected living expenses such as travel, essential shopping & amenities.

CASE STUDY

Kilmarnock, Scotland

Location: Kilmarnock East Ayshire, Scotland

Status: In Progress (to be completed November 2024)

Building method: 100% modular



Fig. 7 Rendering of development

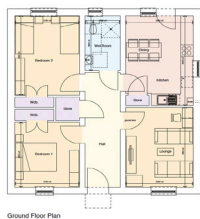
The Cunningham Housing Association in partnership with East Ayshire Council, the Scottish Government and local company Connect Modular LTD are in progress of constructing and delivering 101 low-rise affordable homes.

This new development is a the first of its kind undertaken by the Cunningham Housing Association and will be once completed the largest modular construction program with a Registered Social Landlord (RSL) undertaken by Connect Modular LTD.

The Shortlees neighbourhood of East Ayshire is deemed by the Scottish Government to be an area with a high demand for social housing. This private and public partnership will be delivering on the need for high-quality affordable housing and is heavily backed by government funding.



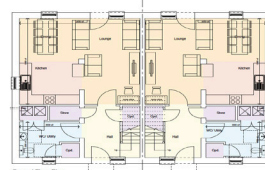
Fig. 8 Site Plan



House Type C
2 Bedroom 4 Person
Amenity Bungalow
Gross Area 79m²



Fig. 9 Amenity Bungalow

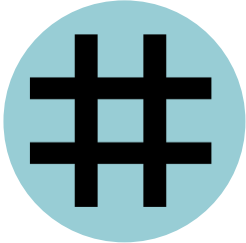


House Type B
3 Bedroom 6 Person
General Needs House
Gross Area 105m²

Fig. 10 3-Bed Housing Type



SCOTLAND FRAMEWORK



Yield (Number of Units)

The development is set to deliver 101 low-rise housing units and include a mix of 2,3 and 4 bedroom standard homes as well as 10 amenity bungalows and 5 wheelchair accessible bungalows. All units will be built to the highest construction standard of Connect Modular LTD.



Construction Time

Construction works started late July 2022 and completion is estimated to be in November 2024. The contract period states the development will run over a duration of 122 weeks.



Construction Cost

The project costs for this housing development are set to be a total of £17 million.

The finances for this project are broken up into two sources: £10.5 million come from Grants financed by the Scottish Government and the Housing Association, while £7 million of the funds come from private financing.



Quality & Design

Designs proposals for the homes have been worked on over a period of 18 months between the Housing Association, Connect Modular LTD and the architects Robert Potter & Partners.

All units will be built off-site in a nearby factory and delivered to the site equipped with pre-fitted kitchens, bathrooms, plumbing and electrics.



Affordability

This development ensures priority to families in immediate need of housing and guarantees affordability.

All housing units in this development will be available for rent to applicants selected from the East Ayrshire Council Common Housing Register. Rent costs are determined by the Registered Social Landlord and are often based on the national average (Scottish Housing Regulator 2016, p. 15).

CASE STUDY

Stockholm, Sweden - Ekgarden Apartments

Location: 📍 Sodertalje, Sweden

Status: Completed

Building method: 100% modular

Ekgarden Apartments is a rental apartment housing development completed in a neighbourhood of Stockholm, Sweden. This case speaks strongly to the efficiency of modular construction as final assembly was achieved in a matter of 8 days.

The key players in this development included the modular construction company FORTA PRO, general contractor the Blumenthal Group, STUD-LIVING and their client developer Paradoumo Group. The modules were manufactured by FORTA PRO in their factory in Latvia and then transported to be assembled in Sweden. See Appendix C & D for FORTA PRO floor layouts and room sizes.



Fig. 11 Ekgarden Apartments

SWEDEN FRAMEWORK



Yield (Number of Units)

This development consists of 30 low-rise modular apartments covering a total of 1797m² in 48 modules.



Affordability

The area need for affordable housing encouraged this development to be encouraged by municipality. Rental units were prioritized for young families.



Construction Time

From signing the contract to residents moving in the development took 10 months to complete and the assembly of the modular units was realised in only 8 days. Completion was ahead of schedule, allowing residents to move in sooner and stakeholders to get a faster return.



Quality & Design

The goal of this housing development was to build comfortable rental apartments with high-quality design features and outdoor amenity space. FORTA PRO offers a flexible interior designs based on client specifications and all units come fitted with fully equipped bathrooms.

CASE STUDY

Barking, UK - Wivenhoe Apartments

Location Wivenhoe, Barking

Status: Completed

Building method: 100% modular

Wivenhoe Apartments were part of an emergency housing project to help the Government address homelessness in the country and meet housing targets.

The client of this housing project was Be First the regeneration agency of the London Borough of Barking and Dagenham and together with the Jerram Falkus as the main contractor, ATP Architects and Premier as the modular construction company they delivered housing on a highly constrained site. The site's location in a residential area, directly parallel to a live railway line and within the M25 posed some logistical challenges for the delivery of the housing modules. Nevertheless, Premier construction was only on site for a total of 25 days.



Fig. 12 Rendering of Wivenhoe Apartments by Premier

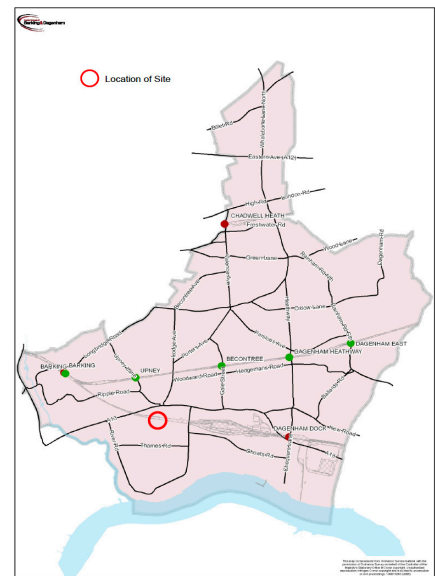


Fig. 13 Site Location

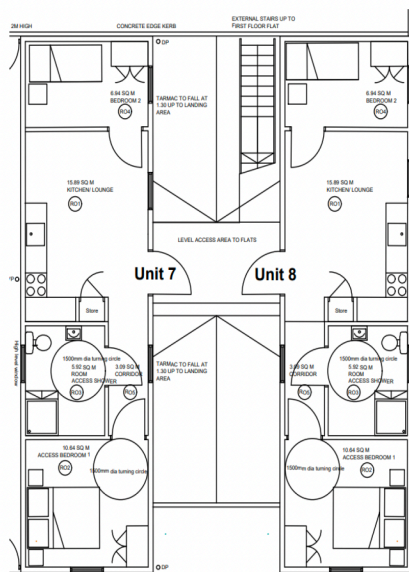


Fig. 14 Ground Floor Plan

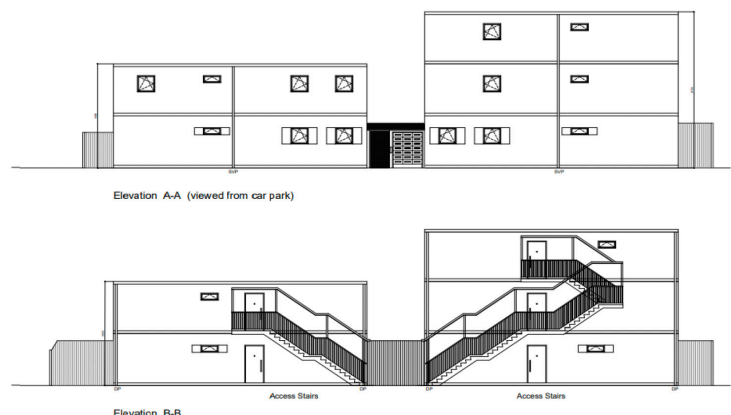
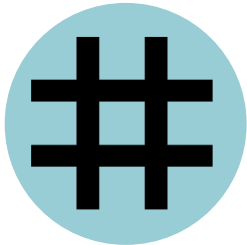


Fig. 15 Building Elevations

BARKING FRAMEWORK



Yield (Number of Units)

Wivenhoe Apartments consists of 20 tow-bedroom apartments divided into two blocks located on a former garage site. These units are part of a permanent biilding solution to the issue of homelessness.



Construction Time

This project was completed towards the end of 2020 within a combined 30 week timeframe. Procurement, manufacturing, and final fittings were completed within 15 weeks.



Construction Cost

The overall housing contract was £1.5 million.



Quality & Design

Each apartment unit occupies a single factory tested module, weighing 12.5 tonnes. This form of a singular module optimises construction efficiency. All apartments are manufactured and fitted in Premier's factory in East Yorkshire using high-quality materials. Final modules come delivered to the site completely equipped with bathrooms, kitchen, flooring, partitions, doors, windows and external cladding. The building design also include sustainable PV panels to generate electricity and communcal bike shelters have been provided.



Affordability

Since this housing project was part of a Social Emergency Housing Project the apartments were offered to families of Barking in urgent need of accommodation.

The affordable apartments are available at 80% of market rent and with the right to buy receipts Be First was able to maintain financial viability of the scheme.

CASE STUDY

Singapore - Clement Canopy

Location: Singapore

Status: Completed

Building method: 100% modular

A recent push in South East Asia to improve construction productivity has encouraged developers to embrace modular construction at new levels.

The Clement Canopy towers, located in Singapore are now the world's tallest modular buildings and are built with nearly 1,900 prefabricated modules across 46,000 m².

See Appendix E for 3D model and Appendix F floor plans and areas.



Fig. 16 Clement Canopy



Fig. 17 Site Plan

SINGAPORE FRAMEWORK



Yield (Number of Units)

Clement Canopy are two 40-storey residential towers with 505 luxury apartments and reach around 140m tall.



Construction Time

Both towers were delivered in 30 months. Building structures were cast in concrete in Malaysia and the final modules were completed in Singapore within 15 days. The whole project was completed six months ahead of the initial timeline.



Quality & Design

All 1,900 modules of this development were prefabricated in a factory setting and all finishes for both the interior and exterior were quality tested before being assembled on site. Each module is about 85% completed before assembly.

CASE STUDY

Manchester, UK - HoUSe Project

Location: 📍 New Islington, Manchester

Status: Completed

Building method: 100% modular



Fig. 18 HoUSe Project

The House project done by Property Developer Urban Splash and Architects ShedKM aimed to bring an alternative to the standard of modular boxes often found with modular housebuilders. This development sought to deliver urban regeneration viable for the long term by creating housing and places for people old and new.

The new housing to be built on the old Cardroom Estate, was to combine the cost benefits of modern methods of construction (MMC) with the design flexibility modular properties can have with architect-designed units. The way in which this development was set up, clients of the new houses were able to customize their modular units according to their needs and desires.

The success achieved by Urban Splash and ShedKM allowed for further housing to be built to the same aim and standard as the homes in New Islington. In total this partnership and their innovative vision delivered 410 homes over six sites.



Fig. 19 3D plan

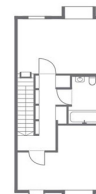


Fig. 20 Development Phasing

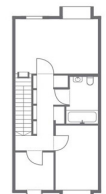
First floor
Floorplan options



F1 (base)



F2

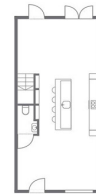


F3

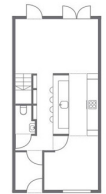
Ground floor
Floorplan options



G1 (base)



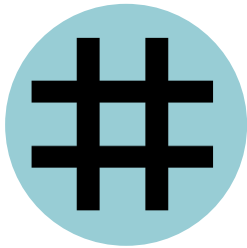
G2



G3

Fig. 21 Floor plans

MANCHESTER FRAMEWORK



Yield (Number of Units)

The New Islington housing was built on a major regeneration site and alongside new public spaces, 44 homes were built in 4 main phases.



Construction Time

Once a client has decided on various design specifications it takes about 16 weeks for their home to be built and delivered. Within a further three to four weeks all interiors are finalized and the completed house is assembled.



Construction Cost

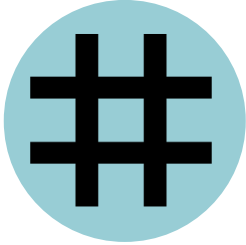
The starting costs of these flexible design units begin at about £200,000.



Quality & Design

The flexibility and customization of these units allows for high-quality and desirability to be effectively achieved. Although the exterior of the modules are there a number of aspects of the interior that can be adapted to a client. To begin with clients have a choice between two or three storey houses and rooms can be arranged at any level. Floor sizes range between 93 sq m. and 140 sq m. and can be fitted to a number of layout options. Smaller details such as floor finishes, colours and wardrobes are all customizable.

DESIGN PRINCIPLES



Yield (Number of Units)

Affordable housing units should be built primarily in high-rise buildings to maximise density and yield. Tower blocks require innovative architectural design and are ideal to integrate modular construction. As the case studies of Singapore, Sweden and Barking have shown building modular apartments is viable and highly effective with regard to time, cost and quality. The Billingsgate site should include high-rise modular buildings built to a standard and cost that can provide a high yield of affordable housing.



Quality & Design

Both market and affordable housing should be built to high-quality construction and design standards to mitigate visual architectural differences and improve tenure integration. Pre-approved design layouts would ensure greater efficiency in the design and building process. People of Tower Hamlet on the list for affordable housing should be involved in the discussions about quality and design layout to ensure their needs are being met. Guaranteeing high-quality affordable housing can allow for residents to further integrate into the site and retain communities.



Affordability

To ensure communities of Tower Hamlet are retained residents on the local waiting list for social housing as well as families with an earning below the average of the borough should be given priority to the new housing and access to units at lower rental prices. Affordable housing units should be council owned to reduce private rental properties across the site.

REFERENCES

Nazir, F. A. et al. (2020) "Comparison of Modular and Traditional Uk Housing Construction: A Bibliometric Analysis," *Journal of Engineering, Design and Technology*, 19(1), pp. 164–186. doi: 10.1108/JEDT-05-2020-0193.

Smith, R. E. (2010) *Prefab architecture : a guide to modular design and construction*. Hoboken, N.J.: John Wiley & Sons.
Available at: <https://ebookcentral-proquest-com.oxfordbrookes.idm.oclc.org/lib/brookes/reader.action?docID=698719> (Accessed: November 17, 2022).

Thompson, J. (2019) 'Modular Construction: A Solution to Affordable Housing Challenges', *Cornell Real Estate Review*, Volume 17 Article 21, 90 -97.

Wallance, D. and Szenasy, S. S. (2021) *The future of modular architecture*. New York: Routledge, Taylor & Francis Group.

APPENDIX

APPENDIX A

JEDT 19,1	Advantages Availability of materials Thermal performance	Description Materials are manufactured and sourced locally, meaning availability is provided openly Because of high thermal mass in the materials to absorb and store heat, this allows houses during the summer period to be kept in a cool temperature while during winter heat is stored during the day As this is the most common form of house construction in the UK, the accessibility of skilled workers is high for any residential projects needed Houses that were built centuries ago are still standing in many parts of the UK and they are able to withstand severe weather/temperatures. This leads to very less maintenance over their whole lifecycle as bricks are not in need of paint or sealant to maintain their appearance	Citations The Self Build Guide (2019) The Self Build Guide (2019)
174	Popularity		Brigden (2013)
	Durability alongside flexibility		Brigden (2013)
	Disadvantages Slower process alongside weather conditions impact	Description On average, it takes 20 weeks or more to build in masonry. The form is of wet construction meaning more time is desired to completely dry out at several intervals. Masonry cannot be laid when it is raining heavily or when temperatures fall below freezing. This is where alternative methods such as modular construction fits in, as the process is completed in a factory-based environment Unintended bridges may form and allow damp to seep through the inner skin of the wall, if large amounts of mortar fall on the cavity ties above the damp-proof course. This will cause limited energy efficiency ratings. When moisture from rainfall, melting snow or soil enters bricks, it can freeze and thaw causing spalling. Cracks eventually increase in size that will eventually lead to crumbling	Citations Brigden (2013), Fewins (2019)
	Occurrence of dampness (spalling)		Brick hunter (2019)
	High building costs	Building with bricks is commonly considered rather extravagant because of the need for more building materials. Depending on the actual manufacturing process and time of purchase, costs per brick varies from £300-£1,200 per 1,000 bricks	Brick hunter (2019)
	Whole house performance	The multiple limitations of model-based assessments of traditional buildings means that a gap is frequently identified between modelled assessments and the monitored realities of traditional building performance. In addition, traditional buildings are not well served by current buildings energy assessment models; this is of significant concern given the prevalence of modelling within the disciplines that guide construction practices, including overarching policy decisions	STBA (2012)

Table 6.
Advantages and disadvantages of traditional masonry construction

Fig. 22 Pros & Cons - Traditional Construction
(Nazir, F.A et al., 2020)

APPENDIX B

JEDT 19,1	Advantages Quicker construction method	Description Quicker construction: modular homes are faster to build because of the use of a continuous operating assembly line. In addition, each building component is checked as they become ready instead of needing to wait for a city inspector to sign everything off, which is time-consuming. Up to 50% time-savings compared to the traditional method, with an average construction time of 180 days. Greater repeatability, automation and collaborations ensures house completions to be built in approximately less than two months at the factory Because of its affordability as several units are constructed at once, therefore, economies of scale are in effect. Savings between 10%-20% are achieved through the use of modular techniques During the actual building process this is reduced around 67%	Citations CRI. (2018), MTX. (2017); Golawski (2018)
176	Cost-effective		CRI. (2018), MTX (2017)
	Reduced energy consumption Better durability and quality houses	Drawings are much more detailed compared to traditional where every single detail is elaborated, as well as a higher health and safety level in the factory minimises risks, leading to better durability	MTX (2017) Golawski (2018)
	Disadvantages Flexibility	Description The space planning, detailed design and service integration all need to be completed earlier compared to traditional projects. Incorporating late design variations to the modules will cause high costs Due to the requirement of frequent communication and effective coordination between the involved parties, the fragmented nature of the construction industry these factors making it difficult to standardise designs for the modular method A thorough choice of supplier to develop a close relationship is crucial because once engaged there is usually very little scope to source modules from an alternative company if the original supplier fails to perform The requirement for highly skilled labor for both producing parts/modules of the houses in factories and the precision of on-site assembly of parts is needed. Generally, many workers in the construction industry have had little or no experience with modular construction, which emphasizes on the fact that university-level students are not receiving enough materials to learn	Citations Construction Methods Modular, (2018) Rahman (2014)
	Industry-related issues		Rahman (2014)
	Procurement		Construction Methods Modular (2018)
	Lack of skills/ experience needed		Rahman (2014)

Table 7.
Advantages and disadvantages of modular housing

Fig. 23 Pros & Cons - Modular Construction
(Nazir, F.A et al., 2020)

APPENDIX C



Fig. 24 FORTA PRO standard floor layouts

APPENDIX

APPENDIX D

Apartment type	Size (m2)
1 room apartment	(29 m2)
2 room apartment	(49 m2)
2 room apartment	(52 m2)
3 room apartment	(65 m2)
Total apartments	

Fig. 25 FORTA PRO standard apartment sizes

APPENDIX E

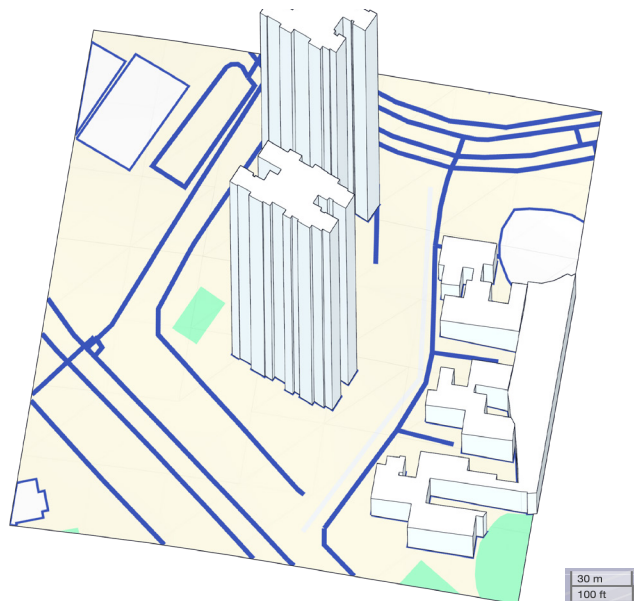


Fig. 26 Clement Canopy (Singapore) 3D Massing

APPENDIX F



Fig. 27 Clement Canopy (Singapore) Floor plans and area