CONSTRUCTION
INDUSTRY COUNCIL
建造業議會

POTENTIAL UTILISATION OF PREFABRICATION YARDS AND PREFABRICATED COMPONENTS IN HONG KONG

FEASIBILITY REPORT

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Potential Utilisation of Prefabrication Yards and Prefabricated Components in Hong Kong

- Feasibility Report -

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EXECUTIVE SUMMARY

In view of the growing trends of using prefabrication construction, the Committee on Environment (Com-ENV) of the Construction Industry Council (CIC) has engaged Ove Arup & Partners Hong Kong Ltd (Arup) to study the feasibility of utilisation of prefabrication yards in Hong Kong. To determine the viability of setting up prefabrication yards in Hong Kong, technically feasibility as well as economically justifiability were explored.

The feasibility report maps out the history and development (i.e. manufacturing construction components in a yard, plant, factory or other places outside the construction site and then transported to the construction site for assembling) of prefabrication and the utilisation of its components in Hong Kong, Japan and Singapore.

Although prefabrication yards existed in Hong Kong in the early 1970s-1990s, all of those that prefabricated concrete components have since moved northward into Mainland China. At present, only two government approved prefabrication yards producing steel reinforcing bars are still operating in Hong Kong.

As technology advances, alongside the shortage of skilled labours, the need for efficiency & quality and the demand for prefabricated components, some of Hong Kong's neighbouring countries has already made advancements to change the way it operates in the construction industry. For example, the Singapore government has undertaken many initiatives to promote the use of prefabrication in developments. These include:

- setting conditions in land sale for the use of prefabricated components in residential/commercial development;
- establishing a statutory board to develop and regulate Singapore's building and construction industry (i.e. improve construction productivity and process); and
- making available Integrated Construction and Prefabrication Hubs (ICPH) to prefabrication manufacturers below market prices.

At present, there are 5 manufacturers operating in the ICPH producing prefabricated concrete and structure steel components and modules.

To define the preliminary base case for setting up a prefabrication yard in Hong Kong in the absence of a preliminary design for the proposed yard, we have utilised existing size and scale of several comparable manufacturers operating in Singapore as benchmarks to derive the yard size, gross floor area (GFA) and its production capacity for our yard design and operation.

Based on the 'benchmark' exercise, a yard of average 19,000sqm land size, 28,000sqm GFA, annual production capacity of 277,200 tonnes prefabricated concrete components have been derived. These preliminary figures were used to further identify a possible site in Hong Kong for the yard's establishment.

With considerations to the required land size, spatial requirements, statutory planning, transportation and environmental factors, Tuen Mun Area 40 (i.e. for illustrative purpose) was selected as the more favourable site to be used as an example for proposing the fabrication yard.

For Tuen Mun Area 40, the base case for the feasibility study would entail a land size of 19,000sqm with a development potential of 33,500sqm GFA, equating to an annual production capacity of 331,650 tonnes prefabricated reinforced concrete components/modules.

The feasibility study has been based on the usage of prefabricated reinforced concrete components.

To determine the future demand of prefabricated reinforced concrete components, the future supply of residential and commercial properties were studied and analysed for their contribution to the demand of prefabricated components for the prefabrication yard base case.

The housing supply forecast was estimated based on a number of factors and published figures, including Hong Kong's population growth, types of housing, number of applications for public rental housing, number of public housing units produced annually and land supply by the Hong Kong government. For the analysis, we have focused on a 5-year projection. The total housing supply forecast from 2017-2021 are approximately 193,900 units (97,200 units of public housing and 96,700 units of private residential development).

According to the forecast of housing supply, the amount of prefabricated reinforced concrete components/modules that could be adopted in public housing and private residential development was estimated. For public housing, we obtained the total number of prefabricated concrete elements used per floor and the weight in tonnes from a pilot project in Kwai Chung Estate. Using those data, we analysed that the prefabricated concrete components used per unit in tonnes for an average housing project to be around 20% of the total concrete volume. The 20% is an average figure only.

For private residential development, historically only façade components are prefabricated, in which the façade equates to approximately 1% of the total GFA. Public housing and private residential units' estimated demand for prefabricated reinforced concrete components in 5 years (2017-2021) amounts to 2,680,741 tonnes. This estimated demand for prefabricated components of housing is around the same as the estimated productivity by the prefabrication yard per annum as set out from the benchmarking exercise.

To determine the industry viability of undertaking a prefabrication yard development in Hong Kong, a preliminary financial analysis was developed looking at three (3) scenarios (i.e. yard owner, manufacturing company and yard owner/manufacturing company combined). The financial analysis was based on a high level methodology by developing a financial model for each scenario. Accordingly, the cash flow, capital costs, operating costs and revenue based on Net Present Value (NPV) and nominal values were determined for each of the scenarios.

The financial assessment shows that for base case 1, the yard owner (i.e. yard owner purchase land and construct the yard facility to lease out to a manufacturing company to operate) and base case 3 (i.e. yard owner purchase land, construct the yard and operate the facility) would not be independently financially viable. Only base case 2, where a manufacturing company who rents the yard facility from the yard owner can generate an Internal Rate of Return (i.e. IRR) of 10%. Based on a 10% IRR, the manufacturing business would likely be viable assuming a suitably available facility of current market industrial rent levels.

Accordingly, the potential demand for prefabricated components and the base case scenario where a manufacturing company who rents and operate the prefabrication yard would likely to be viable for developing a local prefabrication yard in Hong Kong.

1 INTRODUCTION

1.1 Background

In view of the world's growing trend of using prefabrication construction, the Committee on Environment (Com-ENV) of the Construction Industry Council (CIC) has engaged Ove Arup & Partners Hong Kong Ltd (Arup) to further explore the feasibility for a wider application of prefabrication construction with the view of improving productivity and sustainability for the construction industry in Hong Kong (The Consultancy Services).

1.2 The Survey Report

The "Survey on the Potential Utilisation of the Prefabrication Yards – Survey Report" (Survey Report) released by CIC in September 2017 recommended the following key areas for further studies:

- Quantifying the potential demand such that it is justified for the input of resources in developing local prefabrication yards;
- Exploring the essential factors for developing local prefabrication yards, including land supply, technological requirements, relevant talents for operating the prefabrication plants in Hong Kong, etc.; and
- Investigating the impact on the existing local labour market.

1.3 The Feasibility Report

In accordance with the scope of the Consultancy Services in the assignment brief, the Consultancy Services' objectives in respect to the report sections are as follows:

Clause	**Description**	**Report Section**
3.1(a)	Identify the requirements and study the feasibility of the proposed prefabrication yard for reinforced concrete in Hong Kong	4, 5, 6, 7, 9
3.1(b)	Identify the pros and cons of establishing a prefabrication yard for reinforced concrete in Hong Kong compared with a prefabrication yard outside of Hong Kong	2, 3, 10
3.1(c)	Setting out identification criteria of feasible locations of the prefabrication yard for reinforced concrete	4, 5
3.1(d)	Explore opportunities to adopt more technology and machinery on-site and within the prefabrication yard for reinforced concrete	3, 9.2

Clause	Description	Report Section
3.1(e)	Evaluate manpower savings on shifting on-site works to the prefabrication yard for reinforced concrete	9.1
3.1(f)	Identify any facilities that can be provided in the prefabrication yard to improve working environment	9.4
3.1(g)	Study any changes to skill set required for adopting prefabrication construction along the whole value chain of construction projects	9.3
3.1(h)	Consult and obtain information from stakeholders through conducting stakeholders engagement forums and separate interviews	10
3.1(i)	Prepare quantifiable and scientific justifications to support the study findings	7,8
2.6	Study the feasibility of Design for Manufacturing and Assembly (DfMA) and identify which sector will be most receptive to such a paradigm change	9.5

Based on the above Consultancy Services objectives and adopting prefabricated reinforced concrete components in the study, the Feasibility Report is arranged into 10 sections with the following topics:

Section	Description
1	Introduction
2	Prefabrication in Hong Kong
3	Prefabrication in other countries
4	Defining the “Preliminary Base Case”
5	Assessment of possible sites
6	Defining the “Base Case”
7	Preliminary analysis of industry viability
8	Demand analysis
9	Other considerations
10	Key finding from interviews and stakeholder forums

2 PREFABRICATION IN HONG KONG

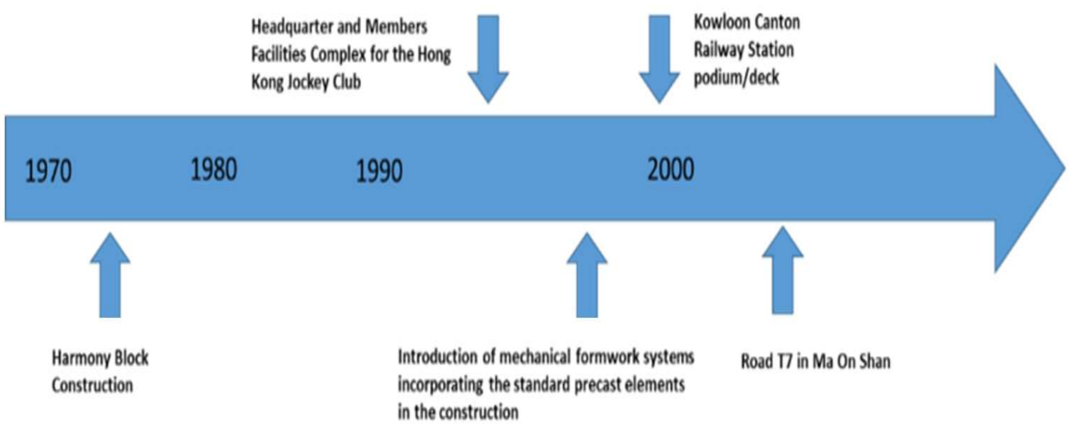
This section of the report describes the history and development of prefabrication (i.e. manufacturing construction components of a structure in a yard, plant, factory or other places outside the construction site and then transport to the construction site for assembling) in Hong Kong.

2.1 Background & Current State

The use of prefabrication in Hong Kong could be traced back to the early 1970s, but it was not popular until the 1980s where a significant amount of prefabricated components were adopted in construction.

The most common materials adopted in prefabricated construction is concrete, steel and wood. Prefabrication components made of concrete and steel are most popular in Hong Kong respectively.

The following diagram provides an overview of the history of prefabrication in Hong Kong[1].



[1] Information from: Raymond Wong, *Prefabrication Construction Practices in Hong Kong City University of Hong Kong*, Archive on Urban Studies and General Education related Studies

The history of prefabrication in Hong Kong is further elaborated as follows:

1970s – 1990s	The history of the use of prefabrication in Hong Kong can be traced back to the early 1970s where a few trial projects had been executed, however it was not popular until the 1980s where a significant amount of prefabrication components including stair flight, floor slab and minor beam were used by the Hong Kong Housing Authority in public housing projects. Since then, there have been other milestone projects employing prefabrication such as the headquarter of the Hong Kong Jockey Club and the Kowloon–Canton Railway Hung Hom station podium extension. Packaged projects were introduced from the late 1990s onwards by the Hong Kong government for the construction of a series of schools using semi-prefabricated method and also a series of government quarter buildings using similar prefabrication construction techniques in the 2000s. The inclusion of a pledge to provide 85,000 housing flats each year in the Hong Kong housing policy in 1997 has led to a massive demand in public housing in Hong Kong. In order to fulfil the soaring number of public housing projects and to shorten the construction time, the demand of prefabrication components has increased significantly.
2002 Onwards	The introduction of a new guideline[2] encouraged the use of prefabricated façades as a form of green elements in construction (exemption of Gross Floor Area) and resulted in the popularising use of prefabricated external walls in residential buildings from 2002 onwards.[3] Other than residential housing projects, prefabrication is also commonly used in bridges and railway projects to save construction time. The prefabrication components required in these infrastructure projects are usually more specific due to the complexity of the construction.
Current Situation	In 2017, the Development Bureau of the Hong Kong SAR Government announced that the Science and Technology Park and

2 Second Package of Incentives to Promote Green and Innovative Buildings, http://www.landsd.gov.hk/en/images/doc/JPN02_text.pdf
3 Prefabricated Construction Systems for Building and Civil works adopted in Hong Kong - Raymond W M Wong

	the University of Hong Kong will be the sites for two trials of prefabricated homes for students and employees[4]. The proposed project "InnoCell" will be an 18-story building at Hong Kong Science Park and provide around 500 cubicles including a gym and multifunction room. The project is scheduled to commence in 2018 and complete in 2020 with an estimated cost of HK$800 million.[5]

Despite the demand for prefabricated components in Hong Kong, there are currently no concrete prefabrication yards in Hong Kong and only two government approved prefabrication yards producing steel reinforcing bar - SW Construction Limited and VSC Construction Steel Solutions Limited:

- SW Construction Limited ("Shiu Wing Steel")

It has been the leading manufacturer and retailer of reinforcing bars for over 45 years and the only steel rolling mill in Hong Kong. Shiu Wing Steel has its steel mill situated in Shek Kok, Tuen Mun, Hong Kong. It provides hot rolled steel bars for the reinforcement of concrete and off-site cut and bend services to ensure a reliable supply of prefabricated rebars. Besides prefabricated steel bar production, it also runs three scrap yards in Yau Tong, Tsing Yi and Tuen Mun respectively, providing scrap collection, processing and recycling services.[6]

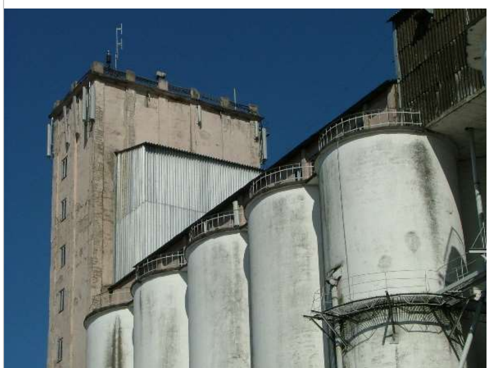
- VSC Construction Steel Solutions Limited ("VSC")

A joint venture between VSC Steel Processing Limited and NatSteel Holdings Pte.Ltd. of Singapore. VSC is Hong Kong's first automated rebar processing and assembly facility and is also a Civil Engineering Development Department approved vendor. Its products include reinforcement bars and coupler produced at exact specification, it also provides services such as automated shearing, automated bending, stirrup bending and complete traceability tagging and identification.[7]

2.2 Types of prefabrication components used in Hong Kong

There is a wide range of prefabrication component types used in Hong Kong. Such as facades, staircases, water tanks, walls, slabs, pipeworks, ductworks etc. See table of the prefabrication components photos that are commonly used in Hong Kong below.

4 Hong Kong prefabricated home trials to be launched at HKU and Science and Technology Park – South China Morning Post – Kimmy Chung
5 InnoCell project eyed for Science Park – The Standard – Ellen He and Michelle Li
6 Shiu Wing Steel Limited website
7 VSC Construction Steel Solutions Limited website

Prefabricated Facades 	**Prefabricated Staircases** 
Prefabricated Ground Floor Water Tank 	**Prefabricated Panel Wall** 
Semi-Prefabricated Slabs 	**Volumetric Prefabricated Bathrooms** 

Prefabricated Steel Works	Prefabricated Pipe Works
	
Tunnel Segments	**Bridge Segments**
	

2.3 Advantages and Disadvantages of Using Prefabrication Components

There are advantages and disadvantages of using prefabrication components as a construction method.

2.3.1 Installation of Prefabrication vs. Traditional Construction Method[8,9,10,11,12]:

2.3.1.1 Advantages

There are many advantages linked to the usage of prefabrication in construction. Some of the examples include:

[8] Canada Mortgage and Housing Corporation
[9] Ministry of National Development Singapore
[10] Hong Kong Housing Authority
[11] Prefabrication Construction Practices in Hong Kong - City University of Hong Kong
[12] Construction Industry Council Hong Kong

1. **Shorter construction period and reduced labour quantity**

   Since prefabricated components can be made in a factory using automation systems and prior to construction period commencement, it can shorten the construction period and reduce the number of labourers required.

2. **Reduce adverse weather disruption during construction period**

   Prefabrication components are produced in a factory environment which is unaffected by weather or seasonal conditions that would have stalled traditional construction. For example, moulding of concrete cannot be done when cast-in-situ under rainy weather as the concrete cannot be cured properly. This could be solved by prefabrication of concrete components in a factory.

3. **Standardization and mechanization leads to higher productivity, consistent quality and can be worked to a very high structural or architectural standard**

   Comparing to cast-in-situ construction, prefabricated components are made in a highly standardized and mechanized factory, production can be more efficient and the end quality can be better and more stable. Prefabricated components made in factories can be worked to a very high structural or architectural standard[13] compared to cast-in-situ construction.

4. **Reduce amount of waste material**

   As production is standardized, prefabricated components can be casted in moulds and the use of materials can be optimized. This reduce the cost associated with waste material and the cost of production. Therefore, indirectly reducing waste from associated factories e.g. concrete plate and steel plate. As an example, the T30 Tower Hotel generated only 1% construction waste compared with cast-in-situ construction[14]. This shows that prefabrication can have a significant contribution in building sustainability.

5. **Environmental impact**

   Prefabrication can also contribute to a more environmentally friendly construction in the aspects of material optimisation, recycling, noise capture, dust capture, etc.

6. **Site safety**

   Workers working at prefabrication yards are less likely to be involved in accidents than those at construction sites. By using prefabricated components, the need for workers to conduct work-at-height activities is reduced. Also, it provides a better working environment by shifting on-site workers to a sheltered factory environment, with less impact from weather and better assistance with robots and computerized machinery.

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[13] Reference guide on standard prefabricated building components, Building and Construction Authority of Singapore

[14] Zhengdao Li, Geoffrey Qiping Shen and Mustafa Alshawi, *Measuring the impact of prefabrication on construction waste reduction: an empirical study in Shenzhen, China*

2.3.1.2 Limitations

Despite the above-mentioned advantages, there are certain downsides of using prefabrication components. These include:

1. **Higher transportation costs**

   Transportation costs may be higher for voluminous prefabricated sections than for their constituent materials, which can often be packed more densely or efficiently during transport.

2. **Heavy cranes and machinery required for installation**

   Specialised machineries and cranes might be required for installation on site as modular units such as prefabricated bathroom unit and prefabricated stairways are heavier and bulkier than traditional construction components.

3. **Storage and handling costs**

   Before prefabricated components can be delivered to construction sites, they need to be stored indoor to prevent wear and tear and effects of adverse weather. The storage cost and handling cost of the prefabricated parts should also be taken into consideration especially as land cost is high in Hong Kong. However, with good planning it is possible to minimize the need of storage and handling therefore reducing such cost.

4. **Transport restrictions**

   Transport in bulky prefabricated components could face a few challenges on the roads of Hong Kong due to the width and weight restrictions. For example, the overhanging load on vehicle must not exceed 2.5 metres in width and 4.6 metres in height from the road surface. Detailed transport planning should be studied before deciding the proposed prefabrication yard site based on available roads as well as size and weight of prefabricated components.

A summary of the advantages and limitations with installation of prefabricated components against the traditional construction method are as follows:

Advantages of using prefabricated components	**Limitations of using prefabricated components**
Speed up construction time and reduce labour cost	Higher transportation cost
Unaffected by weather/seasonal conditions	Heavy cranes and machinery for installation of prefabricated components
Standardization and mechanization leads to higher productivity and stable quality	Additional storage and handling costs
Less waste materials	Transport restrictions
Prefabricated elements can be worked to a very high structural design or architectural design standard.	
More environmentally friendly	
Reduce site safety incidents	

2.3.2 Locally Produced vs. Imported Prefabrication Components[15]

2.3.2.1 Advantages

When comparing locally produced prefabricated components and imported prefabricated components, the advantages of local productions includes:

1. **Lower transportation cost**

   Prefabricated components are usually bulky in size and could be costly when transporting from China and other countries. Significant transportation cost could be saved if purchased locally.

2. **Better supervision and monitoring**

   Quality control being done locally can be more reassuring as damage during lengthy transportation can be minimized and the local contractor can supervise the process of quality check to ensure the components fulfil the technical requirements and local design standards. For example, local engineers/quality assurers can perform better testing and monitoring at local testing lab if the components are made locally, without the need of long distance travelling.

3. **Reduced wastage of components during transport**

   When importing prefabricated components, additional packaging for protection might be required and some prefabricated components could be in bad condition on arrival if damages are accumulated during transit. Using local prefabricated components can reduce the wastage due to transportation.

4. **More stable quality**

   Better and more stable quality can be produced by highly skilled workers in Hong Kong with an intimate understanding of local standards and conditions

5. **Improve local labour workmanship and intensive training**

   Developing local prefabrication construction industry would create local demand for skilled labour working in factory environment. Skilled labour required by the prefabricated construction industry requires a blend of manufacturing and construction skills. This could encourage existing workers to enhance their knowledge of construction processes and skills.

[15] Survey on potential utilisation of prefabrication yards in Hong Kong – Construction Industry Council Hong Kong

2.3.2.2 Concerns

On the other hand, there are also several concerns over the use of locally produced prefabricated components. These include:

1. **More expensive**

   Huge work space is required for carrying out fabrication works and this is particularly critical in Hong Kong as rental cost could be high due to limited land supply. Heavy rental cost together with the high labour cost in Hong Kong will inevitably lift up the price of prefabricated components.

2. **Low level of supporting industries**

   Hong Kong does not have any concrete prefabrication yards in operation and hence there might be a low level of supporting industries, such as manufacturers and importers of prefabrication machinery.

3. **Longer production time**

   As Hong Kong does not have any concrete prefabrication yards in operation, newly established prefabrication yards would need to take time initially to meet full production whereas other prefabrication yards which have been in operation for quite some time do not need to. Adoption of automation systems could enhance the production efficiency.

The table below summarises the key advantages and disadvantages of using local prefabrication components:

Advantages of using local prefabrication components	**Disadvantages of using local prefabrication components**
Lower transportation cost	May be less cost effective due to higher land and labour costs
Better supervision and monitoring	Low level of supporting industry
Reduced wastage of components during transport	Longer production time initially for newly established yards
More stable quality	
Improve local labour workmanship and intensive training	
Reduced travelling time for inspections and supervision	

3 PREFABRICATION PRACTICES IN OTHER COUNTRIES

This section provides an overview of prefabrication practise in other countries including Singapore and Japan. These two countries have been identified in our study as they are well-versed in the use and manufacture of prefabricated components. These two countries also share similar characteristics to that of Hong Kong, such as limited land supply and labour skills/profiles.

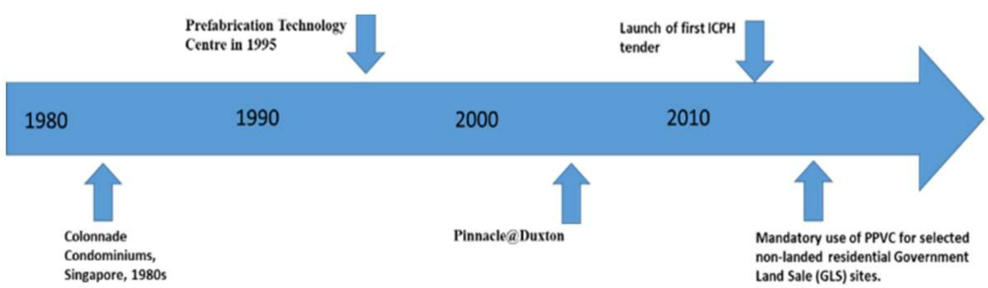
3.1 Singapore

3.1.1 Background and current state[16]

Singapore has been used as benchmarks for prefabrication yards as similar challenges impacting on prefabrication that are encountered in Singapore are currently being encountered in Hong Kong. Such as, increasing labour cost, aging population, limited and high cost of available land.

The use of prefabrication in Singapore also date back to the 1970s. They are the first country in SE Asia to use precast concrete prefabrication technology in the construction industry.

The diagram below provides an overview of the evolution of prefabrication development in Singapore:



[16] Building and Construction Authority of Singapore

The evolution of prefabrication component applications in Singapore are further elaborated as follows:

1970s – 1980s	Singapore is the first country in the Southeast Asia region to use precast concrete prefabrication technology in the construction industry. In the 1970s, contractors using the traditional low productivity cast-in-situ method could no longer cope with the surging demand in construction projects. As a result, the Singapore Housing and Developing Board (HDB) set up the industrialisation programme in public housing in the 1980s to encourage the industry to use innovative construction technologies that were more efficient. The first prefabrication project was awarded for the construction of three and four room flats in Hougang, Tampines and Yishun, while five major contracts were given to foreign contractors by HDB under the programme between 1981 and 1983.
1990s	After completion of these five projects, HDB shifted its emphasis from large scale industrialization to low volume flexible prefabrication. This enabled the setting up of more prefabricated component manufacturers, numbering at 12, making a wide range of components. The combined turnover of these 12 manufacturers comprised about 5% of Singapore’s total building construction by 1990. While public housing remained the major market for these manufacturers, the usage of prefabricated components in private developments were gradually increasing. The Prefabrication Technology Centre (PTC) was set up in 1995 to lead on the development and use of prefabrication technologies. This centre carries out prototyping and test-bedding to nurture the development of new building technologies for larger scale application in future HDB housing projects. The Pinnacle in Duxton is an example of a development that has achieved engineering breakthroughs, as almost the entire 50-storey building was modularised and prefabricated off-site.
2000s onwards	The Building and Construction Authority (BCA) is a statutory board established in 1999 under the Ministry of National Development of the Singapore Government. The primary role of BCA is to develop and regulate Singapore's building and construction industry.

	As part of the plan to increase construction productivity and improve construction process, BCA is encouraging the industry to design in such a way where as much work to be done off-site in a controlled manufacturing environment as possible. Working with various government agencies, BCA has formulated a masterplan for the development of multi-storey and higher density Integrated Construction and Prefabrication Hub (ICPH) on land with a 30-year lease term. As of 2017 BCA has awarded four land tenders for the development of ICPHs. The fifth land tender for the Development of an ICPH was launched in July 2017, with the closing date in January 2018. The government plans for 10 such hubs by 2020. More details of ICPH are mentioned in the Innovation/ Technology section

3.1.2 Innovation & Technology

To help resolve labour shortage problems in Singapore and to improve efficiency in the construction industry, the Singapore government has put in efforts in promoting prefabrication construction and improving prefabrication technology and automation.

PPVC (Prefabricated Prefinished Volumetric Construction) and ICPH (Integrated Construction and Prefabrication Hub) are two of the most notable milestones throughout the history of prefabrication development in Singapore.

3.1.3 Prefabricated Prefinished Volumetric Construction[17]

What is PPVC?

"Prefabricated Prefinished Volumetric Construction" (PPVC) are free-standing volumetric modules (complete with finishes for walls, floors and ceilings) that are Constructed and assembled and or Manufactured and assembled in an accredited fabrication facility, in accordance with any accredited fabrication method, and then subsequently installed in a building.

Benefits of PPVC[18]

Application of PPVC in construction projects entails a number of benefits, including improvements to productivity, reduction on on-site manpower, better construction environment and better-quality control etc. Details are further elaborated as follows:

Productivity Improvement	▪ The concept of Design for Manufacturing and Assembly (DfMA) was promoted by BCA to encourage as much done-off-site work in a controlled manufacturing environment as

[17] Building and Construction Authority of Singapore
[18] PPVC Guidebook - Building and Construction Authority of Singapore

	possible. PPVC is one of the technologies supporting the DfMA concept to speed up construction significantly. ▪ The on-site construction activities can be significantly reduced using PPVC. Fabrication of PPVC can proceed in parallel in the factory while other worksite activities are ongoing to streamline the construction process. ▪ Depending on project complexity, PPVC can improve productivity and save up to 40% in terms of manpower and more than 20% in terms of time[19].
Reduction of On-site Manpower	▪ Worksite safety can be improved as more construction is done in a factory-controlled environment, less individual man-hours working on-site at height will lead to fewer accidents and less downtime.
Better Construction Environment	▪ Off-site activities worked in a factory environment can minimise dust and noise pollution and reduce environmental impact. ▪ Negative impact to surrounding neighbourhoods during construction can be diminished. ▪ Less waste will be generated on-site and transportation with prefabrication of building modules
Better Quality Control	▪ PPVC delivers a majority of the final product from the controlled factory environment leading to increased reliability with higher-quality finishing.

Mandated use of PPVC

The use of Prefabricated Prefinished Volumetric Construction (PPVC) is mandatory for selected non-landed residential Government Land Sale sites in Singapore from 1 November 2014 onwards. Details of the mandatory requirement is attached in ***Appendix A***.

3.1.4 Integrated Construction and Prefabrication Hubs[20]

To encourage improvements in productivity among the construction industry, Singapore BCA has worked with various government agencies to formulate a masterplan for the development of multi-storey and higher density Integrated Construction and Prefabrication Hubs (ICPHs) with a high degree of mechanisation and automation on land parcels with a 30-year lease term.

[19] PPVC Guidebook - Building and Construction Authority of Singapore
[20] Building and Construction Authority of Singapore

Activities in ICPHs include:

a. Prefabrication of individual components

b. Prefabrication of integrated sub-assemblies and/or

c. Prefabricated and Prefinished Volumetric Construction (PPVC)

Background

In 2013, BCA announced the development of the first ICPH at Kaki Bukit awarded under a public tender. Upon completion, the new ICPH is expected to be equipped with a state-of the-art automated production line, which will have an annual production capacity of more than 100,000 cubic metres of prefabricated components (three times more than a conventional, open prefabrication yard).

At the end of 2017, BCA has awarded four land tenders for the development of ICPH, through GeBIZ, an online platform to manage all public tenders received by government. The fifth land tender for the Development of ICPH was launched in July 2017, with the closing date in January 2018. – the procurement portal for the Government.

Information on past tenders includes:

Date of Tender Launch	Date of Tender Award	Location	Site Area (m^2)	Max. Gross Plot Ratio	Successful Tenderer	Bid Price
16 May 2012	28 Feb 2013	Kaki Bukit Road 6 (KB 1 and KB 2)	20,385	1.6	SEF Construction Pte Ltd	$4.30/$m^2$ of land area per month
31 Jul 2013	16 Jun 2014		20,051	1.6	Straits Construction Singapore Pte Ltd	$12,000,000 (lump sum)
30 Oct 2014	21 Sep 2015	Airport Road (Defu 1 and Defu 2)	20,411	1.6	Soil-Build (Pte) Ltd	$22,889,000 (lump sum)
30 Jan 2015	12 May 2016		20,410	1.6	Teambuild Engineering & Construction (Pte) Ltd	$16,800,000 (lump sum)

Awarded Tenders of ICPH

A summary of the four tenderers who have successfully secured one of the plot of land in the ICPH includes:

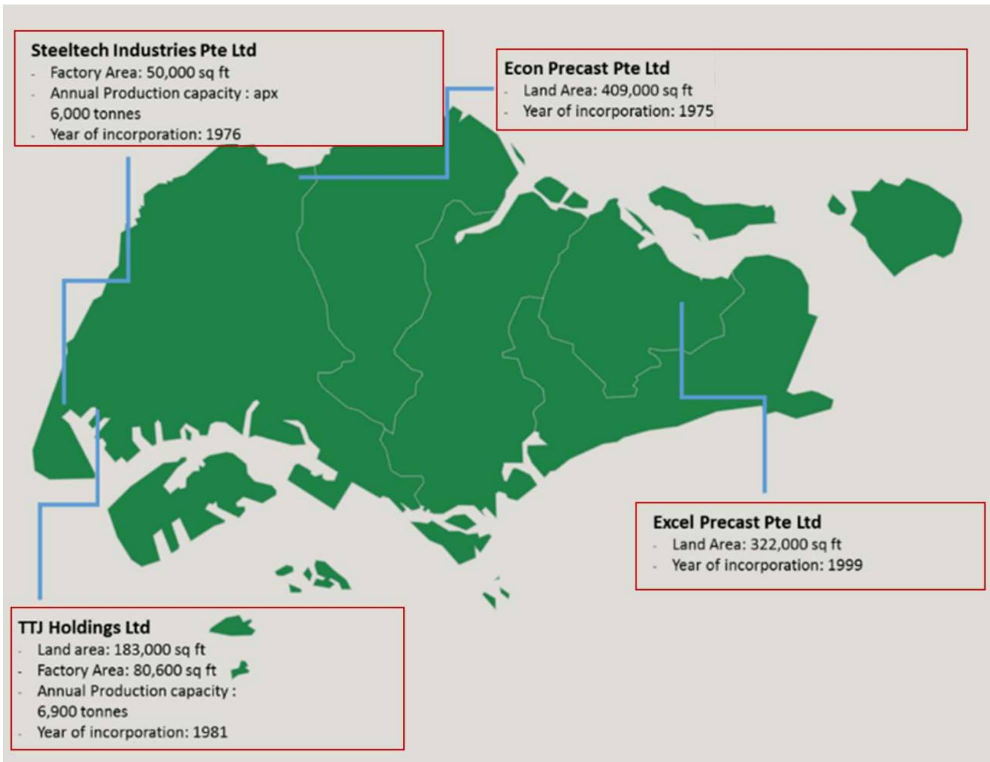
SEF SpaceHub	SEF SpaceHub by SEF Construction Pte Ltd. was the first to launch in 2013, occupied a site of 20,000 sqm, with a build-up area of 32,000 sqm housing 5 automated production lines for prefabricated concrete components.

	The development maximizes land utilization by having an Asia-first high rack automated stockyard for storage of finished prefabricated components.[21]
Greyform Pte Ltd	Greyform Pte Ltd, a member of Straits Construction Singapore Pte Ltd, was incorporated in 2015. It is the second to open with an automated production in a controlled factory environment, with relatively few personnel required to manage the factory floor. The cost of this development was approximately S$150 million. The hub has only 60 workers, and can produce the equivalent of 48 four-room Housing Board flats in 10 days, using half the time of traditional open yard prefabrication facilities.[22] The key capabilities of the hub include Automated Pallet Circulation, Automated Robotic Shuttering, Steel Reinforcement Fabrication and Automated Precast Storage[23].
Soil-Build (Pte) Ltd.[24]	Soil-Build (Pte) Ltd., a wholly-owned subsidiary of Soilbuild Construction Group Ltd. was awarded the tender for ICPH at Airport Road by BCA. The land area is approximately 20,400 sqm and the lease term is 30 years with effect from September 2015. The overall consideration for the lease is approximately S$26 million. The construction comprises factory premises for the integrated precast and prefabrication hub, an administrative office and a worker's dormitory and is scheduled to commence operations in the fourth quarter of 2017
Teambuild Engineering & Construction Pte Ltd[25]	Teambuild adopted the use of concrete PPVC at The Brownstone EC; the first private residential project to adopt PPVC. Teambuild also embarked on the development and construction of its own ICPH. The ICPH is a multi-storey advanced manufacturing facility for producing prefabricated construction elements and will be fitted with automated and integrated production, storage and racking systems. This will facilitate the development and manufacturing of PPVC modules locally, cutting down on transportation and further reduces the manpower needed.

[21] SEF Construction Pte Ltd. website
[22] Singapore Press Holdings Ltd. Co, The Straits Times, BCA to give advance notice on building projects that need high level of prefabrication
[23] Building and Construction Authority of Singapore
[24] Soilbuild Construction Group media statement
[25] Building and Construction Authority of Singapore

3.1.5 Leading Prefabrication Manufacturers in Singapore[26]

Some of the leading prefabrication manufacturers located in Singapore includes Steeltech Industries Pte Ltd, Econ Precast Pte Ltd, Excel Precast Pte Ltd & TTJ Holdings Ltd. Their locality can be seen in the map below:



A summary of each of these leading manufacturers are described in detail below.

TTJ Holdings Limited[27]	TTJ Holdings Limited, incorporated in 1981, is a structural steel specialist offering design, supply, fabrication and erection of a wide spectrum of structural steelworks for use in the construction of buildings, factories, plants and infrastructure. It has won many iconic projects in Singapore and the Middle East including, Changi Airport Terminal 3, the Pinnacle in Duxton, the Singapore New Supreme Court, the Double Helix Duplex Stainless Steel Bridge at Marina Bay as well as the Bahrain World Trade Centre Twin Towers and the Burj Dubai Development Plot 12 & 13. It currently has two fabrication yards including the Pioneer Factory in Singapore and Keluli Factory in Johor, Malaysia, which have approximate land area of 17,000 sqm, and 86,198 sqm respectively. Together these facilities have a current combined maximum annual

[26] Information from Steeltech Industries Pte Ltd website, TTJ Holdings Limited website, Excel Precast Pte Ltd website, Econ Precast Pte Ltd website, Seterra Online

[27] TTJ Holdings Limited website

	production capacity of 42,000 tonnes, making TTJ Holdings Limited one of the largest independent structural steel fabricators in Singapore. Its production ranges from heavy lifting cranes, ship-lift platforms, piping systems for fluid processing plants to structures for high rise buildings and petrochemical complexes, heavy roof truss, bomb shelter doors, steel moulds and launching girders for bridges and highways, pressurize vessels and tanks, vehicular aluminium parapets, expansion joints and bearings for highways and roads.
Steeltech Industries Pte Ltd[28]	Steeltech Industries Pte Ltd is a wholly-owned subsidiary of Tiong Seng Contractors Pte Ltd and was incorporated in 1976 with the name Tiong Seng Equipments Pte Ltd. In 2005, it had a workforce of only 12 but currently it has a workforce of more than 220 including in-house subcontractors. It has been involved in projects such as Capella Hotel in Sentosa, Marina Bay Resorts, Resorts World Sentosa, Park Royal at Pickering Street, Farrer Road MRT Station, Caldecott MRT Station and Draycott Drive. Its factory is based in Tuas Link 2, Singapore with about 50,000 sqft of floor area and capable of producing 6,000tons of output annually. Its core products include metal & stainless steel work, structural steel work, steel mould fabrication and prefabrication toilet & bath unit.
Excel Precast Pte Ltd[29]	Excel Precast Pte Ltd was incorporated on 10 March 1999 to undertake prefabricated concrete design and manufacturing to cater for the increasing demand of prefabricated method of construction in Singapore. It supplies Concrete Prefabricated Prefinished Volumetric Construction (PPVC) system, Prefabricated Bathroom Unit (PBU), and a wide range of prefabricated concrete products such as stair flight, infill wall with beam, concrete façade, water tank, door frame and prestressed plank etc. Its prefabrication factory located at Tampines Industrial Street, Singapore occupies 322,000 sqft of land while another prefabrication factory set up in 2009 in Senai, Johor Malaysia occupies another 430,000 sqft of land. Past projects of Excel Precast Pte Ltd includes “Trivellis” Public Housing Development of 3 blocks of 40-storey residential flats, Punggol West C30, Aerohub in Singapore, The Palette Condominium in Pasir Ris, the Singhealth Polyclinic and the Mandai Crematorium & Columbarium etc.

[28] Steeltech Industries Pte Ltd website
[29] Excel Precast Pte Ltd website

Econ Precast Pte Ltd[30]	Founded in 1975, Econ Precast Pte Ltd has grown to be a leading supplier of prefabricated reinforced concrete piles and building components in Singapore. Its products range from volumetric components such as Space Adding Items, Utility Rooms and Lift-Wells used mainly in HDB's Major Upgrading Program and Lift Upgrading Program. Other prefabricated components include restressed and prefabricated beams, columns, reinforced concrete piles, reinforced concrete cylindrical pipes, refuse chutes, staircase flights, as well as architectural façade wall panels and external walls. Its prefabrication yards are located Kranji Way, Singapore, occupying a combined area of approximately 38,000sqm. In additional to its yards in Singapore, it has another yard in Pontian, Malaysia with an area of approximately 48,000sqm. Econ Precast Pte Ltd has involved in various projects in Singapore including building projects in Queenstown, residential buildings in Sengkang and Geylang and proposed boardwalk from VivoCity to Sentosa.
Others	• SPP System Pte Ltd • Integrated Precast Solutions Pte Ltd • Vico Construction Ptd Ltd • Unitised Building Pte Ltd • Sembcorp EOSM Pte Ltd • Moderna Homes Pte Ltd • AM Modular (Singapore) Pte Ltd • Quicksmart Technology (Singapore) Pte Ltd • iMax Modular Pte Ltd • TK Modular Pte Ltd • Lightrus Pte Ltd • Prefab Technology Pte Ltd

3.1.6 Prefabrication Lessons Learnt in Singapore[31]

Whether it's the production, transportation and/or installation of prefabrication components, there are some vital lessons learned elements that has materialised in Singapore. Some of which are identified in the table below:

[30] Econ Precast Pte Ltd website
[31] Singapore government – Building Careers

Long-span structures are more challenging to build using PPVC as longer modules require more planning for transportation	According to Land Transport Authority's traffic regulatory requirements [32] , police escort will be required for transportation if the vehicle's parameters exceed that stated in the regulation (Height>4.5 meters or Width>3.4 meters or Laden Weight>80 tonnes). Also, transportation of large modules has to be done within restricted hours at night. Long-span structures typically require larger/longer prefabricated components and therefore more specific planning for transportation will be required.
High cost of shipping empty modules	Using prefabrication technology, the NTU hostel project in Singapore costed 18 percent more than it would have done if built using traditional methods. One of the contributing reasons is that a lot of "empty modules" were shipped. Since containers are charged by volume, not weight, this had incurred huge transportation cost. One solution to this is to ship the modules flat-packed. It should be taken into consideration if the proposed prefabrication yard in Hong Kong is planning to import raw materials or to export finished goods to other countries by shipment.
Planning has to be precise to minimise the need for storage	The use of PPVC requires additional land for the fitting-out and storage of the prefabricated components, in Singapore's case most contractors use land in Singapore or Malaysia. It is important for contractors to do proper planning to ensure on-time delivery of components, so that storage and land costs can be minimised by reaching efficiency. Contractors can hire project management consultants to advise on the timeline of construction so that the delivery of prefabricated components can be 'Just-in-time'.
Indirect Subsidy from Government	Despite there were no direct subsidy from the government, the prefabrication industry has been benefiting from various government policies and regulations. For example, the mandatory use of PPVC for selected non-landed residential Government Land Sale sites in Singapore are forcing contractors to use a larger percentage of prefabricated components in their construction projects.

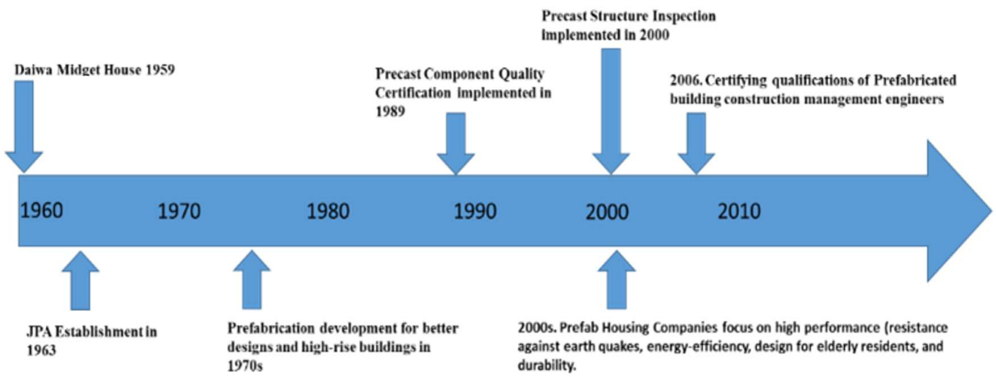
3.2 Japan

The growth of prefabrication in Japan is very much related to the timing of various warfare happening around the world, including World War II and the Korean War.

[32] Building and Construction Authority of Singapore

Due to these unfortunate events, there was a major shortfall of homes which triggered the need for mass production of prefabricated homes.

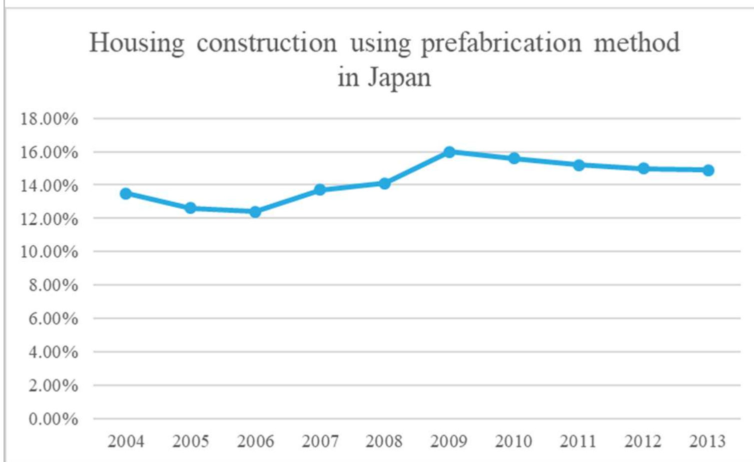
The diagram below provides an overview of the evolution of prefabrication development in Japan:



The evolution of prefabrication component applications in Japan are further elaborated as follows:

1945 – 1950s	The growth of prefabrication in Japan can be seen as related to warfare timing. With the end of World War II in 1945, coupled with supporting the U.S. military with steel production for the Korean War in the 1950s, Japanese factories needed to find alternative source of demand for steel after the conflicts. After years of war, there was a shortfall of 4.2 million housing homes[33]. The Government of Japan established the Government Housing Loan Corporation to provide low-interest fixed-rate mortgages to help with the recovery.[34] Prefabrication for home construction immediately boomed, but this also created a simple mass production product that the public came to associate as low quality.
1950s - 1963	To improve the public image of prefabricated homes, the Japanese Prefabricated Construction Suppliers and Manufacturers Association (JPA) was established in 1963 by the Ministry of Construction and the Ministry of International Trade and Industry to promote prefabrication construction as a way to create a rich living environment.
	From 1963 – 2014, approximately 9 million prefabricated houses was constructed in Japan using mainly iron/steel, concrete, and

[33] Masahiro Kobayashi, *The Housing Market and Housing Policies in Japan, 2016*
[34] Masahiro Kobayashi, *The Housing Market and Housing Policies in Japan, 2016*

1963s to Current	wood[35]. As of 2014, there were 80 registered firms and 98 Sponsors.[36] From 2004 – 2013, there has been an increasing trend of housing construction using the prefabrication method. [37]
	

3.2.1 Housing as long-term investment is not common in Japan

Unlike other countries where having a home is a long-term investment, Japanese homes depreciate within 20-30 years, creating a disposable-home culture. This basically has created an everlasting market with buyers wanting to change the house to reflect their lifestyle. Construction time therefore will not only affect the overall cost in labours and equipment, but with time saved using prefabrication construction, Japanese home owners can move back in faster, which also directly influence the amount saved (i.e. temporary accommodations).

“Rather than spending money on expensive retrofitting, people just build new homes." According to Shuichi Matsumura, a professor of architecture at the University of Tokyo. Prefabricated buildings made up around 7 percent of new homes in the early 1970s. By 2016, they accounted for more than 15 percent.

Another trend the Japanese housing market has created over the years is an influx of architects. According to the International Union of Architects, Japan has almost 2.5 architects per 1,000 residents, whereas Britain only has half an architect per 1,000 residents.

[35] Junichi Goda, *Overview of prefabricated housing in Japan, 2015*
[36] Japan Prefabricated Construction Suppliers and Manufacturers Association, *Progress in Activities for Recovery from the Great East Japan Earthquake, 2014*
[37] Junichi Goda, *Overview of prefabricated housing in Japan, 2015*

3.2.2 Japanese Prefabricated Construction Suppliers and Manufacturers Association (JPA) [38]

Japanese Prefabricated Construction Suppliers and Manufacturers Association (JPA) was established in 1963 as an organization to develop the industrial production of housing and promoting the modernization and rationalization of the construction industry.

In 1989, the Prefabricated Concrete (PC) Components Quality Certification Project was launched to ensure quality of the PC component and competent supply for use in buildings.

With the installation of the Housing Quality Assurance Act in 1999 and the new regulations on performance under the Building Standards Act, in the year 2000, the system for inspecting PC structures was formed to increase the importance of ensuring appropriate structural safety and operability of PC architecture.

JPA started the system for certifying qualifications of PC building construction management engineers in 2006.

3.2.3 Types of Prefabrication Constructions in Japan:[39]

The types of prefabrication components used in Japan vary slightly from those used in Singapore and Hong Kong. Examples of those includes:

Iron and Steel Prefabricated Houses and Buildings Steel frame comprises the main structural members, using wall panels with steel-frame columns and beams	
Unit prefabricated housing and buildings Modules (units) made with frames of steel or wood are produced at the factory and "connected together" at the construction site	

[38] Japan Prefabricated Construction Suppliers and Manufacturers Association website
[39] Source: Junichi Goda, *Overview of prefabricated housing in Japan*, 2015

Wooden prefabricated housing and buildings The main structural members are panels and other items made of wood	
Concrete prefabricated housing and buildings The main structural members are PC panels and other PC components (prefabricated concrete panels produced at the factory)	

3.2.4 Innovation & Technology

Prefabricated components manufactured in Japan typically achieve energy efficiency and must cater for earthquake resistance. Details are as follows:

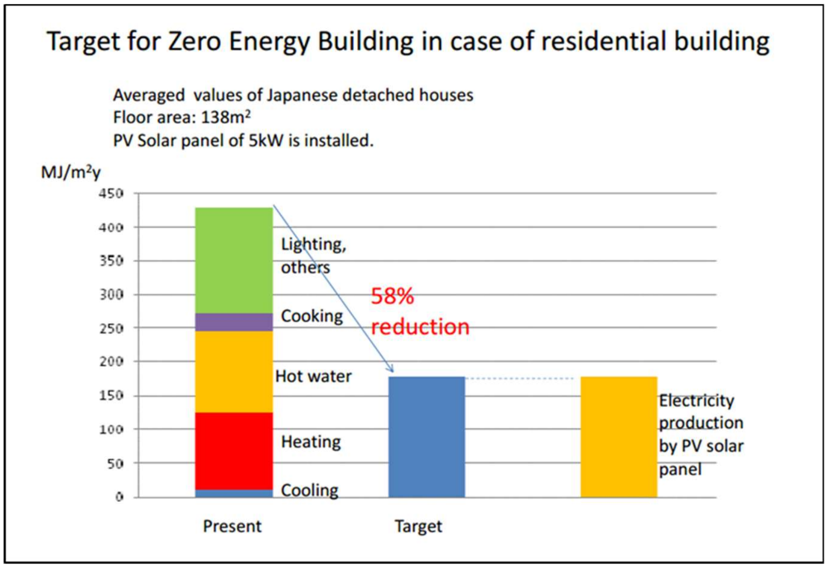
Energy Efficiency

Several companies across the country are now offering zero energy ready prefabricated homes or prefabricated panel components that are suitable for zero energy construction. A Zero Energy House is a house that consumes less energy than it produces on a net annual basis by creating renewable energy, usually through photovoltaic cells installed on the roof. Using the "zero energy" approach, Renew homes are ready for the addition of solar electric panels that will generate all the power they need. [40]

In a study by Professor Ryozo Ooka of the Institute of Industrial Science at the University of Tokyo, he found that zero energy houses are theoretically possible to build in Japan. As detailed in the chart below, a typical 138sqm (about 1,485 sqft) detached house consumes on average 425 Megajoules of energy per square meter per year.

With improved energy-efficiency measures, energy usage could theoretically be decreased by 58%. A 5-kilowatt photovoltaic solar panel installed on the roof could produce the remaining needed energy, resulting in a net zero energy house.[41]

[40] Zero Energy Project website, posted by Bruce Sullivan, 2016
[41] Real Estate Japan Inc, *The present and future of net zero energy houses in Japan*



Earthquake Resistance

The Building Standard Law was enacted in 1950, which covers structural and earthquake safety has been a key focal point for all buildings. Companies such as Sekisui Heim, goes through stringent testing of their products. [42]

3.2.5 Leading Manufacturers in Japan

There are a number of leading prefabrication house manufacturers in Japan, including Sekisui House Ltd, Daiwa House Industry Co, Ltd, Misawa Homes Co., Ltd, Taisei Corporation, Muji Hut etc. Details of each of these manufacturers are summarised as follows:

Sekisui House, Ltd. [43]	Sekisui House is one of the largest homebuilders founded in 1960 with its headquartered in Osaka. Starting 2009, Sekisui House expanded into Singapore, China, Australia and the United States, while 5 factories are located in Tohoku (Miyagi), Kanto (Ibaraki), Shizuoka, Hyogo and Yamaguchi. The Industrialized House Construction segment is engaged in the design, construction and contract work of steel frame, wood frame, concrete houses and low-rise apartment buildings. As one of the largest prefabricated house manufacturers, it has sold 13,612 custom detached houses in 2015.
Daiwa House Industry Co., Ltd. [44]	Founded in 1955, Daiwa House Industry Co., Ltd is one the largest home builders specializing in prefabricated houses. Daiwa House Industry developed the Midget House, which

[42] Mr. Hasegawa Tomohiro, *Introduction to the Building Standard Law – Building Regulation in Japan, 2013*
[43] Sekisui House, Ltd. website
[44] Daiwa House Industry Co, Ltd. website

	started out as a study room that can be constructed within 3 hours, it is also said to be the origin of the prefabricated house. The company today has grown to 92 subsidiaries including construction of factories, shopping centres, health care facilities, and management and operation of other industries.
Misawa Homes Co., Ltd. [45]	Established in 2003, Misawa Homes Co., Ltd is a Japanese based housing construction company which has four business segments. The Group Business Planning and Management segment, Sales and Management segment, Production and Logistics segment, and the Research, Development and Investigation segment. The Planning and Management segment is involved in the manufacture and sale of prefabricated housing, planning and management for procurement and production of housing materials, design, construction planning and management of prefabricated housing.
Taisei Corporation [46]	Established in 1873, Taisei Corporation is the oldest contractor in Japan. Restructured as an employee-owned corporation, Taisei has constructed many civil and architectural projects including residential housing both in Japan and overseas. Taisei is also well known in Japan for its disaster resistant housing brand 'Palcon'.
Muji Hut [47]	Founded in 1979, Muji Hut is a Japanese retail company which sells a wide variety of household and consumer goods. In the 3rd quarter of 2017, it is one of the latest companies in the home prefabrication industry. As a new company in the prefabrication of houses, it offers less than 100 sqft tiny house designed with minimalistic aesthetic, sales are currently targeting Japan market only.
Others	• Orient House Co., Ltd. • Sankyo Frontier Co., Ltd. • Tachikawa House Industry Co., Ltd. • Nagawa Co., Ltd • Nittohkoei Co., Ltd • Hokuto House Co., Ltd. • Omachi World Co., Ltd. • Kohri Co., Ltd. • System House R & C Co., Ltd. • Naito House Co., Ltd. • Nissei Build Industries Co., Ltd. • Fujisangyo Co., Ltd

[45] Misawa Homes Co., Ltd website
[46] Taisei Corporation website
[47] Muji Hut website

3.2.6 Lessons Learnt from Japan

There are reasons why prefabricated components are adopted in Japan which differ to that of Singapore and Hong Kong. The extent of automations implemented in the productions lines of the prefabrication yard are much more focuses than those typically in Mainland China. Details of the lessons learned are summarised as follows:

Reasons customers in Japan chooses a prefabricated house	A survey from the Japan Ministry of Economy, Trade and Industry shows that the major reasons customers chooses prefabricated homes are due to the reliability of large prefabrication companies and the superiority of quality and performance of their work. Moreover, good customer services and detailed explanation from the staffs are key drivers in selling prefabricated houses.
Highly automated production line	Japan's approach to prefabricated houses is similar to that of the automotive industry. Matthew Aitchison, researcher from The University of Queensland Australia, describes the house factories as 'populated with robots, house parts trundling along assembly lines, with technician assembling them like a car.'[48] Companies like Sekisui House has been adopting highly automated production line and computer-controlled automated manufacturing process for a long time (details in Section 9.2), this enabled the high production volume of prefabricated houses in Japan each year despite shortage in construction labour.

[48] Asia Green Buildings, *Lesson from Japan: prefabricated houses for green development*

4 DEFINING THE 'PRELIMINARY BASE CASE'

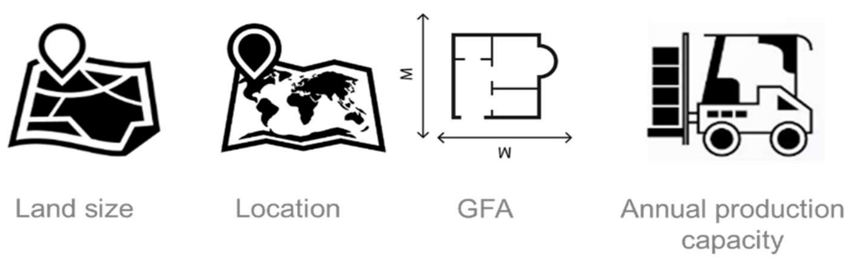
4.1 Overview

For the feasibility study, there is a need for us to define the proposed development / project before we can proceed with our assessment of possible site locations (Section 5). This starting point is known as the "Preliminary Base Case". Once the possible site is identified and before we proceed with preliminary analysis of industry viability (Section 7, we have further analysed and revisit the definition of Preliminary Base Case to ensure that it is defined accordingly, based on key planning, land use, traffic and environmental considerations in the possible site to arrive at "Base Case" (as shown in Section 6.

4.2 Approach

In the absence of preliminary design of the proposed prefabrication yard, our approach to deriving an estimated yard size, gross floor area (GFA) and its production capacity has been to utilise the existing size and scale of several comparable benchmarks.

The diagram below summarises the information required for us to proceed with our assessment.



We have selected four prefabrication yard benchmarks based on the following criteria:

- It is a multi-storey integrated prefabricated manufacturing plant
- It is not an open yard, with a sheltered production area
- It has a production capacity of more than 100,000 tonnes per annum

4.3 Benchmark

With the absence of local concrete prefabrication manufacturers operating in Hong Kong, we have adopted information from several prefabrication yards manufacturers that have been set up and operating in Singapore as benchmarks for deriving the estimated yard size, gross floor area (GFA) and its production capacity for our yard design and operation. Refer to ***Appendix B*** for prefabrication manufacturer case studies.

The table below summarises the outcome of our benchmarking exercise:

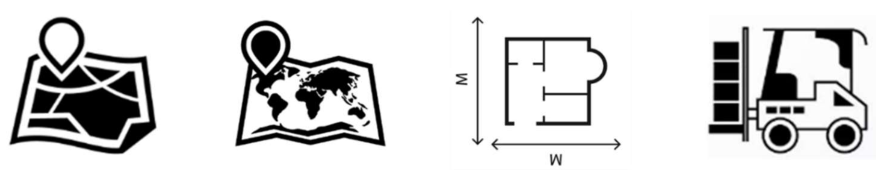
Name	Land plot size (sqm)	Build up area (sqm)	Production p.a. (tonnes)	Production / built up area (tonnes /sqm)
SEF SpaceHub	20,386[49]	32,608[50]	241,000[51]	7.39
Greyform Building	20,051[52]	32,100[53]	>150,000[54]	>4.67*
Tiong Seng Prefab Hub[55]	n/a	19,813	241,000	12.16
Poh Cheong Singapore Plant 1[56]	16,165	9,290*	93,990*	10.12
Average**	**19,000**	**28,000**	**210,000**	**9.9**

* We have excluded these outliers from our analysis.

** The average amount is calculated based on the total values of the comparable dividing by the number of comparable (e.g. tonnes/sqm: (7.39+12.16+10.12)/3)

4.4 The "Preliminary Base Case"

Based on the above 'benchmark' exercise, we have assumed that the development of the yard would have characteristics in line with the mid-point of values shown in the "average" row in table above for the size and scale of the proposed yard.



Land size
19,000 sqm

Location
??

GFA
28,000 sqm

Annual production capacity
277,200 tonnes
(9.9* x GFA)

* 9.9 tonnes / sqm is based on benchmarking exercise outcome shown in Section 4.3,

We note that upon completion of the assessment of possible sites in the next chapter, we would need to revisit the assumptions above, in particular on the land size and GFA, to take into consideration any limitations in the selected site(s).

[49] BCA – Integrated Construction and Prefabrication Hub tender
[50] BCA News Release, *29 July 2013, New integrated construction and precast hub to boost precast production for building demands*
[51] BCA News Release, *29 July 2013, New integrated construction and precast hub to boost precast production for building demands*
[52] BCA – Integrated Construction and Prefabrication Hub tender
[53] JTC Corporation, List of major industrial projects completed in 4th quarter 2016
[54] The Straits Times, *BCA to give advance notice on building projects that need high level of prefabrication*
[55] BCA news press, 4 January 2011, *Tiong Seng's $26 million Prefab Hub – Singapore's 1st automated pre-cast facility and first to receive BCA funding*
[56] Poh Cheong website – Plants & Facilities

5 ASSESSMENT OF POSSIBLE SITES

5.1 Introduction

This section describes the assessment of possible site(s) for the development of prefabrication yard in Hong Kong. We have analysed the site(s) with the objective of identifying suitable location(s) to develop and operate the prefabrication yard, taking into consideration the land size, any spatial requirements and statutory planning considerations as well as the transportation and environmental considerations.

5.2 Approach

In completing our assessment of possible sites, our first step involved developing a criteria list to screen, in order to identify and select the potential site(s). We have split our assessment into two parts:

- Part A: Identification of Possible Industrial Areas
- Part B: Identification of Potential Site(s)

The section below summarises our four-step selection process in identifying the potential site(s) for the development of a prefabrication yard.

5.3 Part A: Identification of Possible Industrial Areas

Step 1: Identification of industrial areas in Hong Kong

As defined in the Preliminary Base Case, the development of a prefabrication yard is most likely to be an MSB (multi-storey building). We have assumed that the proposed prefabrication yard, shall be a facility of "Industrial Use" based on the definition under the broad category of Industrial Use[57]. This assumption is subject to the vetting by TPB (Town Planning Board) and the actual nature of the prefabrication operations.

It is important that during our site selection assessment we look for a potential site that is located within a planning zone that allows the use of prefabrication operations. For the purpose of our analysis, we have prioritised our search on "Industrial" zone on the OZPs. In addition, these "Industrial" zones are shortlisted from the "*Report on 2014 Area Assessments of Industrial Land in the Territory*"[58] published by the Planning Department (PlanD), which contains the official record and most comprehensive analysis for all "Industrial" zones in the territory.

As a result, our analysis shows that there are approximately 23 possible industrial areas in Hong Kong for the development of prefabricated yards as shown in the table below:

[57] See Definitions of Terms, from: http://www.info.gov.hk/tpb/en/forms/dot_revised_broad.html.
[58] Source: https://www.pland.gov.hk/pland_en/p_study/comp_s/industrial_report_2014/index.htm

District	Possible Industrial Areas	Uses
Kwai Tsing	Central Kwai Chung	I
	South West Kwai Chung	I
Western District	Kennedy Town	I
Eastern District	Chai Wan	I
Southern District	Tin Wan Praya Road	I
	Ap Lei Chau West	I
	Ap Lei Chau Praya Road	I
	Po Chong Wan	I
Yuen Long	Ping Shan	I
	San Hei Tsuen. Tong Yan San Tsuen	I
Tuen Mun	Tuen Mun Area 9 and 12	I
	Tuen Mun Area 16	I
	Tuen Mun Area 40	I
	Wu Shan Road	I
	OU (Port back-up storage & workshop use) Zone	I
	OU (Storage & workshop uses) Zone	I
Fanling / Sheung Shui	Fanling Area 48	I
	On Lok Tsuen	I
	Sheung Shui	I
Sha Tin	Fo Tan	I
	Sha Tin Area 65	I
	Siu Lek Yuen	I
	Tai Wan	I

Apart from the conventional “Industrial” zone, we have also considered in our analysis the following new land use zonings:

- “Other Specified Uses” annotated “Port Back-up, Storage and Workshop Uses” (“OU (PBU, Storage and Workshop Uses)”) in Hung Shui Kiu New Development Areas (HSK NDA); and
- “Other Specified Uses” annotated “Storage and Workshop Uses” (“OU (Storage and Workshop Use)”) zones proposed under the Planning and Engineering Study for Housing Sites in Yuen Long South (YLS).

The Government of Hong Kong is encouraging the development of MSBs to accommodate logistics and other brownfield uses (industrial in nature) in the territory in the "OU" zones stated above.

In the event that the potential site is located in a non-industrial zone, a S12A application under the Town Planning Ordinance (TPO) (Cap. 131)[59] would be needed to rezone the site to an appropriate zoning. For the purpose of our analysis, we have assumed that no S12A application is required unless under exceptional circumstances, as the application process could be very lengthy and could create uncertainty for the development of the proposed prefabrication yard. S12A application would require additional technical assessments (not limited to traffic, visual, drainage, sewage, air ventilation, environmental, geotechnical etc.) to demonstrate the feasibility of the development of the proposed prefabrication yard.

Alternatively, should the said 'Industrial' uses for prefabrication yard fall under Column 2 of the Schedule of Uses of the site's zoning, a S16 application under TPO would be required in order to obtain planning approval from TPB for the development of the prefabrication yard. Although the application process of S16 may not be as complicated as S12A application mentioned above, the submission of S16 planning application to the TPB would be subjected to uncertainty in the application timing and approval from TPB.

Step 2: Understanding of locational requirement and the availability of infrastructure

Based on the outcome of our interview sessions in November 2017, we have been informed that the preferred locations for the development of a prefabrication yard should be at least:

- **Requirement 1:** Close to the source of raw materials and chemical that are mainly delivered from Mainland China; and
- **Requirement 2:** Availability of road infrastructure to transport raw materials from Mainland China
- **Requirement 3:** Close to sea transportation routes to allow shipping of raw materials, large size aggregates and prefabricated components by sea.

For the purpose of our analysis, we have assessed the industrial areas by shortlisting district / areas that fulfilled Requirement 1 first before proceeding to analysing Requirement 2 and 3.

[59] The appropriate statutory planning procedures should be determined on a case-by-case basis and subject to the vetting by relevant Government departments.

Opportunities

Our analysis shows that out of the eight selected districts only three of them have fulfilled Requirement 1 (i.e. within close proximity to sources of raw materials and available road infrastructure). The three districts include:

- **Yuen Long:** The Possible Industrial Areas in Yuen Long are located approximately 12km from the borders with Lok Ma Chau and 10km Shenzhen Bay.
- **Tuen Mun:** The Possible Industrial Areas in Tuen Mun are located approximately 14km from the border near Shenzhen Bay.
- **Fanling / Sheung Shui:** The Possible Industrial Areas in Fanling/ Sheung Shui are located 6km from the border near Man Kam To.

As we progressed with the analysis of Requirement 2 (availability of road infrastructure to transport raw materials from Mainland China), we have eliminated Fanling / Sheung Shui from our analysis due to the following reasons:

- Although Sheung Shui / Fanling is located closest to the Mainland China via Man Kam To Road, Sha Tau Kok Road and future Liantang/ Heung Yuen Wai Boundary Control Point, however our analysis shows that there is currently a plan for public housing development in Fanling Area 48 and Sheung Shui Area 30.
- In addition, the road network at Sheung Shui/ Fanling and the strategic highway (i.e. Fanling Highway and Tolo Highway) are experiencing traffic congestion. The future development (i.e. the planned public housing) will further increase the traffic demand of the area.

We have concluded that only two districts i.e. Yuen Long and Tuen Mun are selected as the preferred industrial areas for further analysis, as both districts fulfilled all three requirements:

- **Yuen Long:** Yuen Long is located approximately 5 km from the sea.
- **Tuen Mun:** The Possible Industrial Areas in Tuen Mun are located merely within 1.0m to the pier facilities.

Our analysis of the Possible Industrial Areas is summarised in the table below:

District	Possible Industrial Areas	Requirement		
		1	2	3
Kwai Tsing	Central Kwai Chung South West Kwai Chung	No	No	No
Western District	Kennedy Town	No	No	Yes
Eastern District	Chai Wan	No	No	Yes
Southern District	Tin Wan Praya Road Ap Lei Chau West Ap Lei Chau Praya Road Po Chong Wan	No	No	Yes
Yuen Long	Ping Shan San Hei Tsuen. Tong Yan San Tsuen	Yes	Yes	Yes
Tuen Mun	Tuen Mun Area 9 and 12 Tuen Mun Area 16 Tuen Mun Area 40 Wu Shan Road OU (Port back-up storage & workshop use) Zone OU (Storage & workshop uses) Zone	Yes	Yes	Yes
Fanling / Sheung Shui	Fanling Area 48 On Lok Tsuen Sheung Shui	Yes	No	No
Sha Tin	Fo Tan Sha Tin Area 65 Siu Lek Yuen Tai Wan	No	No	No

Requirement 1 to 3

Requirement 1

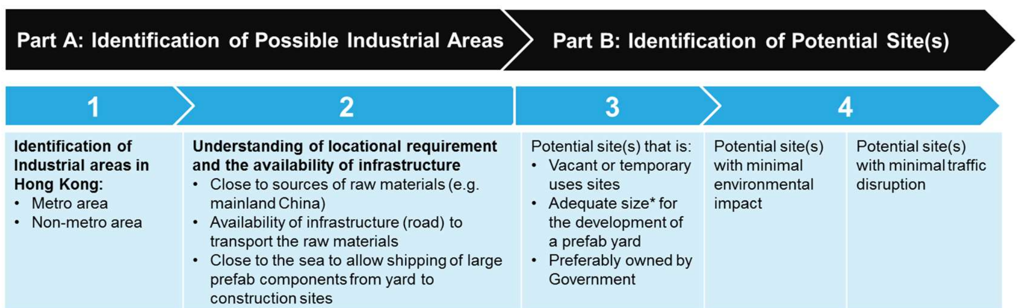
5.4 Part B: Identification of Potential Development Sites

5.4.1 Step 3: Identification of Potential Site(s) from Planning and Land Use Analysis

Based on the outcomes from Section 4, we have further analysed the suitability of each of the eight Possible Industrial Areas in Yuen Long and Tuen Mun for the development of a prefabrication yard. We have undertaken our analysis based on the following criteria / assumptions:

- **Vacant / Temporary uses sites -** We have only considered vacant sites, or sites with temporary uses. We have referred to the Report on 2014 Area Assessment of Industrial Land in the Territory as the official source to determine whether a particular site within the Possible Industrial Area is vacant and/or temporary use in nature.

- **Site area** – We have assumed that the development of the prefabrication yard would have characteristics in line with the mid-point values of our benchmarking exercise shown in Section 4. As described in the Preliminary Base Case, the development of prefabrication yard would need a minimum land area of approximately 19,000 sqm, and a GFA of approximately 28,000 sqm. We note that upon completion of the assessment of possible sites in this chapter, we would need to revisit the Preliminary Base Case to take into consideration any limitations in the selected site(s).
- **Land ownership** – Our analysis has prioritised land owned by the Government in order to avoid delay in the development plan as a result of lengthy time spent in negotiating with multiple private landowners.



* Yard size requirement is based on our benchmarking exercise

In Steps 3 and 4, we concluded our key findings by providing the following rating to each of the Potential Site(s):

Legend		Description
	More favaourable ↕ Least favaourable	Potential Site(s) which fulfilled most of the requirements and / or with minimal constraints ↕ Potential Site(s) which do not fulfill most of the requirements and / or with many constraints

For detail analysis of each of the sites, refer to ***Appendix C.***

The key findings of the sites selected for analysis are summarised in the table below.

District	Possible Industrial Areas	No. of Potential Site(s) and Site Area	Result
Yuen Long	Ping Shan	1 no., about 28,000 sqm	○
	San Hei Tsuen. Tong Yan San Tsuen	2 nos., varying from about 3,900 sqm. to 4,000 sqm.	◔
Tuen Mun	Tuen Mun Area 9 and 12	1 no., about 3,000 sqm	◔
	Tuen Mun Area 16	2 nos., varying from about 1,900 to 10,000 sqm.	○
	Tuen Mun Area 40	1 no., about 36,000 sqm.	◕
	Wu Shan Road	1 no., about 600 sqm.	○
	OU (Port back-up storage & workshop use) Zone	4 nos., varying from about 16,500 to 154,000sqm.	◕
	OU (Storage & workshop uses) Zone	1 nos., about 17,000 sqm.	◔

5.4.2 Step 4: Identification of Potential Site(s) from Environmental Impact and Traffic Condition Analysis

Results		Rationale
Environmental impact	◑	▪ Close proximity to sensitive receivers would be an issue with the noise and air emissions generated from the prefabrication yard operation
Traffic condition	◑	▪ Proximity to adjacent port docking ▪ Current traffic pattern would change due to ongoing large scale development

5.4.3 The selected Potential Site

Based on our site selection analysis above, we have selected Tuen Mun 40 as the more favourable site for the proposed prefabrication yard.

Table below summarises our key findings of the favourable site:

District	Possible Industrial Areas	Planning and land use	Environmental impact	Traffic condition
Tuen Mun	Tuen Mun Area 40	◕	◑	◕
	OU (Port back-up storage & workshop use) Zone	◕	◑	◑

6 DEFINING THE "BASE CASE"

6.1 Overview

As discussed in Section 4, we have defined the "Preliminary Base Case" based on our benchmarking exercise as the basis for us to select the potential site(s) for the development of a prefabrication yard in Hong Kong. As concluded in Section 5, for illustration purpose, we have selected Tuen Mun Area 40 as the more favourable site for the proposed prefabrication yard after taking into account planning, land use, traffic conditions and environmental considerations. For the purpose of financial analysis and demand analysis, we have adopted the parameters of Tuen Mun Area 40 for our proposed prefabrication yard site.

The main objective of this section is to revisit the definition of "Preliminary Base Case" before we proceed with the preliminary analysis of industry viability (Section 7). We have further analysed and revisited the "Preliminary Base Case" definition to ensure that it takes into account the key planning, land use, traffic and environmental considerations in Tuen Mun Area 40. We subsequently refer the redefined "Preliminary Base Case" as "Base Case".

6.2 Redefining "Preliminary Base Case"

Based on our key findings in site selection section (Section 5), the Potential Site in Tuen Mun Area 40 is subjected to the following restrictions:

- A maximum permissible plot ratio of 2.5; and
- A maximum building height of 26mPD[60]

We have looked into two key variables when defining the Base Case, (1) site area and (2) GFA.

6.2.1 Site Area

We have assumed that the required site area for the development of prefabrication yard to remain the same as the "Preliminary Base Case" i.e. 19,000 sqm.

6.2.2 GFA

Based on the maximum permissible plot ratio and building height in the Potential Site, we have developed a high-level design of the proposed prefabrication yard as described in detail below:

Maximum storeys:

Based on the maximum building height of 26mPD and Tuen Mun Area 40 site level height of 5 mPD, the proposed prefabrication yard can be built up to 21m high.

[60] Refers to height of 1.230m below the average sea level.

Based on our estimation[61], the average floor-to-floor height[62] of a prefabrication yard is approximately 7-10 metres for Production area and approximately 4-6metres for office. For the purpose of our analysis, we have assumed that the proposed prefabrication yard would be a 3-storey building:

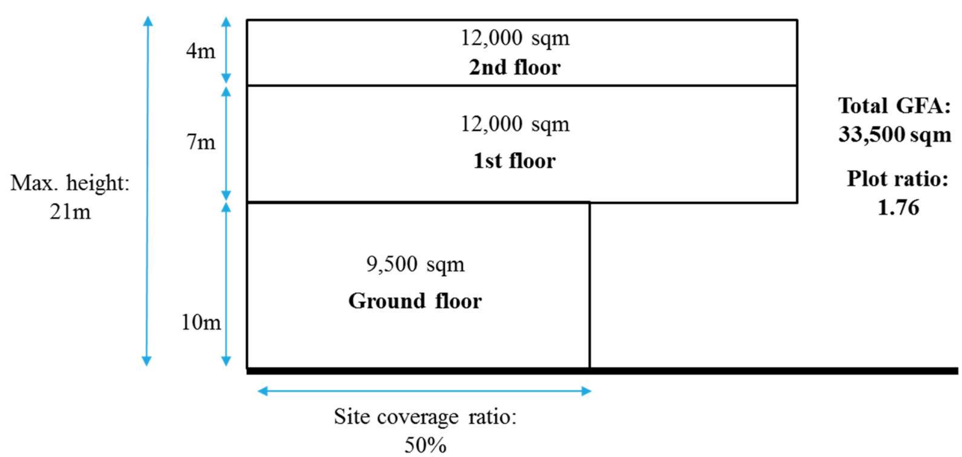
Floor	Potential Usage	Height (m)
2nd floor	Office	4
1st floor	Manufacturing	7
Ground floor	Manufacturing	10
Total		**21**

Site coverage ratio[63]

We understand that the prefabrication manufacturing yard requires open spaces for emergency vehicle access (EVA) and various operational purposes such as the loading of products onto trucks and storage spaces. Based on our high-level analysis on SEF Spacehub, the site coverage ratio is approximately 50%. In simple terms, the SEF Spacehub is built on 50% of the site area while the other 50% of area are open spaces for the various operational purposes. Given the deficiency of information on the minimum open spaces required for a prefabrication yard, we have adopted this ratio to redefine our "Base Case".

GFA:

Given the high-level scope for this analysis, we have had to make a number of simplifying assumptions when estimating the GFA for the proposed prefabrication yard. Based on our high-level analysis, the optimum GFA for the proposed prefabrication yard in the Potential Site would be approximately 33,500 sqm as shown in diagram below:

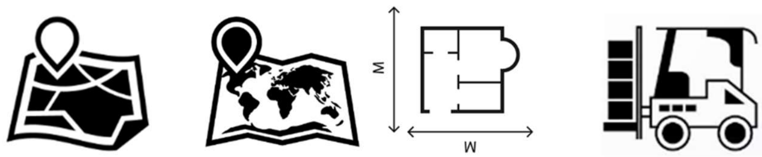


[61] Estimation based on Greyform's buildings height
[62] The height of each storey is based on the ceiling height of the rooms plus the thickness of the floors between each pane.
[63] Site coverage ratio refers to the total building area dived by the total site area.

We wish to highlight that the diagram above is for illustration purposes only and the assumptions are required in order for us to proceed with the preliminary financial analysis.

6.2.3 The "Base Case"

Diagram below summarises the key assumptions for the size and scale of both the "Preliminary Base Case" and the "Base Case" of the proposed yard:



	Land size	Location	GFA	Annual production capacity
"Preliminary Base Case"	19,000 sqm	??	28,000 sqm	277,200 tonnes (9.9 x GFA)
"Base Case"	19,000 sqm	Tuen Mun Area 40	33,500 sqm	331,650 tonnes (9.9 x GFA)

* 9.9 tonnes / sqm is based on benchmarking exercise outcome shown in Section 4.3.

7 PRELIMINARY ANALYSIS OF INDUSTRY VIABIILTY

7.1 Approach

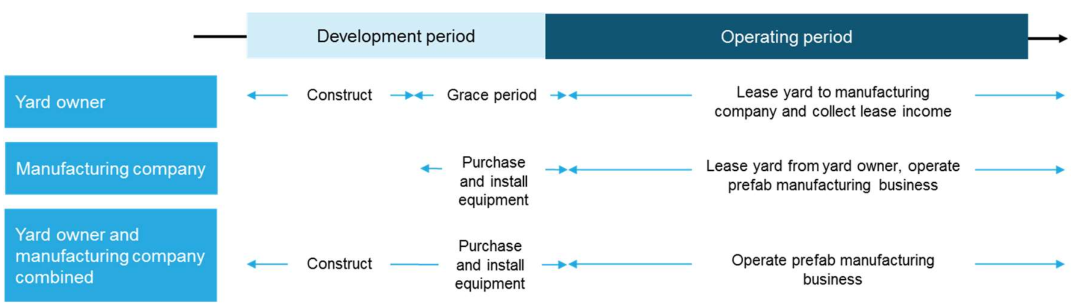
The preliminary financial analysis seeks to analyse the financial viability of undertaking a proposed prefabrication yard development in Hong Kong. For such development, there are potentially two parties involved:

- **Yard owner:** They party involved in constructing the yard and collecting lease rental
- **Manufacturing company:** The party involved in manufacturing and selling prefabrication components

For the purposes of the financial analysis, it was agreed with CIC that we should analyse the viability of the following business entities separately:

- Base Case 1: Yard owner
- Base Case 2: Manufacturing company
- Base Case 3: Yard owner and manufacturing company combined (i.e. a manufacturer that develops and owns its facility)

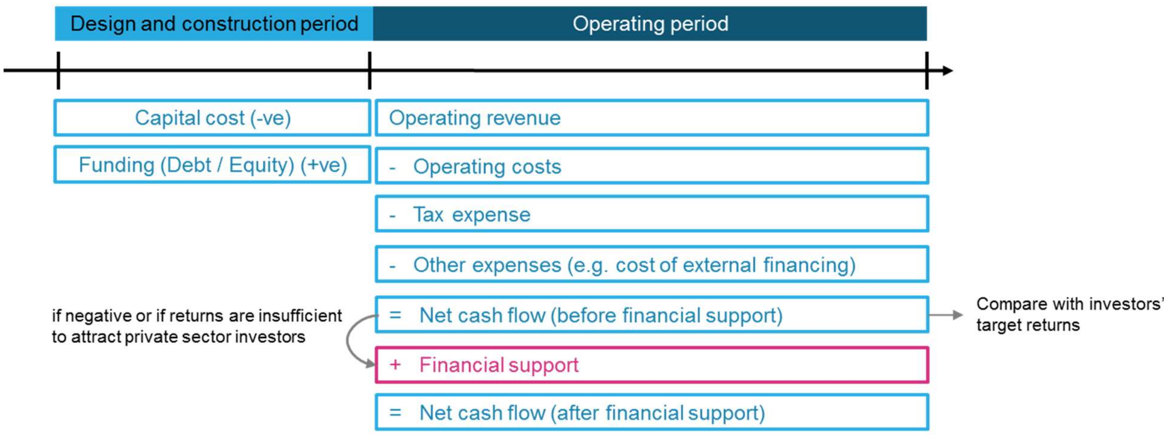
The diagram below summarises the role and responsibility of each business entity under each Base Case:



We have undertaken the preliminary financial analysis based on the following high-level methodology:

1. Developed financial model for each of the Base Case (1 – 3) in order to determine the respective indicative cash flow forecasts;
2. Using the financial model to determine whether each of the cash flow streams:
    - Generates sufficient cash flow to meet expenses
    - Generates a commercially acceptable return; and
    - Would require any financial subsidisation in order to become financially viable.

The business would be considered financially viable where the net cash flow generated by the business entity, including any financial subsidisation, is sufficient to make payments of all the costs incurred by the business entity, including investors' return requirements. The figure below provides a diagrammatic summary of how the business entity's cash flows have been built up in our analysis for each year in the financial model:



The outcomes of the financial analysis are shown in both Net Present Value (NPV) and nominal values, also known as money-of-the-day (MOD). NPV represents the present value of cash inflows less the present value of cash outflows. Present values refer to values as stated in 2018 prices. MOD refers to the true dollar amount of the relevant cash flow item, including the expected impact of inflation.

Refer to ***Appendix E*** for details of the key assumptions underpinning the Base Case analysis.

Refer to ***Appendix D*** for detail financial analysis of Base Case 1 (Yard Owner), Base Case 2 (Manufacturing Company) and Base Case 3 (Yard Owner and Manufacturing Company combined).

7.2 Key Findings

We have analysed the financial viability of undertaking a proposed prefabrication yard development in Hong Kong from 3 different perspectives:

- Base Case 1: Yard owner
- Base Case 2: Manufacturing company
- Base Case 3: Yard owner and manufacturing company combined

The financial assessments show that:

- Base Case 1: Yard owner would not be independently financially viable. In order to encourage a Yard owner to establish the required facilities, financial subsidisation of approximately HK$724m (NPV value) would need to be provided, this could be in the form of cash subsidies, discounted land premium, or a combination of the two.

- Base Case 2: The manufacturing business generates an internal rate of return (IRR) of 10% and cumulative investor cash position of HK$1,208m. Based on a target IRR of 10%, the manufacturing business would likely be viable. This result assumes a suitably available facility at current market industrial rent levels.
- Base Case 3: Given the high cost of land in Hong Kong, the combined developments would only be independently financially viable, in the event that a funding of approximately HK$579m (NPV value) is provided in the form of cash subsidies, discounted land premium or a combination of the two.

Base Case	**1**	**2**	**3**
Key metric	**Yard owner**	**Manufacturing company**	**Yard + Manufacturing**
Shortfall / funding requirement (NPV)	HK$724m	-	HK$579m
IRR	5%	10%	7%

8 DEMAND ANALYSIS

8.1 Introduction

The demand for prefabricated components in Hong Kong is driven by the increasing demand for housing due to expanding population and the shortage of labour. Similar to other Asian countries, the majority of prefabrication used in Hong Kong is in the construction of residential housing, especially public housing due to the simplicity and uniformity of design.

Our approach in undertaking the demand analysis for prefabrication components has been to analyse the trend for the following:

- The housing supply in Hong Kong; and
- The usage of prefabricated components in Hong Kong's housing sector.

8.2 Demand analysis for prefabricated components

One of the factors that determine the future demand of prefabrication components is the future supply of property (residential and commercial) and infrastructure development and how much contribution these new housing supplies has on the demand of prefabricated components.

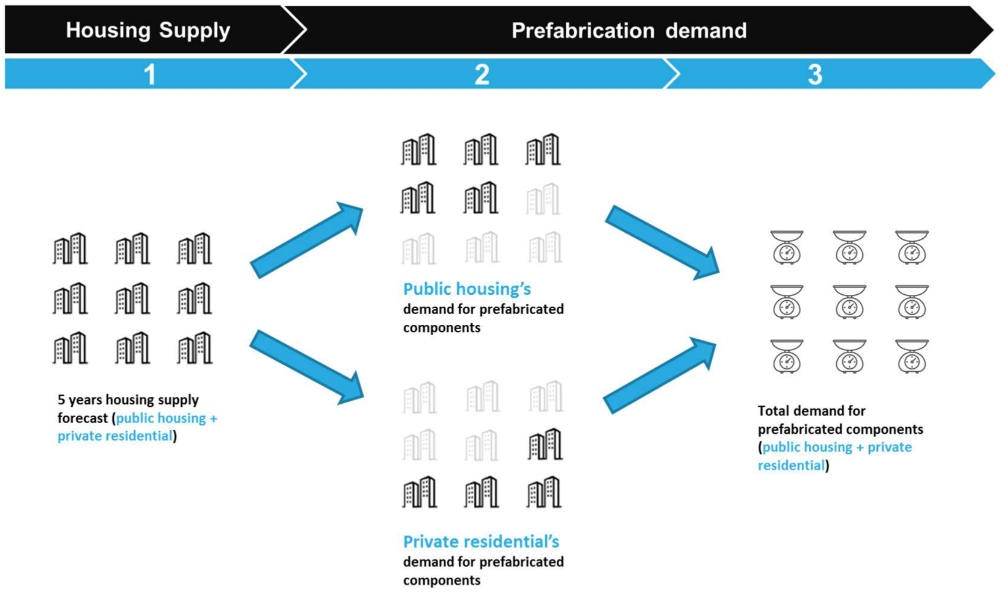
For the purposes of our analysis, we have only taken into consideration the future supply of residential properties and have excluded both commercial properties and infrastructure developments. Commercial properties typically use curtain wall system as compared to prefabricated components while infrastructure developments typically require large components. We have assumed in our analysis that the proposed prefabrication yard will only manufacture prefabricated components for residential buildings due to its site scale.

8.3 Approach

Based on our understanding, prefabrication practices in public housing projects and private residential projects in Hong Kong are very different. In public housing projects, various prefabricated components such as prefabricated facades, semi-prefabricated slabs, prefabricated staircases and prefabricated bathrooms were adopted, whereas in private residential projects only prefabricated facades are commonly adopted.

Given the differences above and the available data we have, our approach first analysis the housing supply in Hong Kong, then we analysis the prefabrication demand in public housing and private residential separately and combined both demands at the end to compare with the supply of our proposed prefabrication yard.

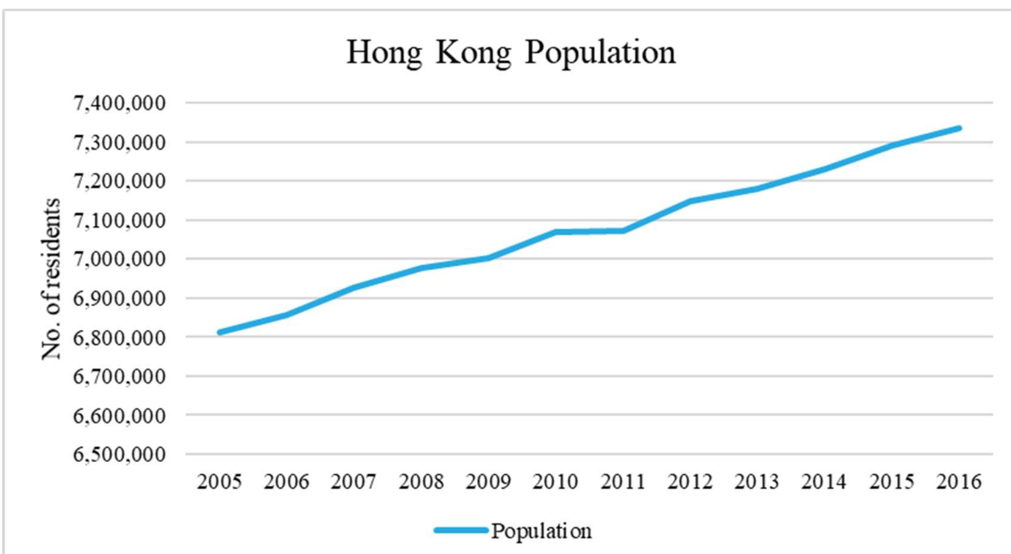
The diagram below summarised our three-step approach to estimate the demand for the prefabricated components in Hong Kong.



8.3.1 Step 1: Hong Kong's Housing Supply Forecast

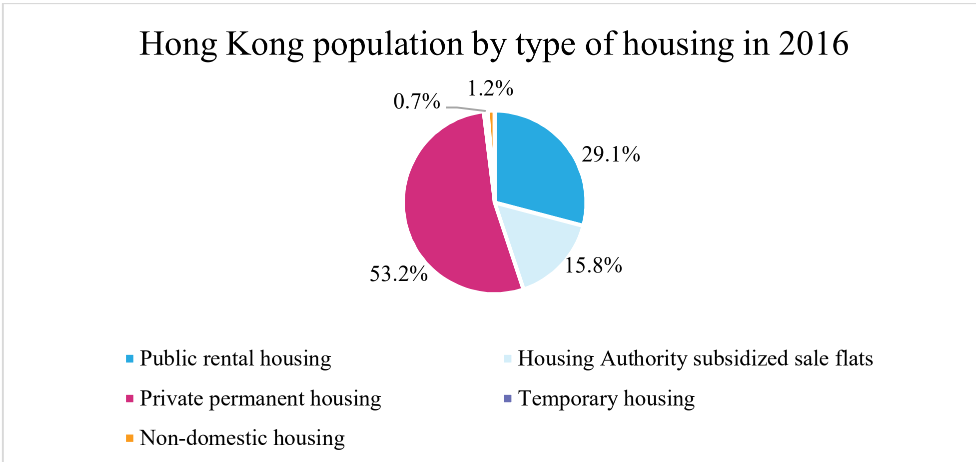
Overview

Hong Kong has experienced steady population growth of approximately 0.7% per year from 2005 to 2016. As shown in the table below, the population has increased from 6.8 million in 2005 to 7.3 million residents in 2016[64].



[64] Hong Kong annual digest of statistics

Historically, the growing population in Hong Kong has been a driving factor of housing demand in Hong Kong. As of the 2016 census[65], 45% of Hong Kong's population was living in public housing (which includes public rental housing and government subsidised-sale public housing), 53% was living in private permanent housing and remaining 2% was living in temporary and non-domestic housing.



Public housing in Hong Kong:

In order to satisfy the housing needs of low and medium income household, the Hong Kong Housing Authority (HKHA) / Government has provided various subsidy programmes for public housing in Hong Kong. These includes:

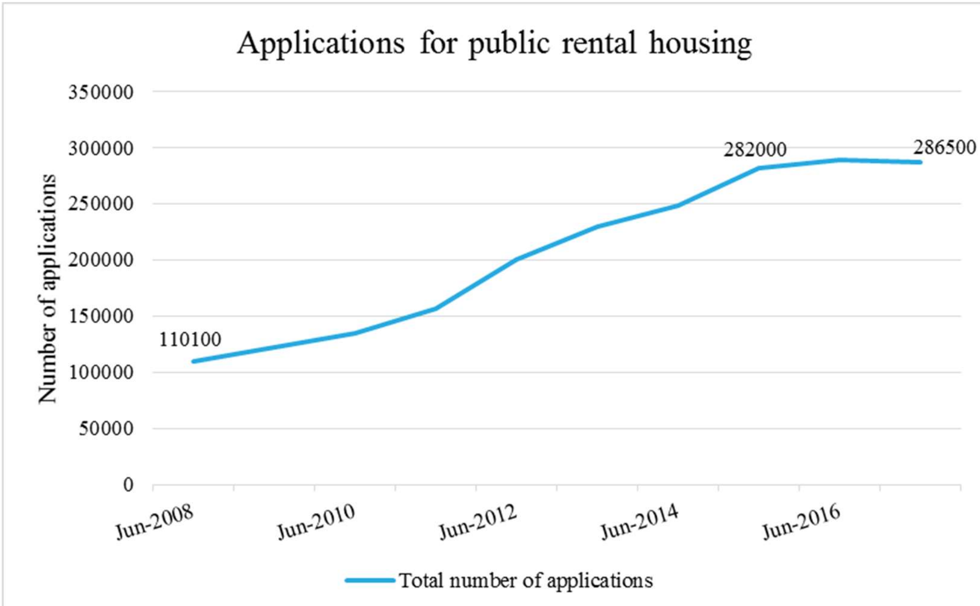
- Public Rental Housing Program - discounted rental flats to low-income residents;
- The Housing Ownership Scheme – subsidised sale public housing units which is earmarked for sale to low-income qualifiers at a heavily discounted price from market value; and
- Other various programmes such as Tenants Purchase Scheme, Interim Housing and Green Form Subsidised Home Ownership Pilot Scheme.

The above public housing programmes are generally subjected to a range of restrictions and eligibility requirements.

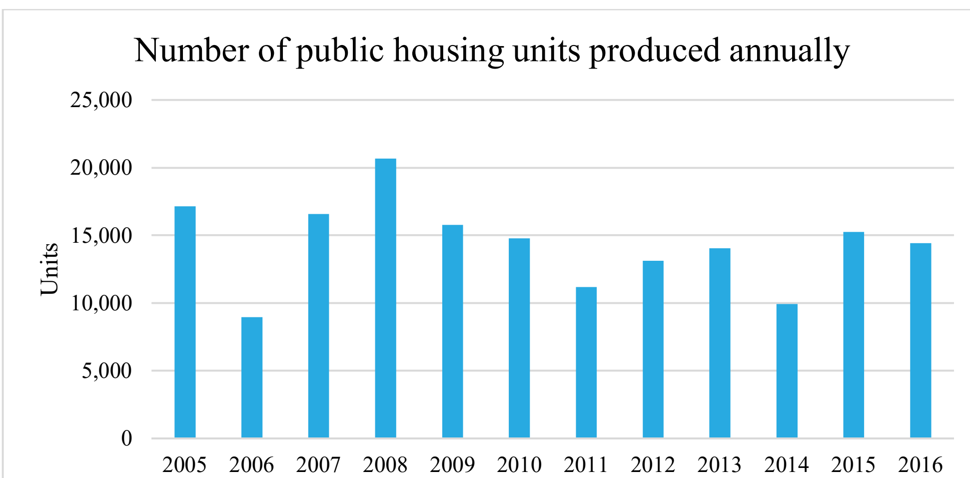
For our demand analysis, we have focused on Public Rental Housing Program as it accounts for the majority of public housing in Hong Kong. Currently, there are over 760,000 flats registered under this program.

[65] 2016 Hong Kong population by-census

Our analysis shows that the demand for public housing under this program has been positive since 2008. For example, the total number of applicants has increased from 110,100 in 2008 to 286,500 in 2016 as shown in the chart below[66]:

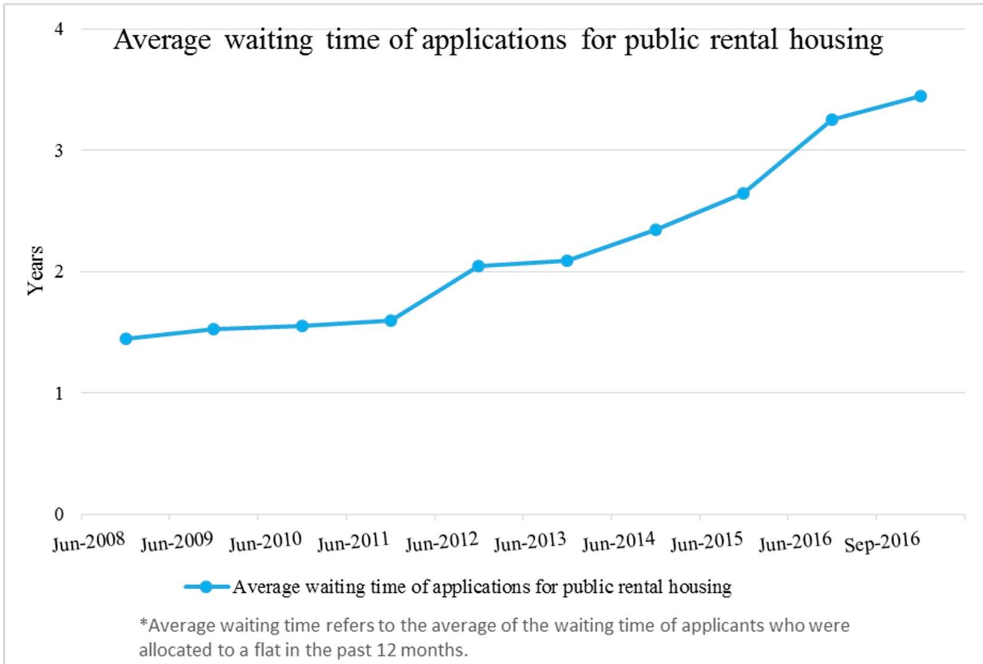


However, we observed that the public housing units produced each year have been unvarying and have not seen a significant increase. The chart below shows that the average number of new public housing units produced by HKHA is approximately 14,300 units per annum in the past 10 years[67].



[66] Legislative Council of Hong Kong – ISSH09/ 16-17
[67] Hong Kong Housing Authority and the Census and Statistics Department

The high demand and low supply trends have resulted in a growing average waiting time of applications for public rental housing in Hong Kong[68].



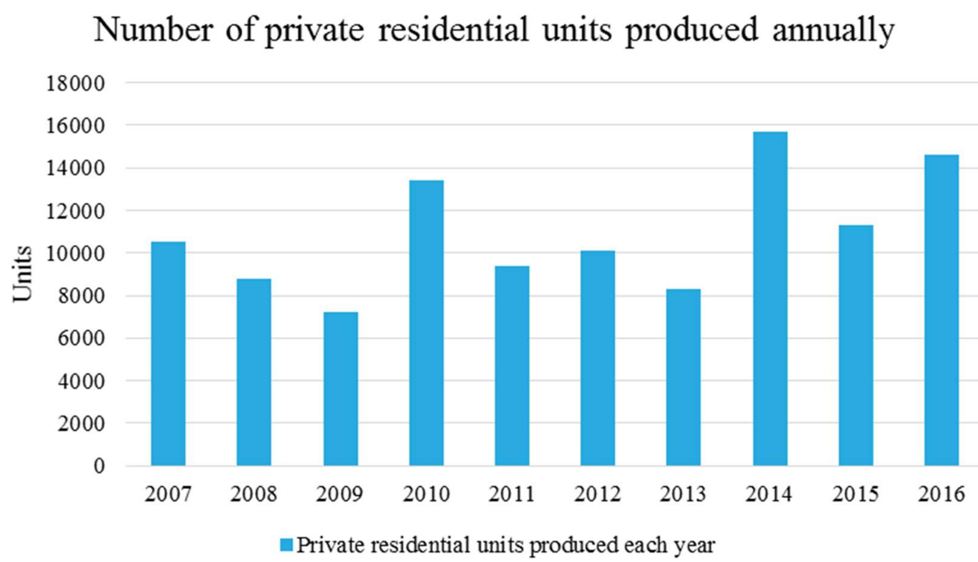
To address the shortage in supply, the Hong Kong government announced the Long Term Housing Strategy (LTHS) to increase the production of public housing. It has targeted to supply a total of 280,000 public housing units for the ten-year period from 2015-16 to 2024-25[69].

[68] Legislative Council of Hong Kong – ISSH09/ 16-17
[69] Transport and Housing Bureau – Long Term Housing Strategy, 2014

Private housing in Hong Kong

Approximately 53% of Hong Kong's population is living in private permanent housing, accounting for more than half of Hong Kong's housing market.

The private residential units produced each year is subject to the land supply by the Hong Kong government. The average number of private residential units supplied from 2005 to 2016 is approximately 12,000 annually[70], as shown in the chart below.



Hong Kong's housing supply forecast:

For the purpose of our analysis, we have focused on a 5-year projection. Based on information provided by Knight Frank[71], the total housing supply forecast from 2017 to 2021 are approximately 193,900 units (97,200 units of public housing and 96,700 of private residential) as presented in the charts below:

[70] Hong Kong Housing Authority and the Census and Statistics Department
[71] Source: Knight Frank

Sector	Note / Source[72]
Public housing	Planned supply units sourced from the LegCo document CB(1)110/16-17(02)
Private residential	Completion of future private residential units is based on Knight Frank's Land Supply System, which sourced raw data from several sections of Monthly Digest published by the Buildings Department. Five-year projection of private residential unit size is based on the short-term projection of Property Review 2017 released by Rating and Valuation Department, and adapted according to market news

8.3.2 Step 2: Housing Supply that Applies Semi-prefabrication Construction

8.3.2.1 Public housing

As shown in Step 1, the total 5-year housing supply forecast of public housing units are 97,200 units. According to a publicly available study[73], historically 100% of public housing units in Hong Kong used semi-prefabrication construction method. Hence, we assume all the 97,200 units of public housing units of the total 5-year housing forecast will be using semi-prefabricated components during the construction phase.

We have obtained and analysed the total number of prefabricated components used per floor and the weight in tonnes of each element from a pilot project in Kwai Chung Estate[74].

The pilot project in Kwai Chung has 60% of its concrete volume coming from prefabricated components. However, to be consistent with the conventional practise and to be prudence, we have assumed 20% concrete volume in public housing projects would come from prefabricated components for our demand analysis. Please refer to the ***Appendix F*** for the detailed analysis.

Based on our analysis on the pilot project in Kwai Chung, public housing units uses 25.063 tonnes of prefabricated components on average (assuming 20% of volume in public housing projects uses prefabricated components). Hence, the estimated demand for prefabricated components for public housing of the total 5-year housing supply forecast (97,200 units) is 2,436,124 tonnes.

[72] Source: Knight Frank's data base
[73] Vivian Tam, C.M. Tam, S.X. Zeng and William Ng, *Towards Adoption of Prefabrication in Construction*
[74] Planning, design, and delivery of quality public housing in the new millennium, Housing Authority

The table below summarises our analysis:

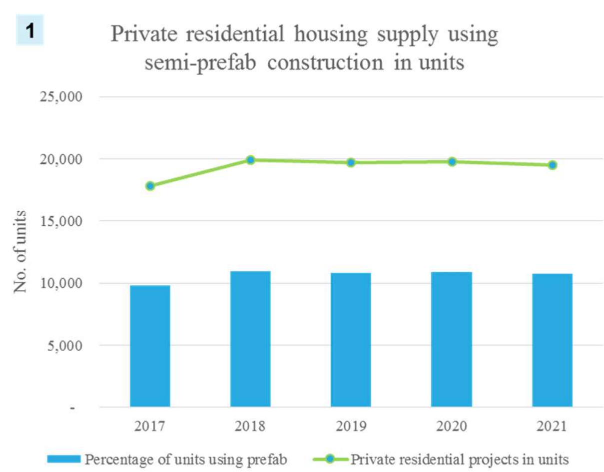
Total 5-year housing supply forecast of public housing units	97,200 units
Percentage of public housing units in Hong Kong used semi-prefabrication construction method	100%
Volume of prefabricated components usage per unit	25.063 tonne per unit
Demand for prefabricated components for public housing of the total 5-year housing supply forecast	**2,436,124 tonnes**

8.3.2.2 Private residential units

Based on the total 5-year housing supply forecast of approximately 96,700 units of private residential units (shown in Step 1), we proceed to estimate the number of private residential projects, which will likely be using semi-prefabrication construction method.

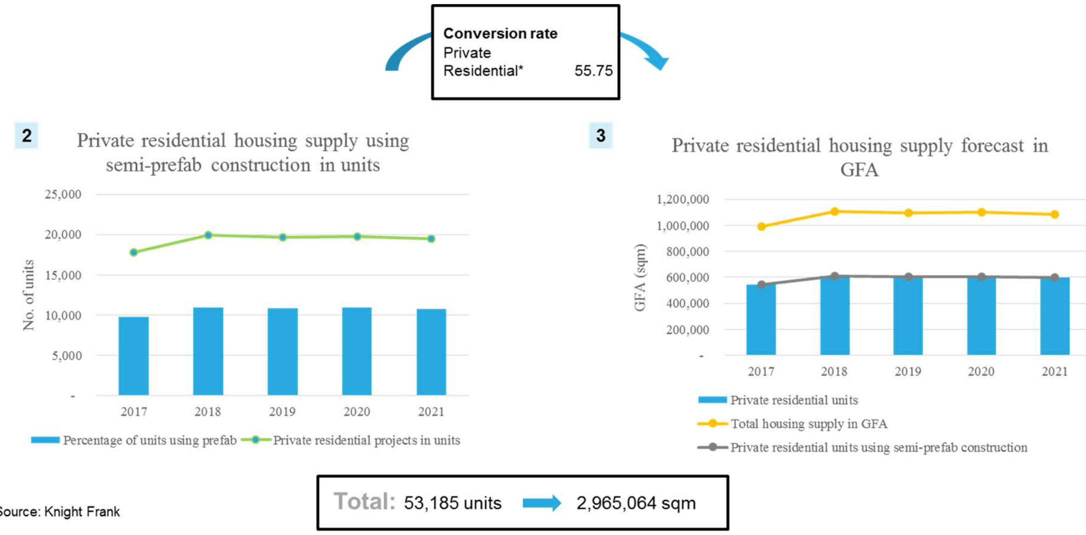
A publicly available study[75] shows that historically approximately 55% of private residential units in Hong Kong used semi-prefabrication construction method. We have applied these data as our assumptions in deriving the 5-year private residential unit supply that uses semi-prefabricated components during the construction phase.

Based on these assumptions (55% of 96,700 private residential units), the estimated total housing supply that uses semi-prefabrication construction methods is approximately 53,185 units as presented in the charts below:



75Vivian Tam, C.M. Tam, S.X. Zeng and William Ng, *Towards Adoption of Prefabrication in Construction*

The 53,185 units of housing supply that uses prefabrication construction method, represents approximately 2.97 million sqm in gross floor area (GFA). The conversion rates of number of units to area (sqm) have been derived from the existing average sizes[76] of public and private housing in Hong Kong.

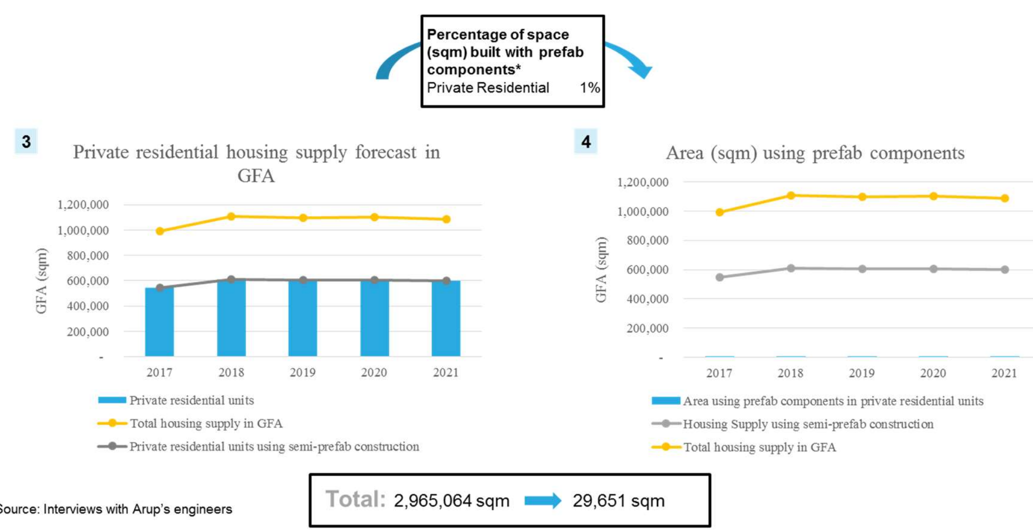


* Source: Knight Frank

Out of the total 2.97 million sqm in GFA, we proceed to estimate the area in GFA which will be constructed with prefabricated components.

Based on our interviews with Arup's engineers and a private residential project, we understand that historically approximately, only 1% of GFA (i.e. mainly for the façade) in private housing construction used prefabricated components.

We have applied these data as our assumptions in deriving the GFA constructed with prefabricated components in private residential units. The estimated GFA constructed with prefabricated components in private residential units is approximately 29,651 sqm as presented in the charts below.



* Source: Interviews with Arup's engineers

[76] Sources from Knight Frank's data base and Transport and Housing Bureau – Housing in Figures 2017

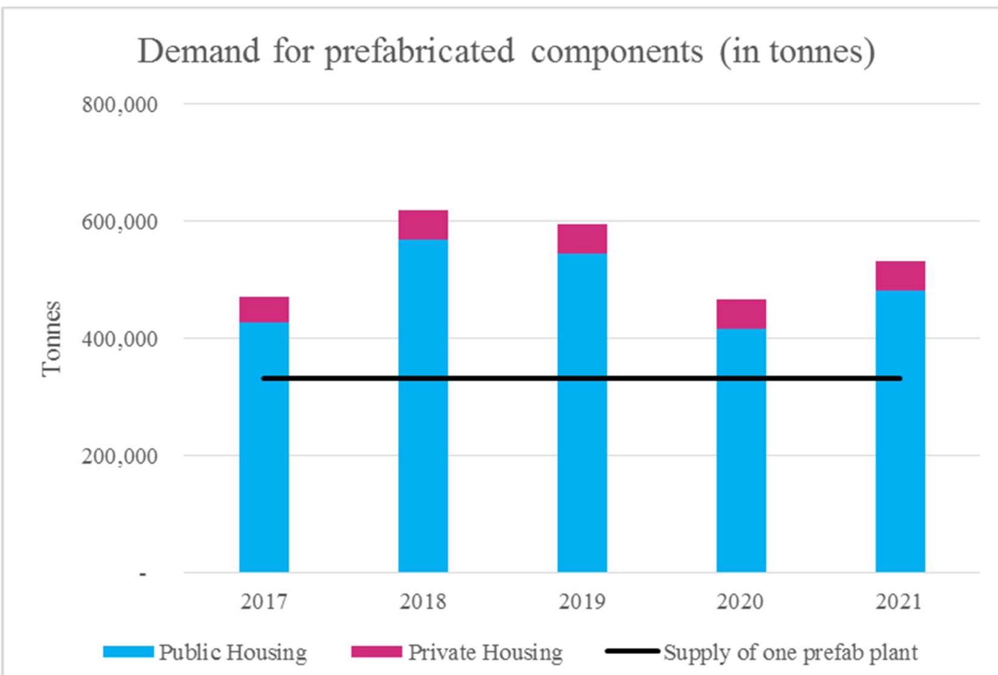
The estimated GFA constructed with prefabricated components of 29,651sqm represents approximately 244,618 tonnes (i.e. using a concrete density of 2450kg/m3 for reinforced concrete) of prefabricated component demand over the next 5 years. The conversion rates of area (sqm) to tonnes have been derived based on conversion from the estimated sqm of the prefabricated component to meter cube (1sqm: $3.3m^3$) and then multiply by the concrete density of reinforced concrete.

8.3.3 Step 3: Prefabricated Components Demand Forecast

The final step of the demand analysis is to combine the prefabricated components demand in public housing and private residential units of the total 5-year forecast.

Based on the above analysis, prefabricated components demand in public housing amounts to 2,436,124 tonnes while demand in private residential units amounts for 244,618 tonnes of the total 5-year forecast. Hence, the total prefabricated components demand of the total 5-year forecast is 2,680,741 tonnes.

As defined in the Base Case, the proposed prefabrication yard will have an annual production capacity of approximately 331,650 tonnes. This suggests that the proposed prefabrication yard is likely to supply approximately 62% of the total demand for prefabricated components of the total 5-year forecast.



9 OTHER CONSIDERATIONS

9.1 Manpower Savings

The shift from site casting to prefabrication off site will affect manpower on the construction site. According to the study by Tam (2002), there could be as much as 43 percent reduction in site labour consumption if there is a shift from the in-situ site casting to prefabrication design. The reduction was postulated and used as the basis to work out the labour consumptions based on typical public housing and residential buildings with a high degree of prefabrication (70% of elements by prefabrication). This coincides with the Irish Concrete Federation, which stated that on-site labour is reduced by 30-50% depending on the finishes.

With trends indicating there is a severe shortage of construction workers (CIC 2012) such as bar bender & fixer, carpenter, rigger etc. to name a few, and trades facing acute aging problems, the manpower reduction is an important advantage. Other advantages with increase in adoption of prefabrication also include on-site safety, product quality, and construction performance. Furthermore, the increased use of prefabrication is not only expected to save labour input on site, but also significant saving, especially in skilled trades such as formwork, masonry or plastering, depending on the type of prefabricated element used.

9.2 Opportunities to Adopt More Technology and Machinery

In terms of new technology and machinery in the prefabrication industry, a lot of prefabricated component production, especially in the U.S. and Japan, involves a high level of automation and computerization. Such new technology improves overall quality, reduces production time and most importantly, it can reduce labour demand. It is proven to be successful and widely applied in Japan where labour costs are high and labour supply is in shortage.

Hong Kong, sharing similar labour market dynamics to Japan (high costs and shortage in labour), could very well adapt to these technologies. Highly skilled labour to produce high quality prefabricated components would help locally made products compete with cheaper prefabricated products offshore. The government could encourage input of foreign research & development personnel specialises in prefabrication automation to help develop technology and machinery locally or import the technology and machinery directly from overseas.

Below are examples of highly automated production line in Japan and U.S.

9.2.1 Sekisui House[77]

1. **Produces high-performance, high-quality and high-precision building components at its factories with Professionals and experts for every production stage.**

   High-tech machine tools are combined with the techniques of skilled workers. Optimally utilising both sides means high performance houses are produced.

2. **Computer-controlled automated manufacturing process. High-tech machine tools help enhance accuracy only in the factory.**

   A total of 16 portions of welded and finished box units in various sizes instantly have their horizontal and vertical accuracy measured with a laser measurement device to inspect whether accuracy and quality have been maintained or not.

   Tensile tests are undertaken on a daily basis to stabilize the strength, meaning stability, accuracy and welding strength can be maintained with quality control that is very difficult to implement at building sites.

3. **Installed robot-equipped production lines in Sekisui House factories successively automate 95% of the production process.**

   All the processes involved in the cutting, welding and drilling of the steel beams used for the Heim steel frame structure are carried out using computerized automated machine tools. For example, the accuracy of drilling is kept within an error tolerance of just 0.1mm, while the process of attaching heavy outer walls is carried out using large machine tools and automated nailing machines are used to manufacture large floor bases.

9.2.2 Progress Maschinen & Automation AG[78]

1. **Highly automated and customized carrousel plants**

   Manufacture carrousel plants, coil processing machinery and plants, mould systems and plants for prestressed concrete products. Also provide batching and mixing plants, bucket conveyors, shutters, 3D software for prefabricated elements, and other components such as cranes and concrete finishing machines.

2. **Battery moulds, tilting tables, various mould systems**

   Supplied battery moulds in customized sizes, number of pouring bays and as single or double battery moulds. Tilting tables are designed for the fabrication of large area reinforced concrete products. Integrated high-frequency vibrators facilitate optimal compaction of the freshly poured concrete. The surface of the steel plate is ultra-flat and guarantees a high-quality concrete surface.

[77] Sekisui House Ltd. website, Sekisui Chemical Co., Ltd. website
[78] Progress Group website

3. Reinforcement machinery and mesh welding plants

Versity bespoke mesh welding machine is a cost-effective mesh solution for medium production needs. The wire can be fed from coil or rebar to suit supply. M-System PowerMesh HS optimizes throughput with a revolving run-out and efficient bar transport system. The wire diameter changes automatically.

9.3 Skill sets requirement

With the extensive use of prefabrication, it is anticipated that the number of site workers will be replaced by factory workers at the prefabrication yards. Some trades may diminish while some new trades would emerge. This would shift the work nature and will induce changes to the skill sets required in the construction industry. Even if the same skill sets apply in a traditional in-situ construction site and a prefabrication yard, the level of 'skills' may be different with the help of technology and automation.

A summary showing the comparison of the skill set/ skill level for a typical public residential building are shown below:

Skill Type / Tradesman	**Traditional In-Situ Concrete Construction**	**Prefabrication Components Manufacturing & Assembly**
	Skill Level	
*Steel Fixer	High	Low
*Formworker/ Mould fixers	High	Low
*Concretor	Medium	Low
Rigger	Medium	Medium
Crane Operator	Medium	High
Navigator	Medium	Medium
BIM Designer / Engineer	n/a	High
Prefabrication Yard Machine Operator	n/a	High
Prefabrication Assembly	n/a	Medium

Traditionally, in-situ concrete construction requires skilled labour which requires relatively longer period of training. With the introduction of automation in prefabrication yards, a number of work types have been replaced and if work types are the same, the level of skills would not be as high as those in traditional in-situ concrete constructions.

Adoption of prefabricated components requires less skilled labour on-site than in-situ concrete construction (except for the crane operator who would be more skilled to operate a heavier crane to lift the prefabricated elements which could be over 10 Tonnes). This is due to the substitution of skilled activities with the placement of prefabricated concrete elements. However, skilled labour is required at the prefabricated manufacturing plant, especially when automation equipment and machines need to be operated. The extent of skilled labour used at the manufacturing plants is determined by the manufacturing method used and is also dependent on the type of element manufactured.

With the advances in technology, automation and robots could potentially replace the traditional trades such as steel fixers, concretor & formworkers. However, new skills would advance with operators of machines and equipment in prefabrication yards, prefabrication component fixers/assembly, BIM designer and engineers with DfMA knowledge etc.

9.4 Workers Welfare Improvement Incentives

In Hong Kong, the construction workforce is facing issues on shortage and aging of labour. There are very few new generation workforces joining the construction sector[79] as the working environment is generally perceived as tough and dangerous. By establishing a prefabrication yard in Hong Kong, construction workers can work in a more controlled, comfortable indoor environment which is less affected by weather. Facilities that can be accommodated in the proposed prefabrication yard to further improve the working environment could potentially attract more people to join the industry.

Referencing other more advanced and newly built prefabrication hubs in Singapore, there are various welfare facilities and features that have been provided alongside these production yards with the aim to improve the working environment and worker's welfare.

Examples of welfare facilities and features adopted in Singapore prefabrication yards includes:

[79] Hong Kong Information Services Department, *Construction manpower to use*, March 22 2017

Urban Farming Plot The Tiong Seng Prefab Hub in Singapore has included a 900 sqm plot of urban farming area[80] next to the dormitory where workers can grow their own crop. This provides workers with a green environment to relax and an alternative activity to do outside working hours.	
Green façade Eco façade has been installed for the Tiong Seng Prefab Hub to allow plants to grow on the outer wall. It povides various benefits such as acoustic buffering, improving air quality, building beautification and increasing thermal insulation.	
Rainwater harvesting Rainwater tanks are located at roof top of Tiong Seng Prefab Hub to harvest rainwater for irrigation. It can reduce usage of potable water[81] and achieve environmental sustainability.	
Entertainment facilities The Greyform prefabrication hub contains entertainment facilities close to the worker's dormitory such as basketball court. This provides activities for workers to enjoy outside of working hours.	**Training Centre** The Tiong Seng Prefab Hub also features a training centre. It provides training for employees and workers, allowing them to improve their skill set and knowledge of new technologies. This can provide workers with job satisfaction by continiuous self-improvement.

[80] Building and Construction Authority Singapore News Press, 4 January 2011
[81] Robin Village Development Ptd Ltd website

Other than the facilities we observed from the above prefabrication hubs, we also suggest the following facilities to be included in the proposed prefabrication yard to improve working environment and workers' welfare:

Dining facilities Dining facilities such as canteen or cafeteria could also provide employees a place to social and share their ideas. If there are constraint on the size of the proposed yard, smaller dining facilities would be more suitable given the number of workers is few.	
Changing rooms, showers and lockers Workers may have to wear uniforms or protective clothes due to exposure to chemicals and construction materials. Private changing areas should be provided with showers and lockers. Showering facility can help maintain sanitation and lockers for workers to store their personal belongings.	

Besides the above facilities, the workplace environment is also important. Elements such as lighting, air ventilation, temperature and noise level should be controlled in order to provide a comfortable and safe working environment and attract new workers into the industry.

9.5 Design for Manufacturing & Assembly

For Hong Kong to elevate to the next level – take-up of the **Design for Manufacture and Assembly (DfMA)** approach, there are key barriers for Hong Kong to overcome, as noted by Paul Lengthorn of Mott MacDonald. First, it will require designers and contractors to collaborate closely to fix and detail the design to be ready for manufacturing offsite. This works for 'design and build' projects as the designer and contractor are in the same team, but this is not a very common model in Hong Kong. [82] By having them on the same team, communication process and procedures for changes are more efficient. Mr. Lengthorn also points out that the fast-paced bidding process allows too little time for the development of innovations that can add significant value through design, manufacture and

[82] www.building.com.hk

assembly. Raising awareness of the benefits of DfMA will encourage clients to favour these projects. Lastly, he mentions that the current Hong Kong building regulations are well adapted to traditional construction solutions, but pose challenges to DfMA projects. Adapting the approvals process to this new technology will encourage more take-up of prefabrication. As he summarises, “all of these challenges can be overcome if the government and developers work closely with designers, engineers and contractors to support stronger take-up of DfMA”.

During the forum conducted with contractors and prefabrication manufacturers, it was mentioned that it is a common practice in Hong Kong for engineers and architects to modify the design therefore the construction drawings at the last minute. As prefabrication requires a well- planned schedule ahead of construction for the manufacturing of prefabrication components, constant changes at such late stage of the project makes it difficult and costly to implement prefabrication in Hong Kong.

In private sector housing, housing designs are usually irregular in shape. This is mainly due to developers trying to maximize GFA on a limited size of land and to present a “luxury” image by constructing unusual design. As a result, the standardized prefabricated components needed for economies of scale would not make it feasibility from a cost perspective.

Feedbacks from engineers also mentioned that Hong Kong does not have enough multi skilled labour necessary to support DfMA. It was recommended that for DfMA to be feasible, skills promotion would be needed once there is such a facility to produce prefabrication components in Hong Kong. The skills would not be limited to concrete elements but also tasks that include pipe work and electrical work that would be conducted at the facility.

This study has found that those who would be most receptive to such paradigm change are those in Environmental, Transportation, Labour, Health & Safety, and Public Sector. Similar to the benefits of having a prefabrication yard, those in favour for DfMA also see technological advancement to achieve better efficiency, cost savings, better quality and reduced risks. Risks from weather, material supply, labour shortage, road access, injuries/deaths, pollution, etc, can be better planned at the design stage.

Forward-thinking designers, engineers, contractors, governments and developers who encourage the adaptation of the technology necessary to succeed in a DfMA approach stand to gain significant benefits from it as seen in other countries, such as Singapore.

As of January 2018, the Singapore government has already set targets to achieve 40 percent adoption of DfMA for construction industry, up from the current 10 percent. On digital technology, more than 70 projects in Singapore have already used building information modelling (BIM) to date. By 2020, the Singapore government wants to see 40-60 projects adopting an integrated digital delivery (IDD), not just BIM but across the entire construction process.

9.6 Potential Benefits and Beneficiaries of Prefabrication

Based on our research, the potential qualitative benefits and its beneficiaries for establishing prefabrication yards in Hong Kong are as follows:

Potential advantages of prefabrication	Potential beneficiaries
Labour	
Workers would work in a sheltered environment, not exposed to the elements.	Workers
Workers could enhance / upgrade their skills through training provided by prefabrication manufacturers.	Workers
Worker productivity and effectiveness could be improved through technology utilised within production sites.	Workers Prefabrication manufacturers Construction industry
Improved working conditions in indoor setting may help to attract more young people to join the industry, relieving pressures of labour shortages.	Construction industry
Safety	
Accident rates could be minimised through establishing controlled factory environments, and scheduled periodic maintenance of equipment.	Workers Construction industry
Weather conditions would not impact safety and production.	Workers Construction industry
The use of technology / machinery may reduce the need for current risky procedures	Workers
Environment and health	
Pollution on site, particularly dust and air-borne particles, would be significantly reduced, and any other discharges and waste water could be more easily treated before disposal.	Neighbouring buildings / residents General public
The use of raw-material could be optimized / reduced through mass production. Wastage could be minimised.	Prefabrication manufacturers General public (through reduced landfill and reduced use of scarce resources)
Noise generated on construction sites could be reduced or eliminated.	Neighbouring buildings / residents

Technology and methodology	
Potential for increased use of technology across the construction industry, e.g. BIM, DfMA, may be adopted more widely	Construction industry
New construction methodologies could be introduced to the industry, including increased use of modular construction techniques	Construction industry
Opportunity to utilise automation and robotics in prefabrication manufacturing, in turn an opportunity to align with Hong Kong's wider ambition to be a technology hub	Construction industry Tech industry
Potential adoption of modular construction, e.g. the use of volumetric building modules, may be considered by public and private sector.	Construction industry
Design and coordination	
An accreditation scheme could be developed to ensure and recognize quality systems as applied at prefabrication yards	Construction industry General Public (through enhanced quality control)
Production	
Potential for improved quality of prefabricated components	Construction industry
The production rate could be faster than cast-in-situ as a result of standardising process and adoption of technology	Construction industry
Potential for improved delivery times from yards to construction site	Construction industry

While there is research that makes qualitative reference to potential benefits of prefabrication, and in terms of individual prefabricated construction projects, we were not able to find in our desktop research of quantifiable socio-economic benefits of establishing prefabrication yard(s).

A detail on quantifiable benefits achieved in other jurisdictions which could in turn provide an indication of what kind of broader socio-economic benefits could be realized in the Hong Kong context. This would be helpful in justifying any future government investments into the sector.

Based on the above, it is recommended that further studies (i.e. economic analysis) is undertaken by the Government and or CIC to quantify the costs and benefits of the proposed prefabrication yard in the context of Hong Kong.

With reference to the feasibility study findings, the Government could also consider the following:

1. Make references to the prefabrication yard developments in Singapore and the initiatives undertaken by the Singapore Government. For example:
    - setting conditions in land sale for the use of prefabricated components in residential/commercial development;
    - establishing a statutory board to develop and regulate Singapore's building and construction industry (i.e. improve construction productivity and process); and
    - making available Integrated Construction and Prefabrication Hubs (ICPH) to prefabrication manufacturers below market prices.
2. Develop specific prefabrication guidelines & technical specifications that could be effectively adopted in Hong Kong by making references to those that has already been tested and used in Mainland China. Such as:
    - 混凝土預製拼裝塔機基礎技術規程 (JGJ/T197-201)
    - 預製預應力混凝土裝配整體式框架結構技術規程 (JGJ224-2010)
    - 預製帶肋底板混凝土疊合樓板技術規程 (JGJ/T258-2011)
    - 住宅衛生間模數協調標准(JGJ/T263-2012)
    - 裝配式混凝土結構技術規程(JGJ1-2014)
    - 住宅廚房模數協調標準(JGJ/T 262-2012)
3. Establish statutory board to govern the project
4. Establish the accreditation scope to prefabrication components
5. Take into consideration of Modular Integrated Construction (MiC) which is manufactured in a prefabrication factory.

10 KEY FINDINGS FROM INTERVIEWS AND STAKEFOLDER FORUMS

10.1 Interviews

10.1.1 Background of the Interviews

In order to understand more about the prefabrication industry and the usage of prefabricated components in the construction industry in Hong Kong, we have interviewed 7 companies (i.e. contractors, prefabricated component manufacturers and concrete suppliers). Of the 7 companies, 4 companies accepted our interview invitation. The interviews with the 4 companies were held during the period of late October to early November 2017.

10.1.2 Key Findings

During the interview with the 4 companies, we have extracted key information and opinions. Our interviews were conducted with discussions in the 9 key areas below:

1. Overview and Operation
2. Location and planning
3. Transportation
4. Environmental Impacts
5. Design, coordination and technical issues
6. Labour
7. Costs and demand for prefabricated components
8. Technology
9. Conclusion: Views on establishing a prefabrication yard in Hong Kong

The summary of key findings from the interviews are summarised as follows:

Overview and operation
• The key objective of this section is to provide a preliminary overview of the operation and business model when operating a prefabrication yard. While 3 out of 4 companies own prefabrication yard(s), they are all located in Mainland China (i.e. Guangdong, Hui Zhou and Shen Zhen).
• Their products include prefabricated façades for public and private housings, prefabricated staircases, prefabricated slabs and beams, prefabricated bathroom units and prefabricated windows.

• Prefabricated components are manufactured in production area with metal formwork. Upon completion, it will be transferred to an unsheltered storage to be loaded on trucks for delivery.
• Their prefabrication components mainly support construction sites in Mainland China and Hong Kong.
• Engineers are stationed in the prefabrication yard at the beginning stage of manufacturing to ensure quality control of the prefabricated products. Quality control professionals are employed to minimise errors occurring during all stages of operation.
• The prefabrication yards in Mainland China can operate 24 hours a day during peak periods. However, it is noted that this might not be possible in Hong Kong due to noise permit issues.
Location and yard planning
• The prefabrication yards of the companies we interviewed have land area ranging from 50,000sqm to 160,000sqm. However, we are aware that most of the yards are traditional open yards / single-storey yards, hence larger area is required.
• The prefabrication yards are located in Mainland China mainly due to much lower land and labour costs comparing to Hong Kong.
• Other than the major production facilities, areas should also be reserved for storage and concrete batching.
• As raw materials are delivered from Mainland China by land transportation, the location of the prefabrication yards need to be well connected with roads. Moreover, close access to dock / shipyard is required if finished products are transported by sea.
Transportation
• Based on the experience of the companies interviewed, prefabricated components from Mainland China are usually delivered to Hong Kong in the afternoon. The components will then be delivered on site next day in the morning and installation will start in the afternoon.
• The land transportation vehicle for the delivery of finished products are usually 12-meter long, with carrying capacity up to 30 tonnes.
• Loading and unloading process of prefabricated components usually takes up to 1 hour.

• At peak periods, the transportation of finished products requires approximately 10 truck visits per day.
• At the construction site, a large storage area for prefabricated components is required before installation. Since construction sites are usually limited in space in Hong Kong, site planning is required at the beginning of the construction phase for the planning of storage.
Environmental
• Comparing to on-site construction, wastage of materials including flawed prefabricated components is reduced when manufactured in a prefabrication yard. The wastage is reduced from approximately 5% on-site to 0.5% to 1% in prefabrication yards.
• Chemical admixtures such as retarders, plasticizers, pigments, corrosion inhibitors and bonding agents are stored for concreting.
• Some prefabrication yards have their own water treatment facilities to treat waste water generated from production.
Design, coordination and technical issues
• Approximately 7 months of advanced coordination work for statutory approval, assembling of formwork and moulds of the prefabricated components are required before the production can begin.
• In general, prefabrication construction takes up to 7 days whereas on-site construction usually takes 4 – 6 days, therefore it requires more construction time. However, the construction timetable is more certain as weather condition would have less effect on the construction.
• Quality control and statutory approval process would be a technical difficulty in setting standards for prefabricated components in Hong Kong.
Labour
• The labour in a traditional prefabricated yard consist of low skilled manufacturing labour, quality controller, administrative staffs, professional and technical staffs[83].
• Respondents suggested that there should be sufficient managerial and designing staff in Hong Kong. However, manufacturing workers such as form workers could be difficult to find in Hong Kong.

[83] Labour required in traditional prefabrication yard would be different from labour required in automated prefabrication hub.

Costs and demand for prefabricated components
• Base on past and current projects, public housing constructions can use up to approximately 30% of prefabricated components. However, as public housing stop using volumetric prefabricated bathroom units in recent constructions, the forecast for future utilisation should be less.
• For private housing construction, the usage of prefabricated components in construction is less than 15%.
• Usage of prefabricated components are more common in Mainland China than in Hong Kong. In Singapore, utilisation rate could reach up to 70% as prefabricated beams and columns are adopted as well.
• With the reduction of GFA concession incentives (from 300mm to 150mm concession on external walls/facade), the future demand for prefabricated components in Hong Kong are likely to reduce. For public housing construction, the forecasted demand for prefabricated components is 200,000 to 300,000 tonnes annually. For private housing, it is predicted that less than 10 projects will adopt prefabrication per year.
• In term of construction cost, prefabrication construction would be more expensive that traditional on-site construction
• The approximate breakdown of costs and profit as a percentage of revenue of a prefabrication yard as follows: - Raw materials: 40% - 45% - Labour 15% - 20% - Moulds 8 - 10% - Miscellaneous / Overheads – 15% - Profit – 5%
• Prefabricated components cost approximately HK$2000 – HK$4000 per tonne (i.e. for typical concrete prefabricated components), depending on the types, complexity and size of the prefabricated components.
Technology
• New technology such as radio frequency identification device, 3D modelling and 3D printing (for design coordination purpose) could be implemented in prefabrication production to increase productivity and quality of product.

Views on establishing a prefabrication yard in Hong Kong
In conclusion, we have asked the respondents on their views on establishing a prefabrication yard in Hong Kong. Most of the respondents expressed concerns over the viability of the proposed prefabrication yard in Hong Kong and their major concerns are summarised as follows: • With a well-developed prefabrication industry, Singapore has more resources in terms of land space and labour (supply from immigrants) for construction and manufacturing prefabricated components. Moreover, the Singapore government has set up various policy to promote the use of prefabricated components (please refer to Section 3.1). In Hong Kong, more government subsidy and support is required in order to promote the prefabrication industry and to compete with the prefabricated components from Singapore and Mainland China. • The limited resources on land and labour remains a concern for the establishment of the prefabrication yard. CIC should provide training to workers for prefabrication industry while Housing Authorities should introduce a broader use of prefabricated components in their projects. • It would be beneficial to have prefabrication yards in Hong Kong for contractors, as it reduces the need for them to send engineers to Mainland China for quality inspection purposes.

10.2 Stakeholder Engagement Forums

As part of the study, three stakeholder engagement forums were held. The purpose of the forum was to discuss and obtain views from the stakeholders on the issue of the upcoming challenges facing the construction industry. They are in terms of skilled labour shortages and issues around how to make prefabrication viable in Hong Kong in its local prefabrication yard with reference to the pros & cons of prefabrication components and construction activities in the next 5 years.

The sessions were facilitated and held in Arup's office as follows:

Forum No.	Date	Stakeholder Groups
1	29th Jan 2018	Contractors and Specialist Prefabrication Suppliers
2	2nd Feb 2018	Consulting Firms, Professional Associations & Academics
3	2nd Feb 2018	Developers and Government authorities

At the forums, participants were presented with the following:

- The initial findings on the criteria and barriers for establishing a prefabrication yard in Hong Kong
- Observations and challenges facing the construction industry such as labour skills and labour shortages

- Case studies of prefabrication yards in Singapore; and
- Projects adopted DfMA approach

Topics raised for discussion at the three forums were dependent on the stakeholder group, and were much focused on the stakeholder's association with prefabrication. See table below of the topics raised:

Stakeholder Groups	Topics Raised for Discussion
Contractors and Specialist Prefabrication Suppliers	Labour availability, labour skills, worker conditions, worker safety, cost and efficiency, technology (BIM, Automation)
Consulting Firms, Professional Associations & Academics	Ease of design and statutory approval, innovation (DfMA), standardisation & software technology, flexibility/challenges
Developers and Government authorities	Regulatory/Policy, Codes & standards, Incentives, Cost/Time/Options

The stakeholder forum outcome is summarised as follows:

- A general consensus from all the stakeholders in the 3 forums agreed that the adoption of prefabrication modules / components in construction would benefit from a safety, environmental, sustainability, labour shortage and quality aspect.
- Unless there are real financial benefits, it is unlikely that there would be a significant increase in the % of prefabrication components to be used by the private sector.
- The adoption of prefabrication modules in construction would consume the allowable GFA for the development. This is a 'big' deterrent to private developers in using prefabricated components.
- Advances in technology (i.e. BIM, automation) has made the design and fabrication of prefabricated components more effective,
- Having local prefabrication yards would be beneficial for the convenience of statutory inspections, consistent quality control and easing the demand of local labour. Stakeholders are generally supportive of prefabrication yards in Hong Kong but have reservations whether it is viable or sustainable from a business perspective.
- Governmental support in the areas of land availability & affordability and amendments to its existing regulatory & policy (i.e. mandatory use of prefabrication, GFA concession, adoptable design guidelines & effective design approval procedures & time etc.) would aid prefabrication to be viable in Hong Kong.

Appendix A

Requirements for Prefabricated Prefinished Volumetric Construction

Requirements for Prefabricated Prefinished Volumetric Construction

For the purposes of Regulation 4B(4)(b) of the Building Control (Buildability and Productivity) Regulations, the volumetric modules used for PPVC shall comply with the following requirements:

Minimum level of finishing and fittings to be completed off-site

The extent of finishing and fittings to be completed off-site for the volumetric modules shall comply with the minimum levels stipulated in Table 1. Where any deviation from these minimum levels is necessary, prior approval shall be sought from BCA.

Minimum level of finishing and fittings to be completed off-site	
Element	Minimum level of completion off-site
Floor finishes	80%
Wall finishes	100%
Painting	100% base coat, only final coat is allowed on-site
Windows frame & Glazing	100%
Doors	100%, only door leaves allowed for on-site installation
Wardrobe and Cabinets	100%, only wardrobe and cabinet doors to allowed for on-site installation
M&E including water & sanitary pipes, electrical conduits & ducting	100%, only equipment and fixtures to allowed for on-site installation
Electrical sockets and light switches	100%, only light fittings allowed for on-site installation

Water tightness and prevention of corrosion where steel is used as the primary structural material

The steel shall be galvanised in accordance to ASTMA 123/A 123M or alternative equivalent standards.

The volumetric modules shall be designed and fabricated to:

- prevent water from entering the modules (e.g. by means of waterproofing membrane or other means at the joints and gaps between the modules); and
- allow any water in between the volumetric modules and façade, and in between the modules to be properly discharged and drained completely.

Floor areas intended to be wet (e.g. bathrooms, kitchens) and areas that could be potentially exposed to water (e.g. fire sprinkled areas) shall be treated with waterproofing membrane to ensure water tightness.

Acceptance Framework for Prefabricated Prefinished Volumetric Construction (PPVC)

The acceptance framework consists of two parts – the Building Innovation Panel (BIP) and the PPVC Manufacturer Accreditation Scheme (PPVC MAS).

Under the new acceptance framework for PPVC systems to be used at the mandated GLS sites, PPVC suppliers and manufacturers are required to submit their applications and proposals to the Building Innovation Panel (BIP).

1. The PPVC system and the in-built bathrooms (if any) shall comply with the requirements of the BIP. The accepted PPVC systems including the in-built bathroom (if any) and their respective suppliers/manufacturers will be listed on the BCA website at http://www.bca.gov.sg/BuildableDesign/ppvc.html. Relevant letters of In-Principle Acceptance (IPA) will also be issued to the PPVC supplier/manufacturer.
2. In addition, the production facilities producing PPVC systems which have been accepted through the BIP will be required to be accredited under the PPVC MAS, which is managed by the Singapore Concrete Institute (SCI) and the Structural Steel Society of Singapore (SSSS) as part of the effort to promote greater self-regulation by the industry. The accreditation criteria were jointly developed by SCI, SSSS and BCA. Further details on the accreditation scheme can be found at www.scinst.org.sg and www.ssss.org.sg.

Appendix B

Prefabrication Manufacturer
Case Studies

Case Study 1 – SEF SpaceHub

Incorporated in 1994, the SEF Group acts as the main contractor in planning, coordinating, managing and undertaking works for new construction, addition & alteration, and interior fit-out.

SEF Group undertakes a wide range of projects for the private and public sectors encompassing high-end hotels, luxury residences, heritage buildings, recreation facilities, retail malls, commercial offices, and mixed-use developments.

SEF Group has 5 core divisions[84] including:

1. Construction Division;
2. Interiors Division;
3. Prefabricated Prefinished Volumetric Construction (PPVC) Division;
4. Prefabricated Bathroom Unit (PBU) Division; and
5. Structural Precast Division.

SEF Group won the first land tender by the Building and Construction Authority (BCA) for the development of an Integrated Construction and Prefabrication Hub (ICPH) at Kaku Bukit Road in 2013 with a 30-year lease term[85].

Opened in 2015, SEF SpaceHub is the first prefabrication hub in Singapore to have fully integrated modelling, production and delivery of prefabricated components.

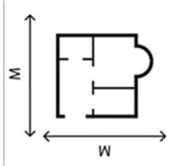
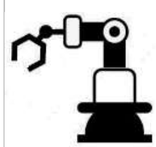
Some facts and figures of the SEF SpaceHub investment cost, development, operation, welfare facilities, automation, equipment and systems and types of prefabrication products manufactured and benefits are listed as follows

Investment Cost

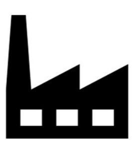
$100mil	The highly mechanised and automated facility was built at a cost of more than SG$100 million[86].

[84] SEF Group website
[85] Building and Construction Authority of Singapore website
[86] New hub to build precast parts with less manpower, Straits Times

The Hub

	**20,000sqm**	The hub is located at Kaki Bukit with approximately 20,000 sqm[87] in land size and a maximum gross plot ratio of 1.6[88].
	**32,608sqm**	The build-up area is approximately 32,608 sqm[89]. Comparing with traditional open yard, the development of a multi-story prefabrication hub allows a more efficient use of land and more workspace.
	**5-storey**	The hub occupies 5 floors. In land scarce Singapore, the vertical development of prefabrication hubs allows higher utilisation of land use.
	**5 automated production lines**	The hub is equipped with 5 automated production lines. The highly mechanised and indoor factory environment enables high throughput and high productivity.

Other Facilities

	**Worker's Dormitory**	The hub includes a seven-storey workers' dormitory as part of the Phase 2 construction.
	**Multi-tiered fully automated storage facility**	SEF SpaceHub is the first in Singapore to use a multi-tiered fully automated storage system, which is capable of storing more than 100 trailers worth of completed components, including bulky 3-D components such as household shelters.

[87] Building and Construction Authority of Singapore news release – 29 July 2013
[88] Building and Construction Authority, ICPH tender
[89] Building and Construction Authority of Singapore website

Office building	A 4-storey office building located next to the hub for engineers, designers and other administrative staffs allows closer alignment and coordination with work progress in the hub.
Automated concrete batching plant with underground storage system	The dust free automated concrete batching plant is equipped with technologically advanced concrete mixer to produce quality concrete. It also has an underground storage system that saves space.

Equipment, Systems and Automation

NEMETSCHEK GROUP **Nemetschek - Precast Software Engineering**	Nemetschek provided integration of Building Information Modelling (BIM) software with the control & management software to gather installation updates from project sites to achieve "Just in Time" production in order to cut down on storage space.[90]
RIB running together SAA **SAA – prefabrication hub automation control system**	SAA provides master computer systems and control systems covering software and technical requirements in connection with the automation of a prefabricated concrete plant. The fully automated system allows tracking of inventory of prefabricated components and the preparation to delivery.
Avermann - Automated prefabricated concrete production line	Automated production line consisting CAD systems, workstations for job preparation, production planning, mixing plants and bucket conveyors etc.
Nordimpianti – Prefabricated pre-stressed concrete machinery	Nordimpianti offers a wide range of pre-cast concrete manufacturing machines from casting machines to pre-stressing machines.

[90] Singapore awards landmark tender for integrated construction and precast hub, Yahoo Finance

	**EVG – Welded Mesh production and steel bars processing machinery**	EVG provides machines for welded mesh production and cutting and bending of rebars.
	**Pemat – Concrete mixing equipment**	Pemat concrete mixer provides high levels of homogenisation and repetition.
	**Terex Demag – Heavy lift cranes**	Demag by Terex provides All terrain cranes, City cranes and Lattice boom crawler cranes.

Productivity

 **240,000tonnes**	The adoption of new technology and machineries, allows the hub to be two to three times more productive than traditional open **prefabrication** yards as work can go on non-stop and several processes can be carried out at the same time [91]. In addition, the covered environment also allows work to be carried out even during bad weather. The hub has an annual production capacity of more than 240,000 tonnes of prefabricated components[92].

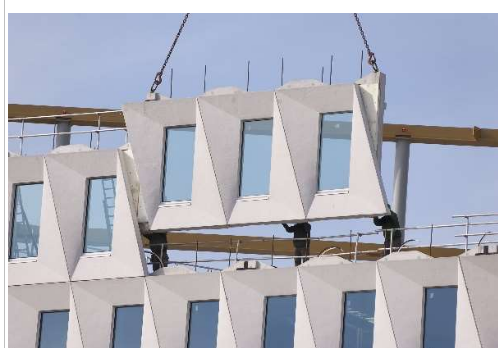
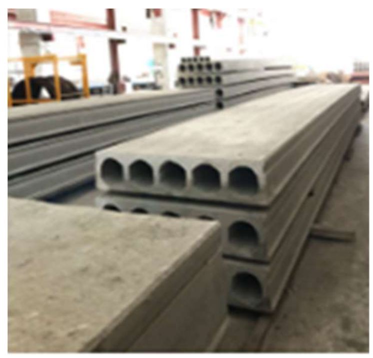
[91] Going off-site to boost productivity, The Business Times

[92] Building and Construction Authority of Singapore news release – 29 July 2013

Prefabricated Products

SEF SpaceHub produces more than 25 types of components. Including columns, beams, planks, walls, façades, staircases, household shelters and prefabricated bathrooms in a factory setting. These components can then be transported for installation on site. Examples of similar products include:

Prefabricated Prefinished Volumetric Construction (PPVC / Modular Construction)	Prefabricated Bathroom Unit
	

Coloured Prefabricated Facades	Prefabricated Structural Components (Columns, Floors, Beams and Walls, Staircases, Slabs)
	

Benefits of the new SpaceHub facility

The prefabricated components were originally manufactured in an open yard factory and very labour intensive. Following the move from an open yard to a multi-storey building factory and advanced technology and automated production lines adopted, there has been vast improvements to its operational efficiency and productivity. Some of the improvements includes:

3x production capacity	Annual prefabricated components production capacity is three times more than a conventional open **prefabrication** yard[93].
Better quality control, faster production	The hub setting speeds up the production process and provides better quality control of the prefabricated components.
70% Manpower savings	The highly automated facility is expected to reduce the number of workers needed by up to 70 per cent[94,95].

[93] Building and Construction Authority News release July 2013
[94] New hub to build precast parts with less manpower, The Straits Times
[95] Prefab Hub to boost construction productivity: Khaw, Yahoo News

Case Study 2: Greyform Building

Greyform Pte Ltd, a member of Straits Construction Group, was incorporated in 2015 and specialises on precast and prefabrication production.

Greyform Pte Ltd manufacturers prefabricated concrete products such as the following:

- Prefabricated bath unit
- Prefabricated façade wall
- Prefabricated Staircase flight
- Prefabricated concrete column
- Prefabricated Slab

Greyform won the land tender from the Building and Construction Authority (BCA) for development of the second Integrated Construction and Prefabrication Hub (ICPH) at Kaku Bukit Road in 2014 with a 30-year lease term.[96]

Greyform Building is the second Integrated Construction and Prefabrication Hub (ICPH) awarded under a public tender by BCA. The multi-storey prefabrication hub was opened in 2017 and uses a high degree of automation to produce pre-fabricated construction elements such as concrete walls, columns and beams.

Some facts and figures of Greyform's investment cost, development, operation, welfare facilities, automation, equipment and systems and types of prefabrication products manufactured and benefits are listed as follows:

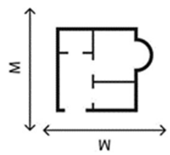
Investment Cost

 **$150mil**	The recently established Greyform Building equipped with advanced technology and machinery costed an SG$150 million investment[97].

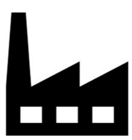
The Hub

 **20,000sqm**	The land size occupied is approximately 20,000 sqm[98], with a maximum gross plot ratio of 1.6. It is located at Kaki Bukit next to SEF Spacehub.

[96] Building and Construction Authority of Singapore website
[97] The Straits Times, *BCA to give advance notice on building projects that need high level of prefabrication*
[98] Building and Construction Authority of Singapore

 **32,100**sqm	The Greyform Building has a gross floor area of 32,100 sqm. When compared to the traditional prefabrication yards that are housed in large open areas, it optimises the use of land better by developing vertically.
 **4**-storey	The Greyform Building comprises a four-storey prefabricated concrete components production factory and office. It allows workers to work in a controlled and safe environment, improving the working conditions.

Other Facilities

 **Workers' Dormitory**[99]	In addition to the 4-storey production factory, three blocks of 12-storey dormitory capable of housing 750 workers are also located next to the hub[100].
 **Multi-storey storage and retrieval system**	In order to store the prefabricated components, an automated, multi-level storage system has been built with the capacity to house up to 5,800 tonnes of products[101].
 **Entertainment facilities**	To improve working environment, entertainment facilities are built closely to the workers' dormitory such as basketball court.

Productivity

 **150,000**tonnes	The Greyform building is equipped with robots and digital modelling for automation, which can operate around the clock regardless of the weather. Productivity can be increased up

[99] Picture from ONG&ONG Corporate website
[100] The Singapore Engineer January 2018
[101] The Singapore Engineer January 2018

	to 40 % and the plant has an annual production capacity of more than 150,000 tonnes[102].

Prefabricated Products

The Greyform manufacturer can produce a wide range of products to fit different building needs. They emphasize on innovations that enable faster construction. Similar examples of Greyform Building's products include:

Prefabricated Stair	Prefabricated Bath Unit
	

Prefabricated Concrete Column	Prefabricated façade wall
	

Benefits of the new Greyform Facility

Advanced prefabricated technologies were adopted by Greyform in their new multi-story facility. Improvements to productivity and saving to manpower have been achieved. Details includes:

[102] The Straits Times, *BCA to give advance notice on building projects that need high level of prefabrication*

 **Increased productivity and improved quality**	Equipped with highly automated production line and precise designing with computer software, the hub is able to improve productivity and increase the quality of prefabricated components.
 **66-75%** **Manpower savings**	The automation manufacturing process also significantly reduces the amount of labour needed. The hub has only 60 workers, which is about one-third to one-fourth of what is needed for a traditional open yard[103].
 **Creating new and higher-skilled jobs**	These heavily automated facilities require high-skilled and trained workers as well as technical staffs such as engineers and designer. It creates new and higher-skilled job that attracts locals to work in the construction industry.

[103] The Straits Times, BCA to give notice on building projects that need high level of prefabrication

Case Study 3: Tiong Seng Prefab Hub

Tiong Seng Group was founded in 1959 who had been involved in earthworks and excavation projects. Later in 1970s, the company expanded into civil engineering and since 2002 they have started to extensively adopt the use of prefabricated technology.

Tiong Seng Group's key services include:

- Building construction and civil engineering
- Property development
- Prefabrication
- Green technology
- Metal works & steel works

Tiong Seng Group announced the launch of the Tiong Seng Prefab Hub in 2012 with SG$1 million funding from the Building and Construction Authority (BCA)[104].

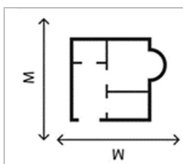
The Tiong Seng Prefab Hub is a multi-purpose facility. It houses the automated prefabricated plant and contains space for the building of prefabricated bathroom units and the pre-assembling, storing and maintaining of advanced formwork systems. It also includes facilities such as training centre, a Building Information Modelling (BIM) Centre and a workers' dormitory. The co-existence of these related activities under one roof makes managing resources easier while improving land productivity.

Some facts and figures of Tiong Seng Prefab Hub's investment cost, development, operation, welfare facilities, automation, equipment and systems and types of prefabrication products manufactured and benefits are listed as follows:

Investment Cost

 $26mil	The Tiong Seng Prefab Hub costs SG$26 million with a SG$1million funding from the BCA.[105]

The Hub

 19,813sqm	Tiong Seng Prefab Hub is located at Tuas, with a gross floor area of 19,813 sqm. Approximately 72% of the gross floor area is allocated for production purpose [106], the

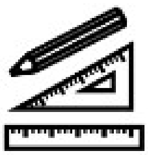
[104] Building and Construction Authority news press, Tiong Seng's $26 million Prefab Hub – Singapore's 1st automated pre-cast facility and first to receive BCA funding
[105] Building and Construction Authority Singapore News Press, 4 January 2011
[106] Building and Construction Authority Singapore News Press, 4 January 2011

	other areas contain multi-purpose space designed with green building concepts.
5-storey	The 5-storey prefabrication hub consists of areas for production and several facilities as described below.
2 automated production lines	The hub has two automated production lines incorporating automated equipment from Germany[107]. While automated machines will perform complex work such as high precision of marking-out of dimensions, automated pallet circuits will be installed to transport products from one workstation to another for processing.

Other Facilities

Office area	Ancillary offices are located at all floors to closely align designers and engineers with the production line.
Workers' dormitory and urban farming plot	The workers' dormitory includes a 900sqm plot dedicated for urban farming where workers can grow their own crops[108].
Rainwater tanks	Rainwater tanks are located at roof top for rainwater harvesting for irrigation to reduce usage of potable water[109] and achieve environmental sustainability.
Various green building features	Besides the urban farming facility, Tiong Seng has also incorporated several green building features which include an eco-façade for

[107] Building and Construction Authority news press, Tiong Seng's $26 million Prefab Hub – Singapore's 1st automated pre-cast facility and first to receive BCA funding
[108] Building and Construction Authority Singapore News Press, 4 January 2011
[109] Robin Village Development Ptd Ltd website

	the office block incorporating a vertical green wall, an extensive green roof which provides natural cooling, monsoon windows to improve air ventilation, and rainwater harvesting[110].
 **Training Centre and BIM Centre**	The hub features a training centre and a BIM Centre. It allows Tiong Seng to train their project partners and sub-contractors on the use of BIM, which is a 3D software that can improve coordination of the construction value chain and reduce the amount of reworking on-site.

Productivity

 **240,000tonnes**	As the facility can operate 24-hour production process, the output has doubled from previous plant with annual production exceeding 240,000 tonnes[111]. The facility can produce enough parts for approximately 5,000 Housing and Development Board flats.

Benefits of the new Tiong Seng Prefab Hub

Increase in the productivity capacity and saving to manpower has been achieved. Details include:

 **70% Manpower savings**	With automation, Tiong Seng Prefab Hub has reduced manpower needs up to 70%, requiring only a third of the workers to produce double the volume of prefabricated components[112].

[110] Building and Construction Authority Singapore News Press, 4 January 2011
[111] Building and Construction Authority Singapore News Press, Opening of Tiong Seng Prefab Hub
[112] Building and Construction Authority Singapore News Press, 4 January 2011

Appendix C

Site Analysis

Area 1: Ping Shan

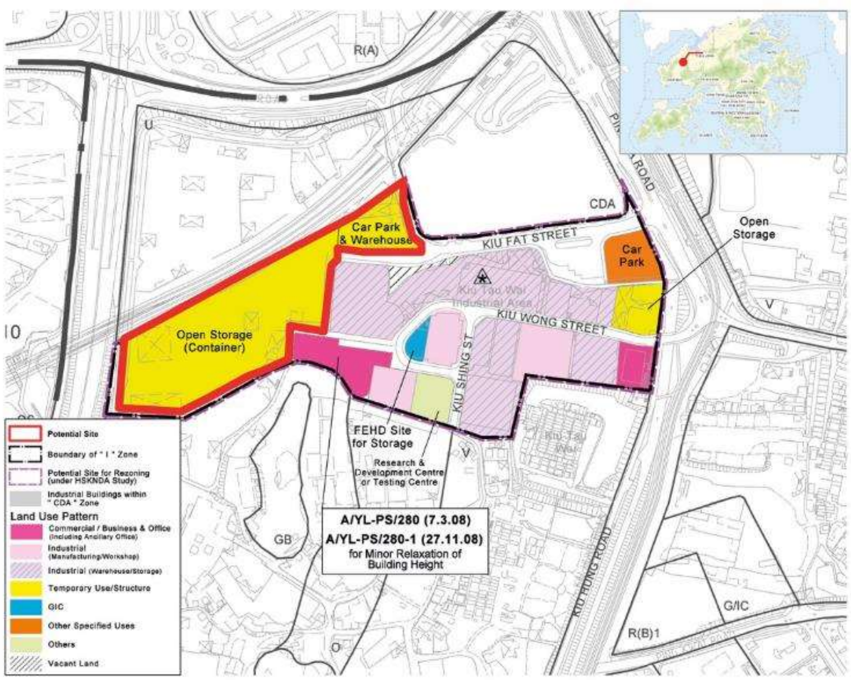
Site analysis:

Possible Industrial Area No.1 is located in between Hung Tin Road and Kiu Hung Road in Ping Shan. As of the year 2014, the predominant uses of this area are 48.2% for Warehouse/Storage and 23.4% for Manufacturing/Workshop.

Our analysis shows that there is currently no vacant site in this Possible Industrial Area, except for a temporary use land (currently occupied by open storage facility, car park and warehouse) on the western portion of the area. The size of this temporary use land is approximately 28,000 sqm (shown in red boundary in Figure 1.3.1). The whole Possible Industrial Area is currently under multiple private ownerships.

These existing uses would be compatible with the prefabrication yard, as the operation would involve both manufacturing and storage services.

Figure 1.3.1: Potential Site in Ping Shan[113]



113 Adapted from Appendix 3.6 of Report on 2014 Area Assessments of Industrial Land in The Territory, from: https://www.pland.gov.hk/pland_en/p_study/comp_s/industrial_report_2014/appendices/a26.pdf. .

Table 1.3.1 Key Information of Ping Shan

	Description
Possible Industrial Area	Ping Shan
Total area (as in 2014)[114]	9.86 ha
District	Yuen Long
OZP	Draft Hung Shui Kiu and Ha Tsuen OZP No. S/HSK/1
Current Zoning	“C(2)” and “OU (Mixed Use)”
Predominant Uses (as of 2014)	Warehouse/Storage (48.2%) and Manufacturing/Workshop (23.4%)
Vacant Site (as of 2014)	0 site
Vacancy Rate (based on GFA as of 2014)	4.5%
Ownership (as of 2014)	Mainly private ownership
Number & Area of Potential Site(s)	No. of Potential Site: 1 Site area: 28,000sqm

Other considerations:

It is important to note that in the prevailing Draft Hung Shui Kiu and Ha Tsuen Outline Zoning Plan (OZP) No. S/HSK/1 gazetted published in May 2017, this temporary use land has been defined as “Commercial(2)” (“C(2)”) and “OU (Mixed Use)” zone. The planning intention of the “C(2)” zone is “*primarily for commercial developments*” and according to the Explanatory Statement (ES), the “C(2)” zone will be developed as a secondary node for office, retail and hotel uses. The “OU (Mixed Use)” zone is intended “*primarily for high-density residential development and commercial development in close proximity to the railway stations*.”

As such, the prefabrication yard being an “industrial” use, will not be in line with the planning intention of the current zonings of this area.

Key findings:

Table below summarises our key findings for the Ping Shan site assessment:

Results		**Rationale**
Site analysis	○	**Opportunities:** ▪ Site area is adequate to fit the size of the prefabrication yard as suggested in Preliminary Base Case **Constraints:** ▪ Latest gazette mentioned that the whole industrial area has been rezoned and it is no longer intended for industrial use ▪ Multiple private ownerships

[114] Site A26 (Report on 2014 Area Assessment of Industrial Land in the Territory).

Area 2: San Hei Tsuen / Tong Yan San Tsuen

Site analysis:

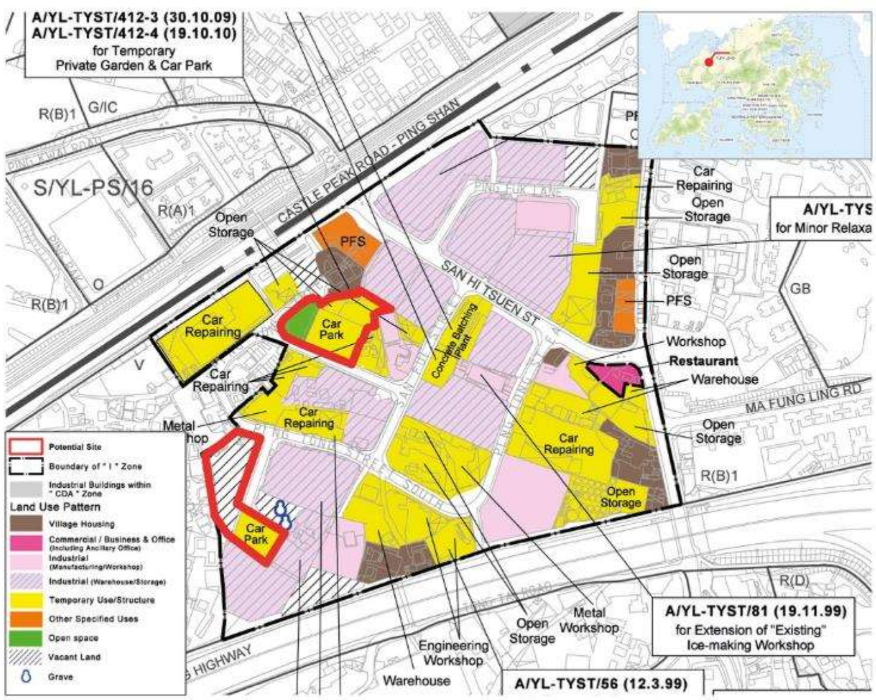
Possible Industrial Area No.2 is situated in-between Castle Peak Road – Ping Shan and Yuen Long Highway at San Hei Tsuen. As of the year 2014, the predominant use of this area is 78.2% for Warehouse/Storage.

Our analysis shows that there are two vacant sites within this Possible Industrial Area:

- **Potential Site 1:** It is currently used as open space and temporary car park, and has a site area of around 3,900 sqm
- **Potential Site 2:** It is partially vacant and partially used as a temporary car park. The site area is around 4,000 sqm.

The site area for Potential Site 1 and Site 2 are approximately 3,900 sqm and 4,000 sqm respectively.

Figure 1.3.2 Potential Sites in San Hei Tsuen/ Tong Yan San Tsuen[115]



[115] Adapted from Appendix 3.6 of Report on 2014 Area Assessments of Industrial Land in The Territory, from: https://www.pland.gov.hk/pland_en/p_study/comp_s/industrial_report_2014/appendices/a25.pdf.

Table 1.3.2 Key Information of San Hei Tsuen/ Tong Yan San Tsuen

	Description
Possible Industrial Area	San Hei Tsuen/ Tong Yan San Tsuen
Total area (as in 2014)[116]	14.80 ha
District	Yuen Long
OZP	Draft Tong Yan San Tsuen OZP No. S/YL-TYST/11
Current Zoning	"I"
Predominant Uses (as of 2014)	Warehouse/Storage (78.2%)
Vacant Site (as of 2014)	2 sites
Vacancy Rate (based on GFA as of 2014)	0.1%
Ownership (as of 2014)	Mainly private ownership
Number & Area of Potential Site(s)	2 nos., varying from about 3,900 sqm. to 4,000 sqm.

Other considerations:

These Potential Sites are subject to a maximum Plot Ratio (PR) of 3 and Building Height Restriction (BHR) of 4 storeys (15m). Minor relaxation of PR and BHR is possible through a S16 planning application to the Town Planning Board (TPB). If the operations of prefabrication yard involve bleaching and dyeing, electroplating/ printed circuit board manufacture, metal casting and treatment, an S16 planning application is also required.

Our analysis also shows that these Potential Sites are located adjoining to "Village" ("V") and "Residential (Group A)" ("R(A)") zones, which are predominately residential in nature. As such, it could lead to a potential Industrial / Residential (I/R) interface issues as well as public objections if a prefabrication yard of a substantial scale is to be developed at these locations.

[116] Site A25 (Report on 2014 Area Assessment of Industrial Land in the Territory).

Key findings:

Table below summarises our key findings for the San Hei Tsuen/ Tong Yan San Tsuen site assessment:

Results		**Rationale**
Site analysis		**Opportunities:** ▪ Zoning in line with industrial use. ▪ Potential Sites held under Government ownership **Constraints:** ▪ The site area is relatively small as compared to Preliminary Base Case requirement; ▪ May require S16 planning application for minor relaxation of building height restriction (4 storeys/15m) and max. PR (PR3) for the prefabrication yard use; ▪ May require S16 planning application should the prefabrication operations involve bleaching and dyeing, electroplating/ printed circuit board manufacture, metal casting and treatment; and ▪ Close proximity to “V” and “R(A)” zones, which may induce I/R issues or possible public objections.

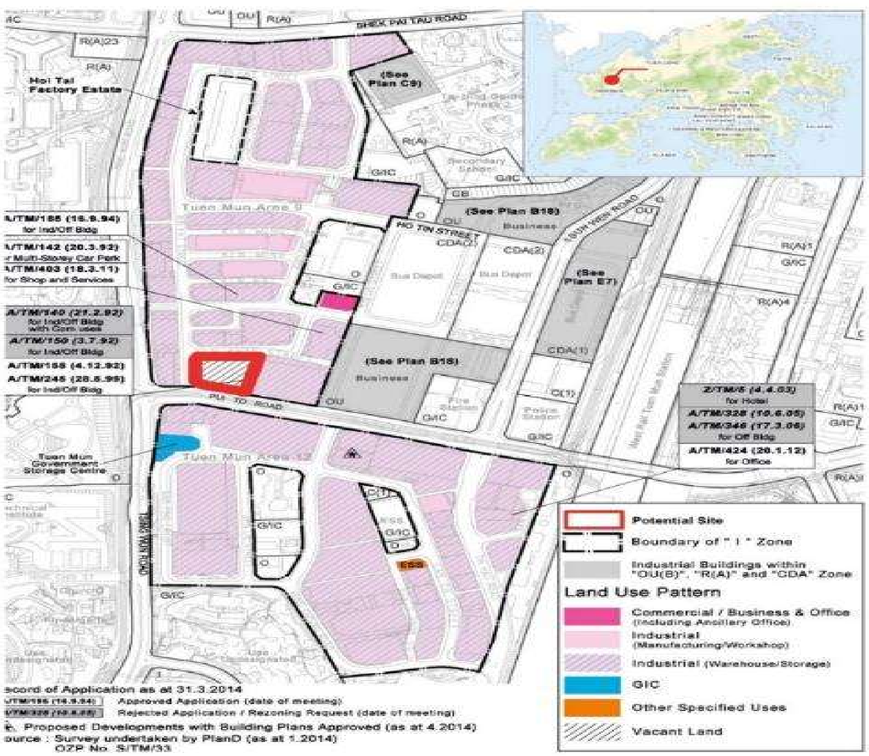
Area 3: Tuen Mun Areas 9 and 12

Site analysis:

Possible Industrial Area No.3 is located to the west of Tuen Mun Town Centre. As of the year 2014, the predominant uses of this area are 65% for Warehouse/Storage and 11.4% for Manufacturing/Workshop.

Our analysis shows that there is a small piece of vacant land, along Pui To Road, with an area of about 3,000 sqm. It is located in between warehouses and storages in the same "I" zone.

Figure 1.3.3 Potential Site in Tuen Mun Areas 9 and 12[117]



[117] Adapted from Appendix 3.6 of Report on 2014 Area Assessments of Industrial Land in The Territory, from:
https://www.pland.gov.hk/pland_en/p_study/comp_s/industrial_report_2014/appendices/a20.pdf.

Table 1.3.3 Key information of Tuen Mun Areas 9 and 12

	Description
Possible Industrial Area	Tuen Mun Areas 9 and 12
Total area (as in 2014)[118]	26.19ha
District	Tuen Mun
OZP	Draft Tuen Mun OZP No. S/TM/34
Current Zoning	"I"
Predominant Uses (as of 2014)	Warehouse/Storage (65%), Manufacturing/Workshop (11.4%)
Vacant Site (as of 2014)	0 site
Vacancy Rate (based on GFA as of 2014)	3%
Ownership (as of 2014)	Mainly private ownership
Number & Area of Potential Site(s)	1 no., about 3,000 sqm

Other considerations:

This Potential Site is subject to a maximum PR of 9.5 and BHR of 100mPD. Our analysis also shows that the Potential Site is currently under a single private ownership.

If the prefabrication yard involves concrete batching operations, a S16 planning application would be required, as this use is under Column 2 of "I" zone in this OZP (Draft Tuen Mun OZP No. S/TM/34).

Key findings:

Table below summarises our key findings for the Tuen Mun Areas 9 and 12 site assessments:

Results		**Rationale**
Site analysis		**Opportunities:** ▪ Adequate site area. **Constraints:** ▪ The site area is relatively small as compared to Preliminary Base Case requirement; ▪ Held under private ownership; and ▪ May require S16 planning application if the prefabrication operations involve concrete batching operations.

[118] Site A20 (Report on 2014 Area Assessment of Industrial Land in the Territory).

Area 4: Tuen Mun Area 16

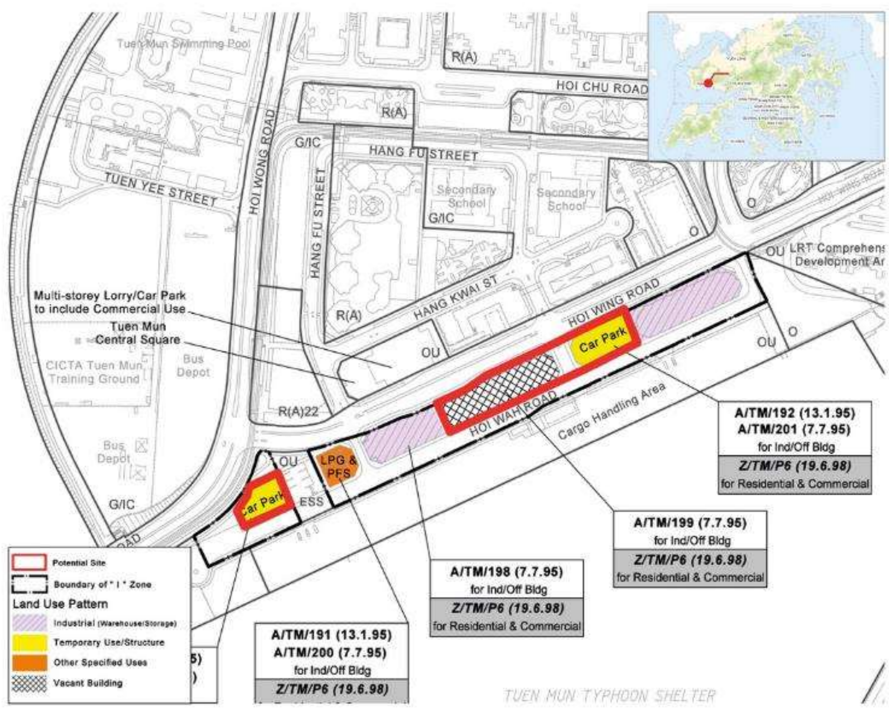
Site analysis:

Possible Industrial Area No.4 is located to the south of Tuen Mun Town Centre and in-between Hoi Wan Road and the Marine Department Tuen Mun Public Cargo Working Area. As of the year 2014, the predominant uses of this area are 18.2% for Warehouse/Storage, 12.9% for Office and 37.4% vacant.

Our analysis shows that there are two Potential Sites within this Possible Industrial Area:

- **Potential Site 1:** located on the western end, which is now used as a temporary car park and is Government-owned, with a site area of about 1,900 sqm.;
- **Potential Site 2:** located in the middle of the larger "I" zone, which consists of a vacant warehouse on private land and a temporary car park on Government land, with a site area of about 10,000 sqm. This site is segregated by a road connecting Hoi Wing Road and Hoi Wah Road.

Figure 1.3.5 Potential Sites in Tuen Mun Area 16[119]



[119] Adapted from Appendix 3.6 of Report on 2014 Area Assessments of Industrial Land in The Territory, from: https://www.pland.gov.hk/pland_en/p_study/comp_s/industrial_report_2014/appendices/a21.pdf.

Table 1.3.5 Key information of Tuen Mun Area 16

	Description
Possible Industrial Area	Tuen Mun Area 16
Total area (as in 2014)[120]	3.42ha
District	Tuen Mun
OZP	Draft Tuen Mun OZP No. S/TM/34
Current Zoning	"I(1)"
Predominant Uses (as of 2014)	Vacant (37.4%), Warehouse/Storage (18.2%) and Office (12.9%)
Vacant Site (as of 2014)	1 site
Vacancy Rate (based on GFA as of 2014)	37.4%
Ownership (as of 2014)	About half held under private ownership
Number & Area of Potential Site(s)	2 nos., varying from about 1,900 to 10,000 sqm.

Other considerations:

The whole area is zoned as "I(1)" and is subjected to a max. PR of 5 and an BHR of 35mPD on the Draft Tuen Mun OZP No. S/TM/34. Minor relaxation of building height restriction of PR and BHR could be sought via a S16 planning application.

The vacant warehouse building in Potential Site 2 has been renovated recently and is held under private ownership. Hong Kong Christian Service Pui Oi School is located across Hoi Wing Road, less than 50m away from Potential Site 2.

Key findings:

Table below summarises our key findings for the Tuen Mun Area 16 site assessment:

Results		Rationale
Site analysis	○	**Opportunities:** ▪ Zoning in line with industrial use; ▪ Existing uses are either vacant or temporary. **Constraints:** ▪ The site areas are relatively small as compared to Preliminary Base Case requirement; ▪ May require S16 planning application for minor relaxation of building height restriction; ▪ May require S16 planning application if the prefabrication operations involve concrete batching. ▪ May cause nuisance to nearby school; and ▪ Not wholly Government-owned.

[120] Site A21 (Report on 2014 Area Assessment of Industrial Land in the Territory).

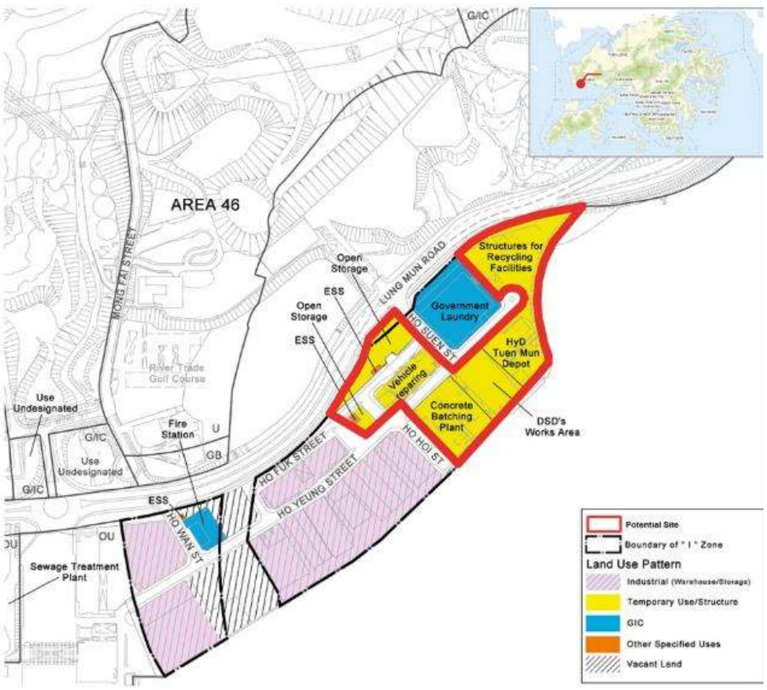
Area 5: Tuen Mun Area 40

Site analysis:

The Possible Industrial Area No.5 is located to the west of Butterfly Beach and to the south of Lung Mun Road along the waterfront in Tuen Mun 40. The area is fully occupied by warehouse and storage uses.

Our analysis shows that there is a Potential Site (36,000 sqm.), located at the north-eastern corner of the area. A number of temporary uses such as structures for recycling facilities, Highways Department (HyD) Tuen Mun Depot, concrete batching plant, vehicle repairing, open storage and two electrical substation (ESS), are currently occupying the Potential Site.

Figure 1.3.4 Potential Site in Tuen Mun Area 40[121]



[121] Adapted from Appendix 3.6 of Report on 2014 Area Assessments of Industrial Land in The Territory, from:
https://www.pland.gov.hk/pland_en/p_study/comp_s/industrial_report_2014/appendices/a23.pdf.

Table 1.3.4 Key information of Tuen Mun Area 40

	Description
Possible Industrial Area	Tuen Mun Area 40
Total area (as in 2014)[122]	10.78ha
District	Tuen Mun
OZP	Draft Tuen Mun OZP No. S/TM/34
Current Zoning	"I(3)"
Predominant Uses (as of 2014)	Warehouse/Storage (100%)
Vacant Site (as of 2014)	2 sites
Vacancy Rate (based on GFA as of 2014)	0%
Ownership (as of 2014)	Majority Government land
Number & Area of Potential Site(s)	1 no., about 36,000 sqm.

Other considerations:

This whole area, zoned as "I(3)" is subject to a maximum PR of 2.5 and MBH of 26mPD on the Draft Tuen Mun OZP No. S/TM/34. The Potential Site is located on a Government-owned land.

We understand that currently there is an on-going study on "Planning and Engineering Study for Tuen Mun Area 40 and 46 and the Adjoining Areas". One of the possible scenarios suggested in the Study indicates that there is an intention to develop this Possible Industrial Area No.4 into modern logistics/ green industry use in MSB with a development scale of approximately PR4 (6-8 storeys high)[123]. The future planning intention seems to be in line with the industrial nature of the prefabrication yard. These premises could allow for the development of a prefabrication yard in the form of MSB as the ICPH model.

The limitations of this Potential Site would be the uncertainty imposed by the abovementioned on-going study. Also, given its relatively low BHR of the Potential Site and the typically high floor-to-floor height of manufacturing, minor relaxation of the building height restriction might have to be sought via a S16 application, which could be an element of uncertainty for the development of prefabrication yard[124].

[122] Site A23 (Report on 2014 Area Assessment of Industrial Land in the Territory).
[123] See http://www.tm4046.hk/download/digest/tm4046_digest1.pdf. This study is, however, on-going and might be subject to further changes.
[124] But this will depend on the detailed design of the prefabrication yard.

Key findings:

Table below summarises our key findings for the Tuen Mun Area 40 site assessment:

Results		Rationale
Site analysis		**Opportunities:** ▪ Zoning in line with industrial use; ▪ Future planning intention in line with industrial use; ▪ Possible scenario of development of MSB for industrial use; ▪ Existing uses are temporary; ▪ Wholly Government-owned; and ▪ Site area is adequate to fit the size of the prefabrication yard as suggested in Preliminary Base Case
		Constraints: ▪ On-going study could impose uncertainty to future use; ▪ May require S16 planning application for minor relaxation of building height restriction; and ▪ May require S16 planning application if the prefabrication operations involve concrete batching.

Area 6: Wu Shan Road, Tuen Mun

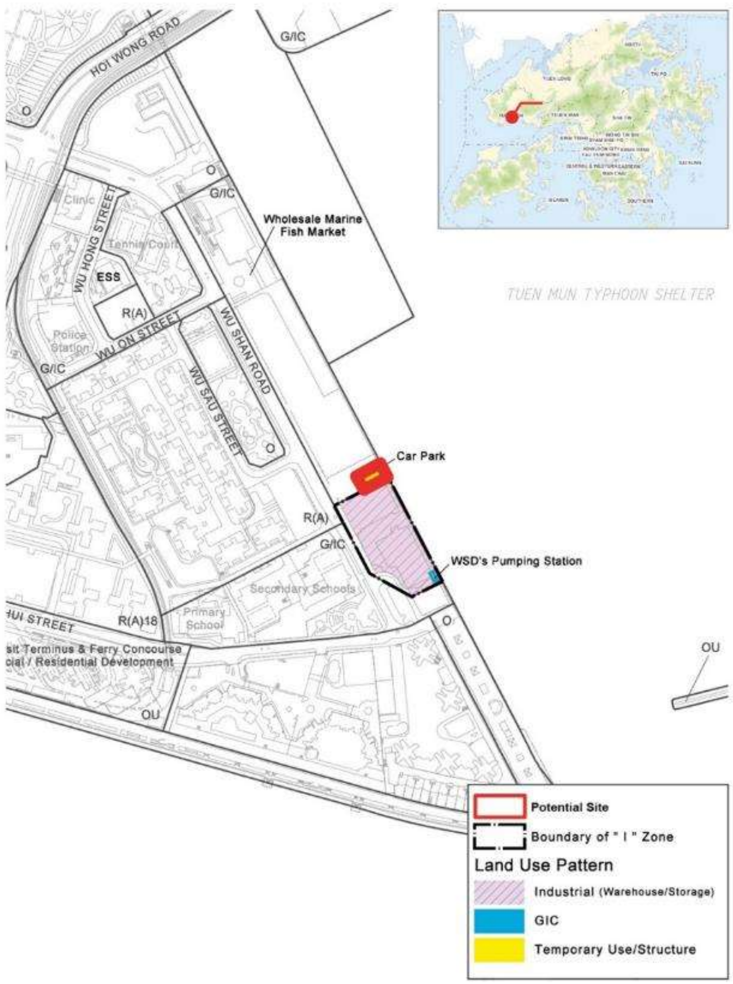
Site analysis:

Possible Industrial Area No.6 is located at the east of Yuet Wu Villa along Wu Shan Road. Currently zoned as "I(2)" in the Draft Tuen Mun OZP No. S/TM/34, the whole area is almost fully occupied by a warehouse named Sun Wah Cold Storage, a Water Services Department (WSD) Pumping Station and a temporary car park.

Our analysis shows that there is a temporary car park, with a site area of approximately 600sqm. within this Potential Industrial Area. This Potential Site is wholly owned by the Government.

This area is subject to a max. PR of 3 and an BHR of 50mPD.

Figure 1.3.6 Potential Site in Wu Shan Road, Tuen Mun[125]



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[125] Adapted from Appendix 3.6 of Report on 2014 Area Assessments of Industrial Land in The Territory, from: https://www.pland.gov.hk/pland_en/p_study/comp_s/industrial_report_2014/appendices/a22.pdf.

Table 1.3.6 Key information of Wu Shan Road, Tuen Mun

	Description
Possible Industrial Area	Wu Shan Road
Total area (as in 2014)[126]	0.84ha
District	Tuen Mun
OZP	Draft Tuen Mun OZP No. S/TM/34
Current Zoning	"I (2)"
Predominant Uses (as of 2014)	Warehouse/Storage (73.7%) and Office (26.3%)
Vacant Site (as of 2014)	0 site
Vacancy Rate (based on GFA as of 2014)	0%
Ownership (as of 2014)	Mainly single private ownership
Number & Area of Potential Site(s)	1 no., about 600 sqm.

Other considerations:

The Potential Site is located next to a residential development (Yuet Wa Villa) and three schools (Ka Chi Secondary School, South Tuen Mun Government Secondary School and Lung Kong World Federation School Limited Lau Tak Yung Memorial Primary School).

Key findings:

Table below summarises our key findings for the Wu Shan Road, Tuen Mun site assessment:

Results		**Rationale**
Site analysis	○	**Opportunities:** ▪ Zoning in line with industrial use; ▪ Existing use is temporary; and ▪ Government-owned. **Constraints:** ▪ The site areas are relatively small as compared to Preliminary Base Case requirement; ▪ May require S16 planning application should the prefabrication operations involve concrete batching; and ▪ May cause nuisance to nearby residents and school.

[126] Site A22 (Report on 2014 Area Assessment of Industrial Land in the Territory).

Area 7: "OU (PBU, Storage & Workshop Uses)" Zones in HSK NDA

Site analysis:

Possible Industrial Area No.7 is located at Ha Tsuen in Yuen Long and west of Kong Sham Western Highway.

This area is not included in the Report on 2014 Area Assessments of Industrial Land in The Territory. However, we have considered this zone in our analysis as it is intended for the development of MSBs to accommodate port back-up, storage and workshop facilities.

This zone is subjected to a maximum PR of 7 and an MBH of 110mPD. The planning intention for this zone is "primarily to cater for the port back-up facilities and container related uses" and "port back-up related development such as container freight station, logistics centre, container vehicle park and container storage, repair yard and rural industry workshop."

Our analysis shows that there are a few Potential Sites within this area and the size varies from about 16,500 to 154,000 sqm. This zone's planning intention leans towards logistic uses, but is also industrial-orientated, as evidenced by its planning intention.

Despite their size and relevant planning intention, the amount of land that would be available for MSB particularly for prefabrication uses will be subjected to concurrent studies, as this zone is primarily intended to provide alternative spaces for the existing brownfield users that are affected under the HSK NDA and YLS PDAs.

The land ownership will also be subjected to the results of the concurrent studies. Also, if the prefabrication operation involves cement manufacturing, concrete batching, metal casting and treatment, and open storage of cement/sand, a S16 planning application would be required.

Figure 1.3.7 Potential Sites – "OU (PBU, Storage & Workshop Uses)" Zones in HSK NDA[127]

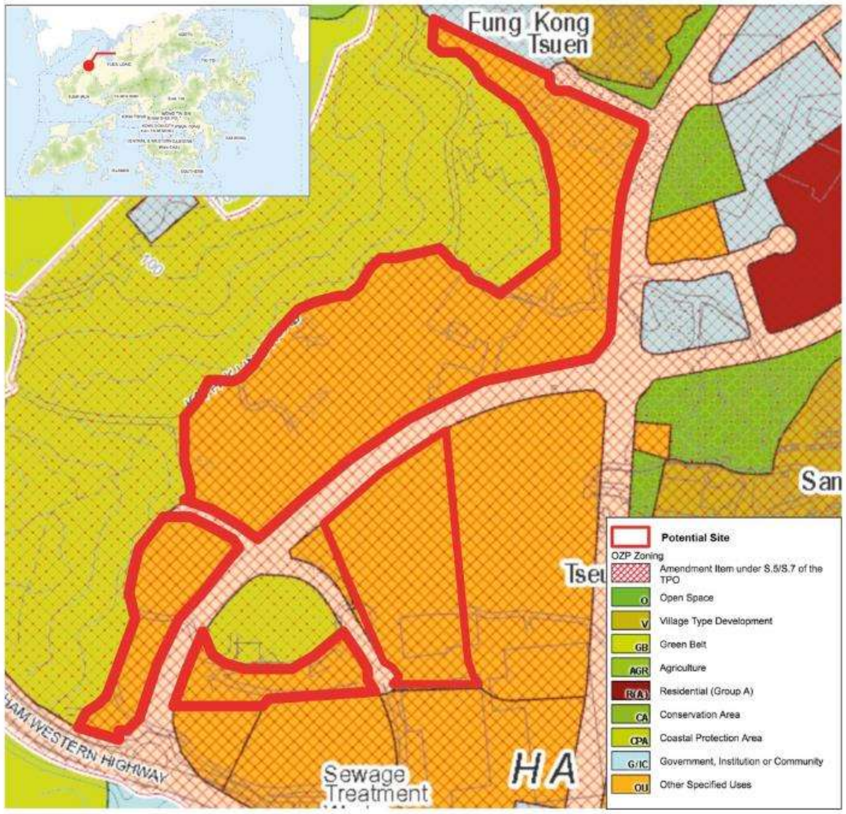


Table 1.3.7 Key information of "OU (PBU, Storage & Workshop Uses)" Zones in HSK NDA

	Description
Possible Industrial Area	"OU (PBU, Storage & Workshop Uses)" Zones in HSK NDA
Total area (as in 2014)[128]	24.80ha
District	Yuen Long
OZP	Draft Hung Shui Kiu and Ha Tsuen OZP No. S/HSK/1
Current Zoning	"OU (PBU, Storage & Workshop Uses)"
Predominant Uses (as of 2014)	Mainly container storage[129]
Vacant Site (as of 2014)	--
Vacancy Rate (based on GFA as of 2014)	--
Ownership (as of 2014)	--
Number & Area of Potential Site(s)	4 nos., varying from about 16,500 to 154,000 sqm.

[127] Adapted from Statutory Planning Portal 2, from: http://www2.ozp.tpb.gov.hk/gos/default.aspx#.
[128] Draft Hung Shui Kiu and Ha Tsuen Outline Zoning Plan No. S/HSK/1.
[129] As observed from the aerial photo on Geoinfo Map.

Key findings:

Table below summarises our key findings for the "OU (PBU, Storage & Workshop Uses)" Zones in HSK NDA site assessment:

Results		Rationale
Site analysis		**Opportunities:** ▪ Zoning in line with industrial use; ▪ Zoning will take in consideration of MSB development; ▪ Sufficient site area; ▪ Adjacent to Kong Sham Western Highway could facilitate import of raw materials; and **Constraints:** ▪ Available land and land ownership is subject to on-going and further studies; and ▪ May require S16 planning application should the prefabrication operations cement manufacturing, concrete batching, metal casting and treatment, and open storage of cement/sand.

Area 8: "OU (Storage & Workshop Uses)" proposed under YLS PDA

Site analysis:

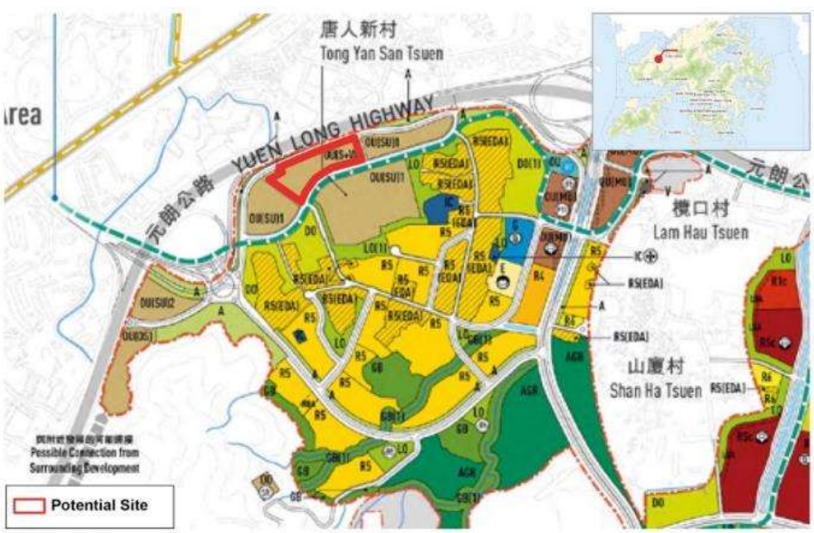
Possible Industrial Area No.8 is located along the south of Yuen Long Highway and north of Tong Yan San Tsuen. Our analysis shows that there is a Potential Site, which is a strip of "OU (Storage & Workshop Uses)". Currently zoned as "I(D)". Its planning intention is "*primarily for industrial uses that cannot be accommodated in conventional flatted factories due to extensive land and/ or high ceiling requirements*" and it is also "*intended for the redevelopment of existing informal industrial uses*". Studies are currently being undertaken to re-plan for the OU zone.

Under the latest RODP of the YLS study, this strip of OU is intended to be developed as the Employment Belt where MSBs will be constructed.[130].

This Potential Site is of 17,000sqm and comply with the Industrial land use classification and MSB development. and within close proximity to Yuen Long Highway, which is one of the main arterial roads.

As the YLS Study is still on-going, and the proposed "OU(Storage & Workshop Uses)" has yet to be reflected in statutory OZP, there could be uncertainties to the current site analysis conditions.

Figure 1.3.8 Potential Site - "OU (Storage & Workshop Uses)" proposed under YLS Study[131]



[130] Please refer to the Information Digest of YLS study, from: http://www.yuenlongsouth.hk/links/information_digest.pdf.
[131] Adopted from the RODP of YLS study, from: http://www.yuenlongsouth.hk/links/RODP.pdf.

Table 1.3.8 Key information of "OU (Storage & Workshop Uses)" proposed under YLS Study

	Description
Possible Industrial Area	"OU (Storage & Workshop Uses)" proposed under YLS Study
Total area (as in 2014)[132]	Approx. 1.7 ha[133]
District	Yuen Long
OZP	Draft Tong Yan San Tsuen OZP No. S/YL-TYST/11
Current Zoning	"I(D)" (intended for "OU (Storage & Workshop Uses)" under YLS Study)
Predominant Uses (as of 2014)	Mainly storage/warehouse[134]
Vacant Site (as of 2014)	--
Vacancy Rate (based on GFA as of 2014)	--
Ownership (as of 2014)	--
Number & Area of Potential Site(s)	1 nos., about 17,000 sqm.

Key findings:

Table below summarises our key findings for the "OU (PBU, Storage & Workshop Uses)" Zones in YLS PDA site assessment:

Results		Rationale
Site analysis		**Opportunities:** ▪ Zoning in line with industrial use; ▪ Zoning will take in consideration of MSB development; **Constraints:** ▪ Insufficient site area; ▪ Uncertainties on the future zoning Land ownership not fully captured at present

[132] Recommended Outline Development Plan (RODP) in Planning and Engineering Study for Housing Sites in Yuen Long South – Investigation, from: http://www.yuenlongsouth.hk/links/RODP.pdf.

[133] Estimation from the RODP of YLS.

[134] As observed from the aerial photo on Geoinfo Map.

Appendix D

Financial Analysis

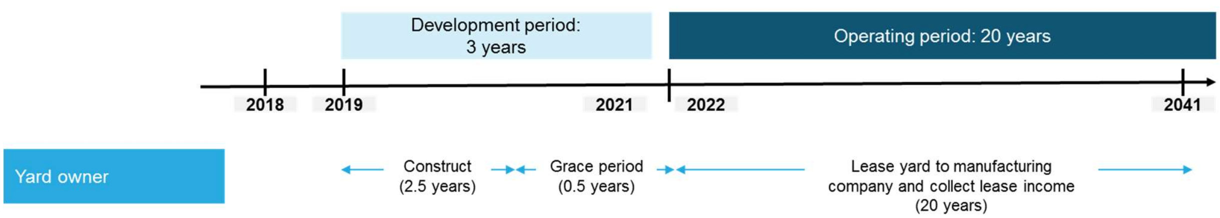
Base Case 1: Yard owner

Overview

Under Base Case 1, we have assumed that the yard owner would:

- Acquire the land for the establishment of the prefabrication yard;
- Construct the prefabrication yard;
- Fund the development cost (land and construction cost) through a combination of debt and equity in line with market norms;
- Lease the prefabrication yard to the manufacturing company upon completion of construction; and
- Receive lease rental over the operating period; and
- Receive a suitable return from its equity investment based on industry benchmarks for investments at this nature and with similar risk profiles.

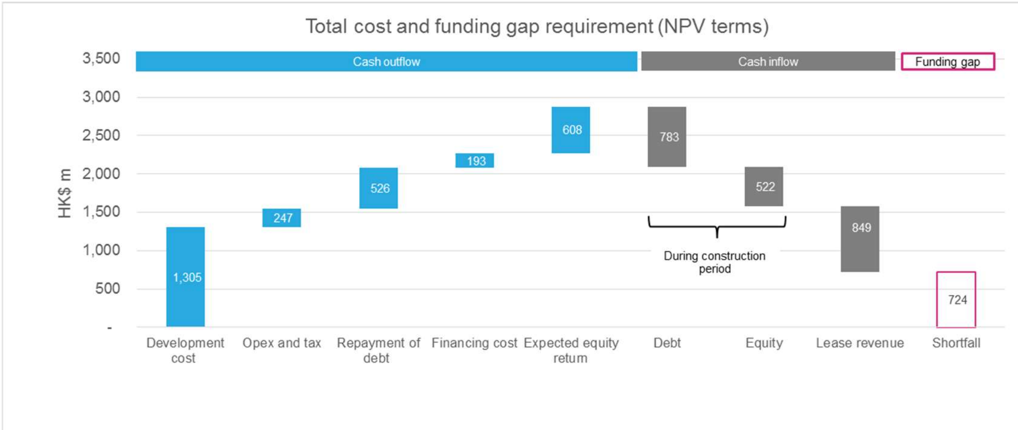
Diagram below illustrates the project timeline and key events in the financial analysis for Base Case 1: Yard owner:



Findings and results

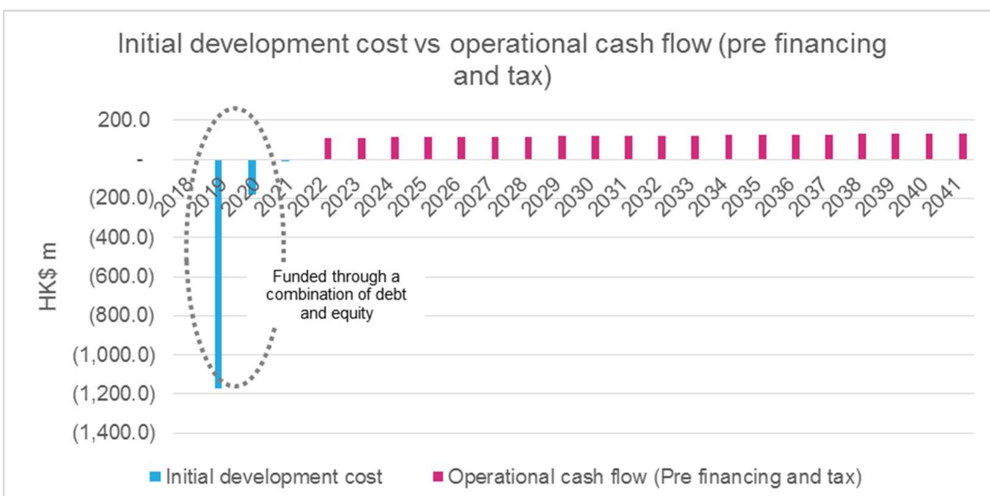
Overall result:

Based on the approach and assumptions above, the yard development (Base Case 1: Yard owner) would not be independently financially viable. Our analysis shows that the level of shortfall / funding requirement is approximately HK$724m (NPV value).



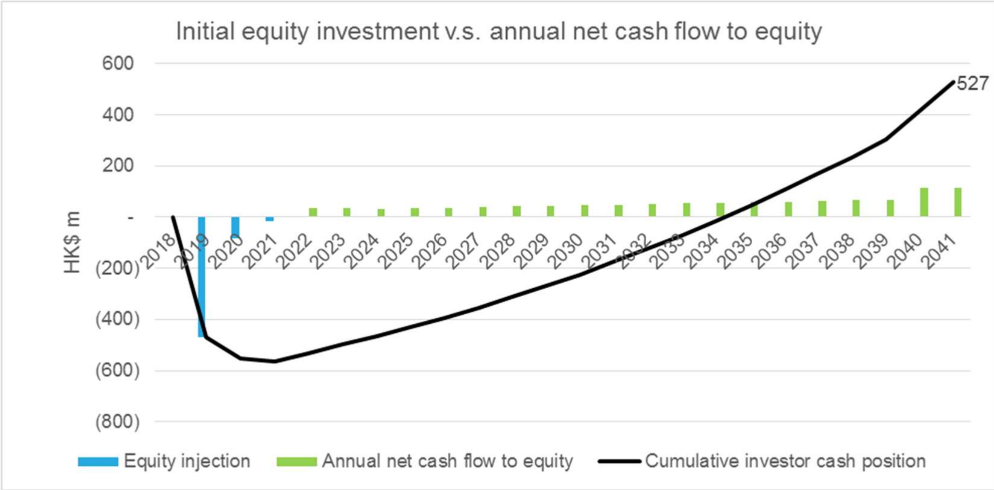
We have assumed that during the construction phase, the yard owner would fund the development cost through a combination of debt and equity. The shortfall represents the financial subsidisation required during the operating period in order to be financially viable i.e. enabling the yard owner to pay off all relevant costs / expenses such as operating costs, tax expense and payment of principal and interest of debt. In addition, the operational cash flow would need to provide the yard owner (equity holder) with a suitable return.

Using the financial model, we have determined the annual operational cash flow (i.e. cash flow pre-financing and tax) of the yard leasing operation. Our analysis shows that the annual operational cash flow, pre-financing and tax is relatively small as a proportion of initial development cost requirement as shown in diagram below:

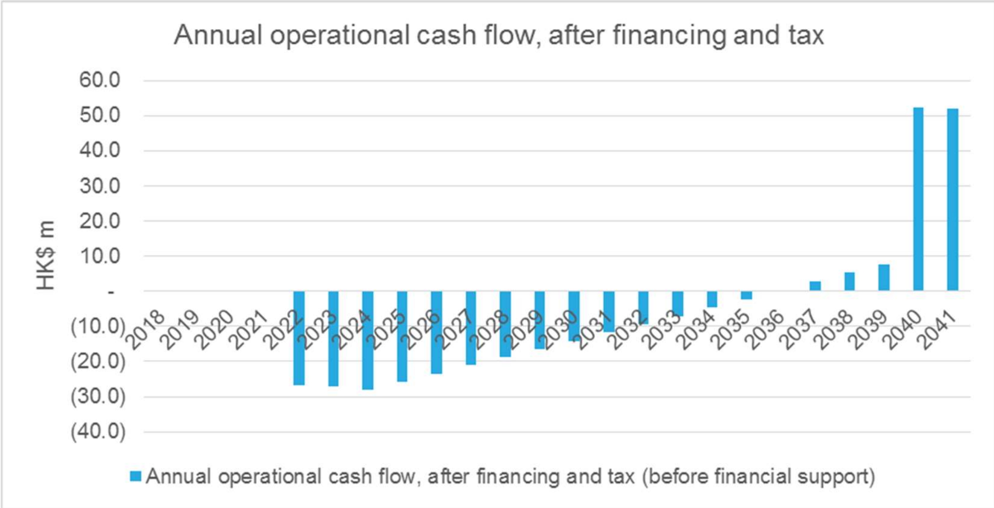


We have calculated the expected return based on industry benchmarks for investments at this nature and with similar risk profiles i.e. based on a target IRR of 5%[135]. The diagram below shows the relationship between the initial equity investment and the expected annual net cash flow to equity in order to achieve the target IRR of 5%.

[135] Please see Appendix E for further details.

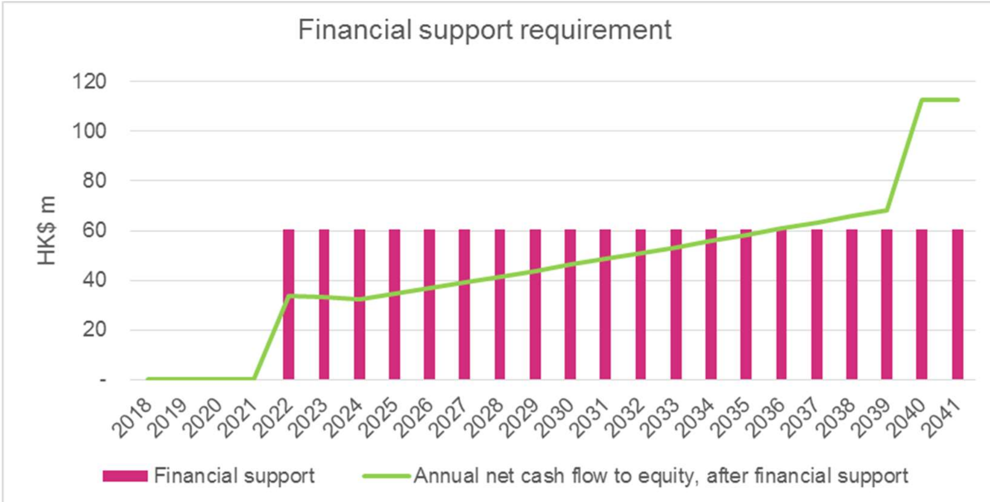


The operational cash flows analysis continues to build up to include the tax payment, debt repayment, financing cost and expected equity return to the yard owner (equity holder) during the operating period. After incorporating tax and financing into the analysis, the financial assessment shows that Base Case 1: Yard owner would generate negative cash flow in some years over the operating period as shown in chart below:



Based on the analysis above, it is estimated that Base Case 1: Yard owner would require approximately HK$724m (NPV value) of financial subsidisation in order to be financially viable.

Diagram below shows the annual financial subsidisation over the operating period:

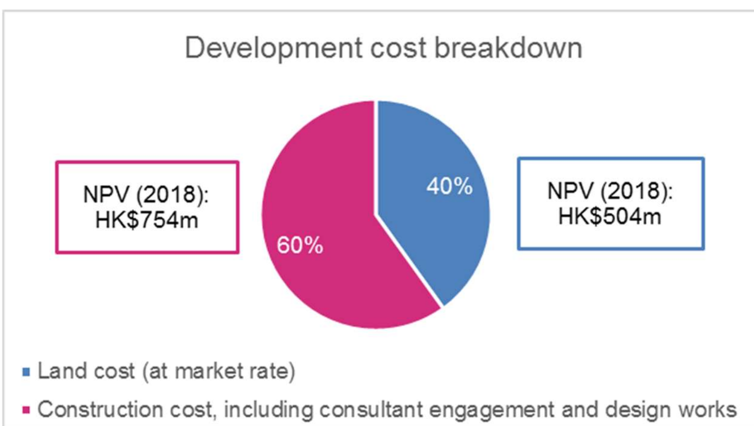


We have explained in detail below the results of each cost and revenue items for Base Case 1: Yard owner analysis:

Development cost:

In the absence of preliminary design of the proposed prefabrication yard, our approach to deriving an estimated construction cost has been to rely on the average market land selling price and construction cost.

Our high level assessment suggests a total development cost of approximately HK$1,258m (NPV values), with 40% for land cost and 60% for construction cost, including consultant engagement and design works. Detailed assumptions underlying this cost estimate are in ***Appendix E***.



Financing structure:

We have assumed that the yard owner would finance the development through a combination of debt and equity. We have assumed a capital structure of 60% debt and 40% equity, which is generally in line with completed property development transactions in Hong Kong.

Other financing parameters in our analysis are consistent with our understanding of the current project financing market in Hong Kong:

- A financing tail of two years and no principal repayment during construction, resulting in a 18 year repayment term. We have assumed a straight line principal repayment profile.
- An interest rate of 3.5% p.a., comprising a base rate of 1.5% and a credit margin of 2.0%.

Table below summarises the sources and uses of capital during the construction phase:

Sources		NPV	MOD
Debt	HKD mil	783	849
Equity	HKD mil	522	566
Total	**HKD mil**	**1,305**	**1,414**

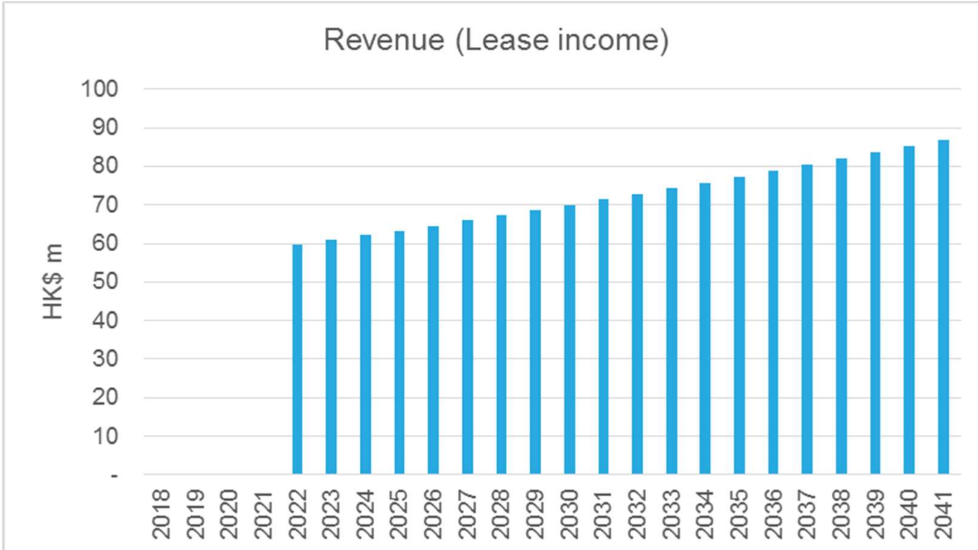
Uses		NPV	MOD
Development cost	HKD mil	(1,258)	(1,361)
Interest during construction	HKD mil	(47)	(53)
Total	**HKD mil**	**(1,305)**	**(1,414)**

Note: MOD refers to the true dollar amount of the relevant cash flow item, including the expected impact of inflation

Revenues:

Our approach to deriving an estimated lease rental income has been to determine benchmark average lease rental unit rates per sqm per month in the Tuen Mun area. Knight Frank has advised that the average lease rate in Tuen Mun Area is approximately HK$10 – 15 per sqft per month. For the purpose of our cash flow analysis, we have applied a 2% p.a. increase to the lease rental unit rate. This represents Hong Kong's historical rental escalation trend from 1997 to 2016 and is a proxy for future growth.

The cash flow analysis shows that the prefabrication yard would be able to generate lease revenue of HK$60m in the first year of operation, growing to HK$87m by the end of operating period.



Other key parameters to our analysis:

We have assumed the following parameters when undertaking the analysis of Base Case 1: Yard owner:

- **Operating expenses:** Based on analysis of industry benchmarks, developers / landlords of industrial buildings would typically incur operating expenses of approximately 16% of revenue.
- **Taxes:** We have assumed that the yard owner would be subjected to Hong Kong's standard corporate tax rate of 16.5% per annum.
- **Depreciation:** In line with accounting standards in Hong Kong, we have assumed a 20 year straight line depreciation of the capital expenditure (yard building) and a 99 year straight line depreciation of the land cost.
- **Discount rate:** Discount rate is used to determine the net present value (NPV) of the future cash flows of the Project, reflecting the project company's weighted average cost of capital (WACC). WACC has been estimated at 3.75%, see assumptions in ***Appendix E*** for more detail.

Summary of key assumptions

Table below shows a high-level summary of the key assumptions used in the financial analysis for Base Case 1: Yard owner. Further detail on the assumptions and how they have been derived is included in ***Appendix E***.

Key driver	**Assumption**
Construction period	2.5 years (30 months)
Operating period	20 years
Land size	19,000 sqm
Land selling price at market rate (2017 price)	HK$26,910 per sqm
Yard GFA	33,500 sqm
Construction cost per sqm (2017 price)	HK$16,550 / sqm
Financing assumptions:	
- Gearing	60% debt
- Interest rate	3.5% p.a.
- Repayment period	18 years
- Financing tail	2 years
Average rental rate (2017 price)	HK$134.55 / sqm / month
Key driver	**Assumption**
Rental price inflation	2% p.a.
Operating expenses	16% of lease income
Expected return	5%

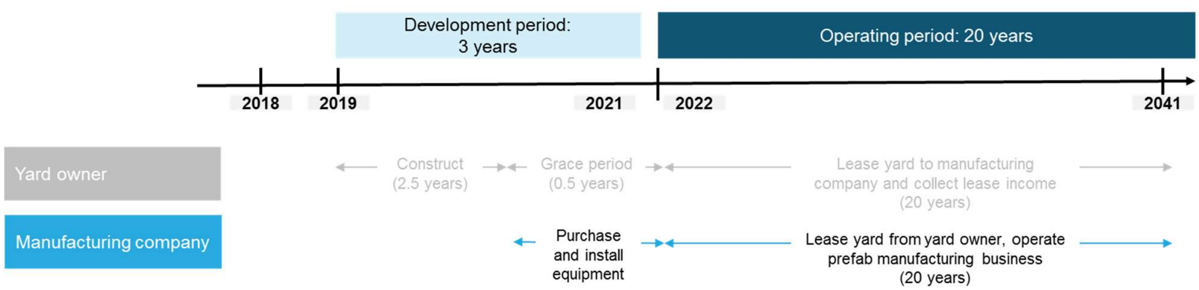
Base Case 2: Manufacturing company

Overview

Under Base Case 2, we have assumed that the manufacturing company would:

- Acquire the equipment for prefabrication operations through a combination of debt and equity in line with market norms;
- Lease the prefabrication yard from the yard owner and pay monthly rental for the premises;
- Maintain and replace the equipment when it is fully depreciated;
- Operate the facility to manufacture and sell prefabricated components; and
- Receive a suitable return from its equity investment based on 5-year Hang Seng Index return on equity as a proxy for suitable return of 10%

Diagram below illustrates the project timeline and key events in the financial analysis for Base Case 2: Manufacturing company:



Findings and Results

Overall result:

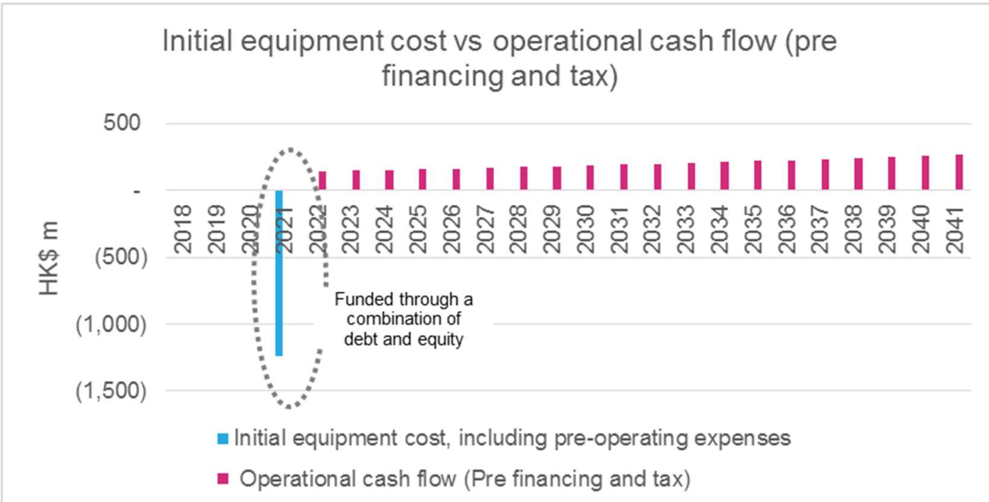
Based on the approach and assumptions above, the manufacturing business (Base Case 2: Manufacturing company) generates an IRR of 10% for its investors, just shy of the return expectation implied by the ROE of the Hang Seng Index of 10%. The financial model shows the following results:

Key metric	Result
IRR	10%
Cumulative investor cash position*	HK$1,208m

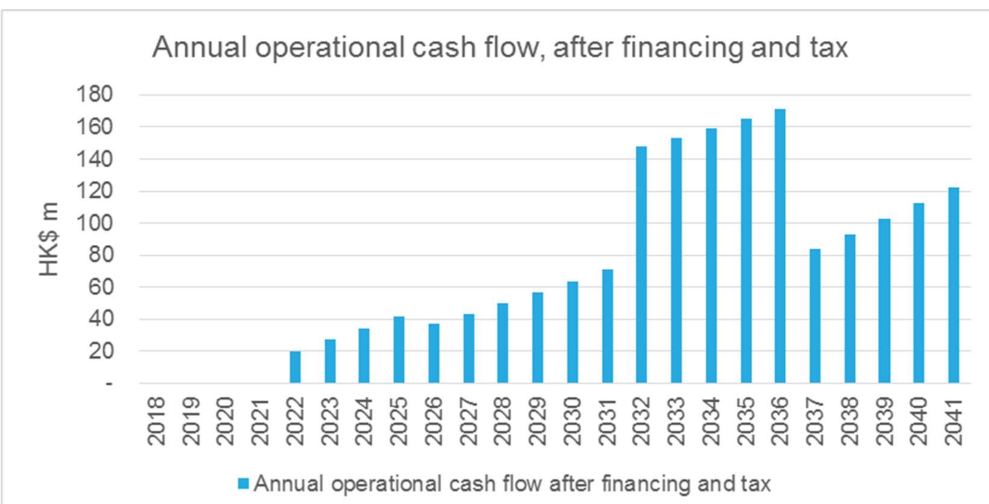
* refers to the cumulative sum of free cash flows to equity, excluding terminal value

The results above indicate that there is little or no financial subsidisation required during the operating period. The manufacture and sale of prefabrication components itself is sufficient to pay off all costs / expenses such as cost of sales, administrative expenses and tax. The business can also make payments of interest and principal to lenders and provide a 10% return to the equity holders.

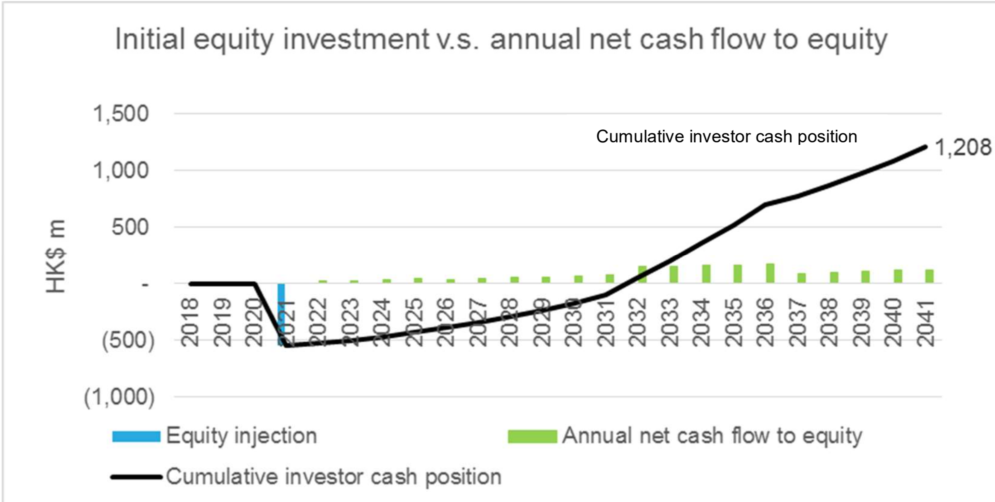
Using the financial model, we have determined the annual operational cash flow (i.e. cash flow pre-financing and tax) of the manufacturing business. Our analysis shows that the annual operational cash flow, pre-financing and tax is relatively higher as there is a proportion of initial equipment cost requirement as compared to Base Case 1: Yard owner, as shown in diagram below:



The operational cash flows analysis continues to build up to include the tax payment, debt repayment, financing cost and expected equity return to the yard owner (equity holder) during the operating period. After incorporating tax and financing into the analysis, the financial assessment shows that Base Case 2: Manufacturing would generate positive cash flow throughout the operating period as shown in chart below:



The manufacturing business generates an internal rate of return (IRR) of 10% and cumulative investor cash position of HK$1,208m as shown in diagram below. Based on a target IRR of 10%, the manufacturing business would likely be viable.



Our analysis also shows that the viability of the manufacturing business is highly sensitive to the assumptions used. For example, a 3% increase in cost / expenses will alter the result from an independently financially viable business to non-viable. Please refer to Appendix D for further details on the sensitivity analysis.

In the absence of comparable business model in Hong Kong, our assessment of the manufacturing business is highly dependent on the outcomes from our interviews with prefabrication concrete manufacturers in China and Hong Kong, in particular on the operating cost items. On this basis, we would recommend further detailed analysis to be undertaken at a subsequent stage in order to capture a more accurate operating cost based on a specific operating environment of the proposed prefabrication manufacturing business.

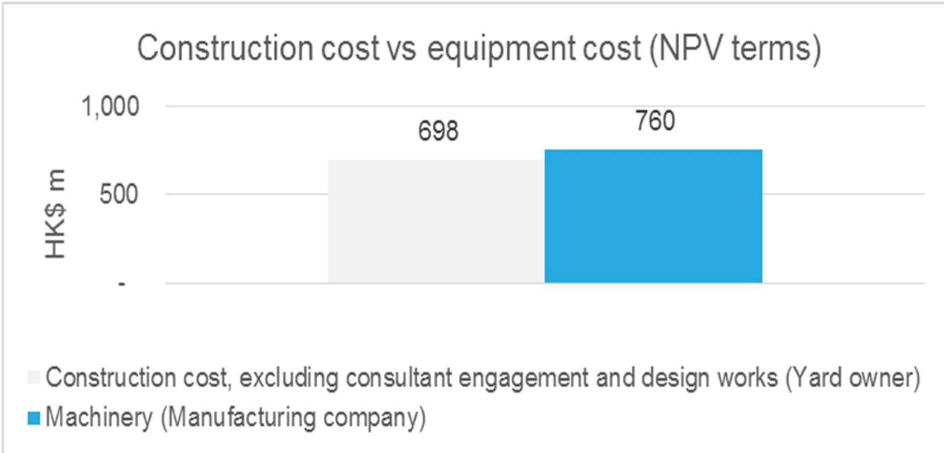
We have explained in detail below the results of each cost and revenue item for Base Case 2: Manufacturing company analysis:

Equipment cost:

We have assumed that the responsibility of purchasing, installing and maintaining the machinery / equipment would lie with the manufacturing company.

In the absence of preliminary design of the proposed prefabrication yard and type of equipment required, our approach to deriving an estimated equipment cost has been to rely on the experience of other prefabrication yard/hub projects constructed within the region. Based on comparable prefabrication yard/hub projects, it is estimated that the equipment cost is approximately 119% of the overall yard/hub construction cost.

Our high level assessment suggests a total equipment cost of approximately HK$760m (NPV values):



Financing structure:

We have assumed that the manufacturing company would fund the equipment cost through a combination of debt and equity. We have assumed a capital structure of 70% debt and 30% equity.

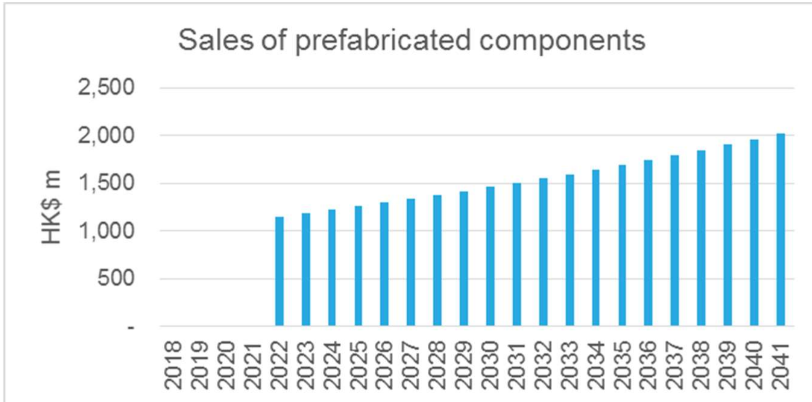
Other financing parameters in our analysis are consistent with our understanding of the current financing market in Hong Kong:

- A 10 year repayment term, with a straight line repayment profile.
- An interest rate of 3.5% p.a., comprising a base rate of 1.5% and a credit margin of 2.0%.

Revenues:

Our approach to deriving an estimated sales price of prefabricated components has been to utilise the outcomes from our interviews with prefabricated concrete manufacturers in China and Hong Kong. We have been informed that the average selling price for prefabricated components for public housing projects in Hong Kong is approximately HK$3,000 per tonne. For the purpose of our cash flow analysis, we have applied a 3% p.a. escalation rate per annum to the selling price, representing the inflation rate in Hong Kong.

The outputs of the cash flow analysis (below chart) shows that the manufacturing company would be able to generate revenue of HK$1,153m in the first year of operation, growing to HK$2,023m by the end of operating period.



Operating cost:

In the absence of comparable business model in Hong Kong, our assessment of the manufacturing business is highly dependent on the outcomes from our interviews with prefabrication concrete manufacturers in China and Hong Kong, in particular on the operating cost items. As the manufacturers were reluctant to share in detail their operating cost items, we were only able to obtain the high level breakdown of the operating cost as a percentage of manufacturing revenue.

The outcomes from the interviews suggest that approximately 90% of the revenue is used to cover the operating cost such as raw materials, labour, moulds, transport and miscellaneous expenses as shown below:

Key driver	Percentage of revenue
Cost of sales:	
- Raw materials	42.5%
- Transport	11.5%
- Cost for moulds	10.0%
- Labour cost	11.5%
Selling, general, admin expenses	15.0%
Total	**90.5%**

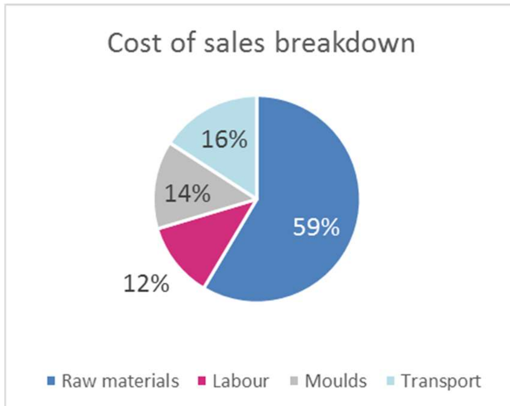
We have applied the above breakdown in our analysis, however have adjusted the following to be based on Hong Kong manufacturing sector benchmark[136]:

- labour cost
- Selling, general and admin expenses

[136] Please refer to Appendix E for further details

Cost of sales:

Cost of sales refers to the direct costs attributable to the production of the goods sold in a company (i.e. prefabricated components). We have obtained the following breakdown of cost of sales based on the outcomes of our interviews. The estimation for labour cost is based on worker density guidelines per the Planning Department of Hong Kong and the average monthly salary published by Census and Statistics Department of Hong Kong.

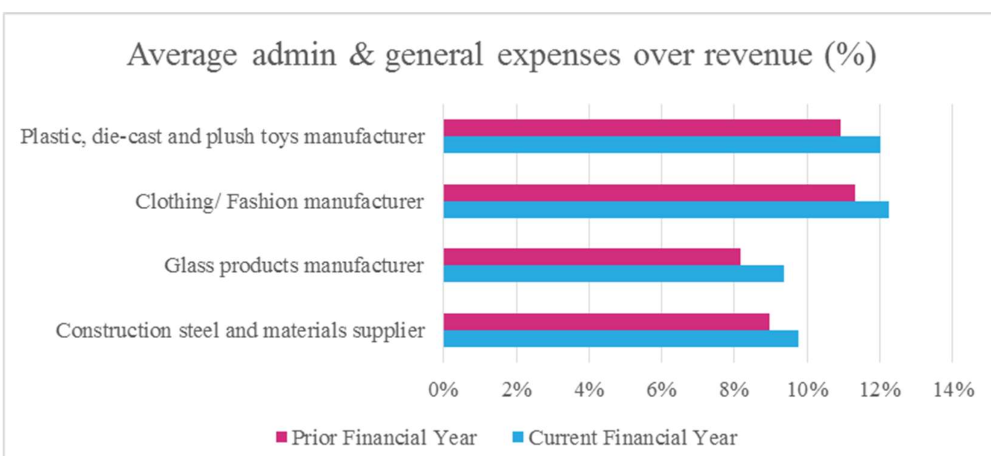


We have applied the above breakdown in our analysis. We note that this breakdown is a simplified assumption and results in cost of sales increasing over time in line with sales of prefabricated components.

In practice, we would expect a combination of fixed and variable costs. We would suggest that further analysis is undertaken to determine the suitability of these numbers once a more detailed business / operating model can be identified.

Selling, general and admin expenses:

Our benchmark analysis on selected manufacturing companies in Hong Kong shows that on average, the companies incur approximately 10% of their revenues for general and administrative expenses. We have assumed selling, general and admin expenses of 10% of revenue based on the mid-point of values of our benchmarking exercise as shown below:



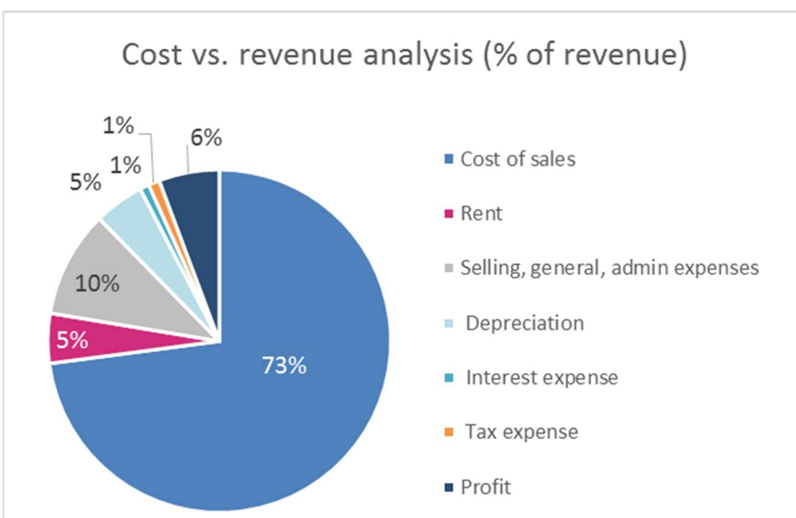
Other key parameters to our analysis:

We have assumed the following parameters when undertaking the financial analysis of Base Case 2: Manufacturing company:

- **Taxes:** We have assumed that the manufacturing company would be subjected to Hong Kong's standard corporate tax rate of 16.5% of taxable profits.
- **Depreciation:** In line with accounting standards in Hong Kong, we have assumed a 15 year straight line depreciation for equipment.
- **Equipment replacement:** While we have assumed an operating period of 20 years, the manufacturing company would need to replace the equipment by year 15 (the useful life implied by the deprecation assumption). We have also assumed that this equipment replacement cost would be funded by a combination of debt (70%) and free cash flow (30%) from the operations / business. A maintenance reserve account (MRA) has been set up in the financial model to allow sufficient cash to be set aside by the operator to fund the 30% of the replacement cost.
- **Working capital:** In order to ensure that sufficient cash is available during the first few months of the operation, we have included a working capital requirement for the manufacturing business. We have assumed that the working capital amount is equal to one quarter (3 months) of the first year's operating expenses and this working capital amount would be funded entirely through equity.
- **Discount rate:** Discount rate is used to determine the NPV of the future cash flows of the Project, reflecting the operator's WACC. WACC has been estimated at 6.85%, see assumptions in ***Appendix E*** for more detail.

Cost versus revenue analysis (% of revenue):

Our analysis shows that the largest cost component of the manufacturing business is cost of sales (raw materials, labour, etc) which is approximately 73% of overall revenue as shown in chart below:



Summary of key assumptions

Table below shows a high-level summary of the key assumptions used in the financial analysis for Base Case 2: Manufacturing company. Further detail on the assumptions and how they have been derived is included in ***Appendix E***.

Key driver	Assumption
Equipment procurement / installation	Year 1: 0% Year 2: 0% Year 3: 100%
Operating period	20 years
Equipment cost	119% of plant cost,
Financing assumption:	
- Gearing	70% debt
- Interest rate	3.5%
- Repayment period	10 years
- Financing tail	2 years
Yard GFA	33,500 sqm
Production p.a.	331,650 tonnes
Selling price per tonne (2017 price)	HK$3,000
Cost of sales:	
- Raw materials	42.5% of revenue,
- Transport	11.5% of revenue,
- Cost for moulds	10% of revenue,
- Labour cost	
o Worker density	75 sqm per worker
o Average salary per month (2017 price)	HK$15,913
Selling, general, admin expenses	10% of revenue,
Rental expense (2017 price)	HK$134.55 / sqm/ month
Equipment replacement:	
- Useful life	15 years
- Equipment replacement cost	NPV: HK$395 m
- Equipment replacement funding - Gearing - Interest - Tenure	70% debt, 30% free cashflow 3.5% 10 years
Working capital:	
- Working capital requirement	Prior to operation of the yard
- Working capital amount	One quarter of first year's expenses
- Working capital funding	100% equity

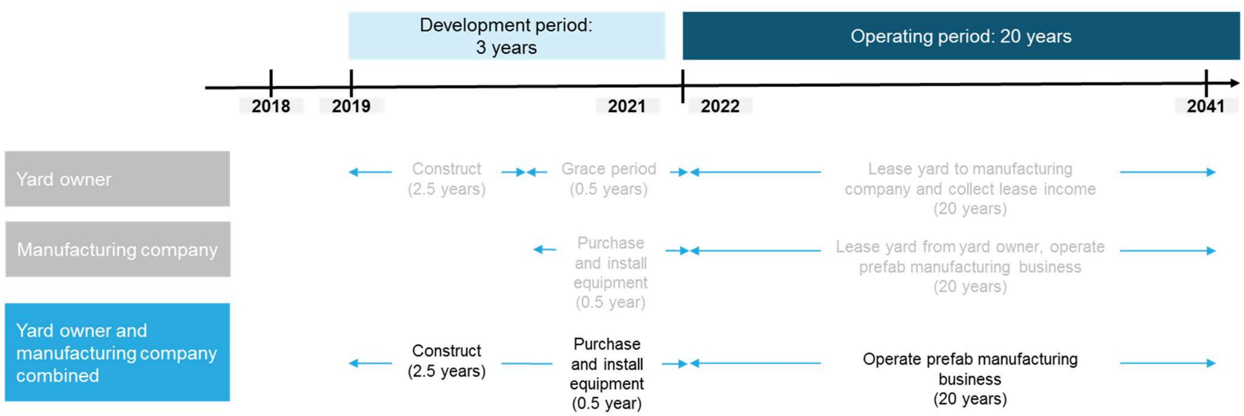
Base Case 3: Yard owner and manufacturing company combined

Overview

Under Base Case 3, we have assumed that the Project Company would undertake both the role of yard owner and manufacturing company. The Project Company would:

- Acquire the land for the establishment of the prefabrication yard;
- Construct the prefabrication yard;
- Acquire the equipment for prefabrication operations;
- Fund the development cost (land, construction and equipment cost) through a combination of debt and equity in line with market norms;
- Operate the prefabrication manufacturing facility; and
- Maintain and replace the equipment

Diagram below illustrates the project timeline and key events in the financial analysis for Base Case 3: Yard owner and manufacturing combined:



Findings and Results

Overall result:

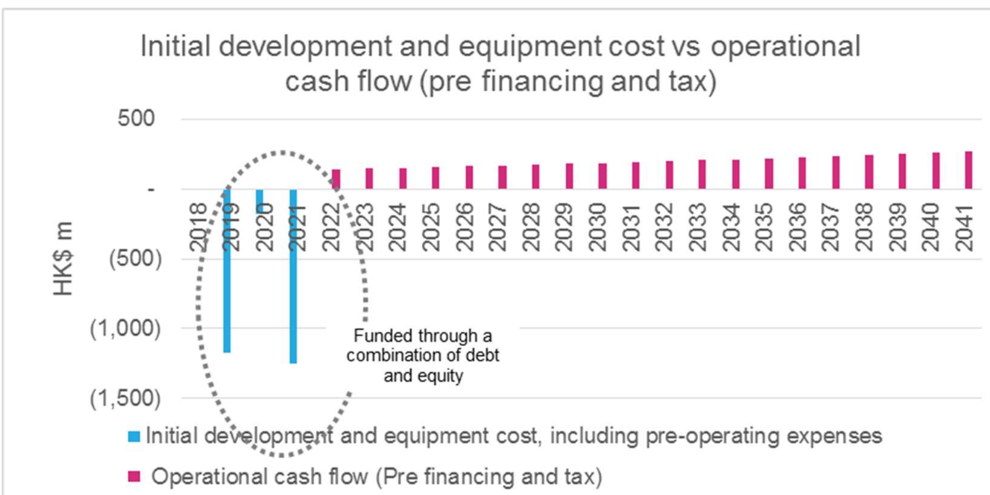
When undertaking the analysis for Base Case 3, we have combined the operating cash flows (before any financial subsidisation) of both the yard owner and manufacturing company derived in Base Case 1 and Base Case 2 respectively.

Base Case	1	2	3
Key metric	**Yard owner**	**Manufacturing company**	**Yard + Manufacturing**
Shortfall / funding requirement (NPV)	-	-	??
IRR	-10%	10%	3%
Cumulative investor cash position*	(HK$682m)	HK$1,208m	HK$525m

* refers to the cumulative sum of free cash flows to equity, excluding terminal value

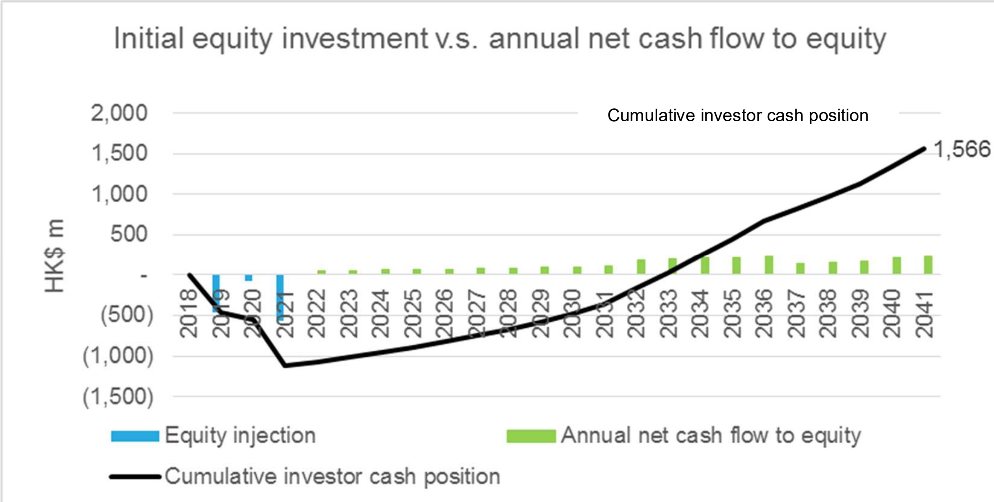
Our analysis shows that the combined developments (Base Case 3: Yard owner and manufacturing company combined) provide an IRR of 3% and positive cumulative investor cash position of HK$525m. In order to make the combined developments attractive to private investor, financial subsidisation is required in order to provide suitable return to an investor. Our benchmark analysis shows that manufacturing companies, which own their plants, typically generate return on equity of approximately 7%.

Using the financial model, we have determined the annual operational cash flow (i.e. cash flow pre-financing and tax) of the manufacturing business. Our analysis shows that the annual operational cash flow, pre-financing and tax is relatively low as a proportion of initial development and equipment cost requirement as shown in diagram below:

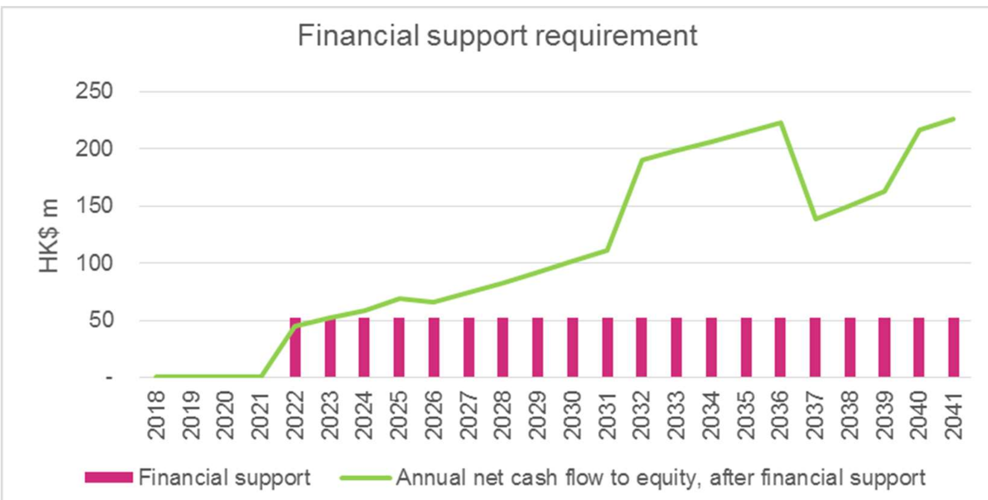


We have calculated the expected return based on industry benchmarks for investments at this nature and with similar risk profiles i.e. based on a target IRR of 7%[137]. The diagram below shows the relationship between the initial equity investment and the expected annual net cash flow to equity in order to achieve the target IRR of 7%.

[137] Please see Appendix E for further details.



Based on the analysis above, it is estimated that Base Case 3: Yard owner + manufacturing would require approximately HK$579m (NPV value) of financial subsidisation in order to be financially viable. Diagram below shows the annual financial subsidisation over the operating period:



Applying this assumption, our financial analysis shows that the level of shortfall / funding requirement is approximately HK$591m (NPV value).

Base Case	**3**
Key metric	**Yard + Manufacturing**
Shortfall / funding requirement (NPV)	HK$579m
IRR	7%
Cumulative investor cash position*	HK$1,546m

* refers to the cumulative sum of free cash flows to equity, excluding terminal value

Limitations and Exclusions

We have had to make numbers of simplifying assumptions given the limited information available in the market and that there is no precedent of such development in Hong Kong. In addition to those outlined on the previous pages, we specifically wish to highlight that our analysis:

- Is based on research undertaken on a best efforts basis to determine relevant comparable metrics / data points in the market. We have also depended on the outcomes from interview sessions with selected Chinese prefabricated concrete manufacturers in our analysis. Such prefabrication business are typically private endeavours and so information available in the public domain is limited
- Has not considered any specific design for the estimation of GFA and capital costs, and we have not involved our design and quantity surveying team in detail in this analysis. We would recommend further analysis of likely construction cost be undertaken once a preliminary design is developed
- Has not considered the type of prefabricated components to be manufactured by the proposed prefabrication yard and the specific equipment / machinery that may be required for such production. We would recommend further analysis to be undertaken.

Sensitivity Analysis

Overview

Given the accuracy of financial outcomes is highly dependent on the quality of underlying assumptions used, we have undertaken a sensitivity analysis on key assumptions within the financial model.

The objectives of the sensitivity analysis are to:

- Identify key assumptions that have the greatest impact on the financial model's outcomes and therefore, should be the subject of greater effort and scrutiny as analysis progresses; and
- Test the impact of positive and negative movements to total funding requirement under the three Base Case analyses.

We have undertaken sensitivity analysis on the following key assumptions:

Sensitivity	Description
A	Construction cost (+/-), keeping other Base Case assumptions constant
B	Rental rates (+/-), keeping other Base Case assumptions constant
C	Equipment cost (+/-), keeping other Base Case assumptions constant
D	Selling price per tonne (+/-), keeping other Base Case assumptions constant, including cost of sales and other expenses
E	Sales volume (+/-), keeping other Base Case assumptions constant
F	Labour cost (+/-), keeping other Base Case assumptions constant
G	Selling, general, admin expenses (+/-), keeping other Base Case assumptions constant

Findings and Results

The key results of the sensitivity analysis are summarised below:

- Whilst maintaining the target IRR of 5% for Base Case 1 and 7% for Base Case 3, a 15% reduction in construction cost will result in potential upside of HK$116m and HK$112m savings in financial subsidisation for Base Case 1 and Base Case 3 respectively.

- Changes in rental rates has minimal effect to the overall viability analysis.
- Movement in selling price per tonne has the largest impact on the overall results in Base Case 2 and Base Case 3. A 15% increase in selling price per tonne leads to a 26 percentage point increase in IRR in Base Case 2. Under Base Case 3, the combined development is independently financially viable (i.e. no financial subsidisation required) and is able to generate an IRR of 16%.
- In addition, Base Case 2 is also highly sensitive on the upside/downside to changes in operating cost. We have tested this analysis on Sensitivity G – selling, general and admin expenses. Our analysis shows that a 3% decrease in selling, general and admin expenses leads to a 6 percentage point increase in IRR, from 10% to 16% under Base Case 2. The downside of 3% increase in expenses results in an increase in funding requirement for Base Case 2 from HK$0m to HK$329m and Base Case 3, from HK$579m to HK$1,090m.

Sensitivity A: Construction cost (+/-), keeping other Base Case assumptions constant

	1. Yard owner		2. Manufacturing company		3. Yard owner and manufacturing company combined	
Impact to ➔	Funding requirement (HK$m, NPV value)	Target IRR (%)	Funding requirement (HK$m, NPV value)	Resulting IRR (%)	Funding requirement (HK$m, NPV value)	Target IRR (%)
-15%	608	5%	-	10%	467	7%
-10%	642	5%	-	10%	500	7%
-5%	683	5%	-	10%	557	7%
Base Case	**724**	**5%**	**-**	**10%**	**579**	**7%**
+5%	763	5%	-	10%	636	7%
+10%	808	5%	-	10%	670	7%
+15%	849	5%	-	10%	703	7%

Our analysis shows that a 15% reduction in construction cost will result in potential upside of HK$116m and HK$112m savings in financial subsidisation for Base Case 1 and Base Case 3 respectively.

On the downside, a 15% increase in construction cost will result in additional financial subsidisation of HK$125m and HK$124m for Base Case 1 and Base Case 3 respectively.

Sensitivity B: Rental rates (+/-), keeping other Base Case assumptions constant

	1. Yard owner		2. Manufacturing company		3. Yard owner and manufacturing company combined	
Impact to ➔	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Resulting IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**
-15%	831	5%	-	12%	579	7%
-10%	796	5%	-	11%	579	7%
-5%	760	5%	-	11%	579	7%
Base Case	**724**	**5%**	**-**	**10%**	**579**	**7%**
+5%	690	5%	-	10%	579	7%
+10%	654	5%	41	10%	579	7%
+15%	619	5%	41	10%	579	7%

Our analysis shows that a 15% reduction in rental rates will result in a (1) potential downside of additional HK$107m financial subsidisation for Base Case 1 and (2) potential upside of 2% increase in equity IRR for Base Case 2.

A 15% increase in rental rates will result in a (1) potential upside of HK$105m savings in financial subsidisation for Base Case 1 and (2) potential downside of HK$41m increase in financial subsidisation for Base Case 2.

Changes in rental rates will have no impact to Base Case 3.

Sensitivity C: Equipment cost (+/-), keeping other Base Case assumptions constant

	1. Yard owner		2. Manufacturing company		3. Yard owner and manufacturing company combined	
Impact to ➔	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Resulting IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**
-15%	724	5%	-	13%	418	7%
-10%	724	5%	-	12%	487	7%
-5%	724	5%	-	11%	533	7%
Base Case	**724**	**5%**	**-**	**10%**	**579**	**7%**
+5%	724	5%	-	10%	649	7%
+10%	724	5%	62	10%	707	7%
+15%	724	5%	-103	10%	777	7%

Our analysis shows that movement in equipment cost will impact the IRR of Base Case 2 and the overall funding requirement in Base Case 3. A 15% reduction in equipment cost leads to a 3.0 percentage point increase in IRR in Base Case 2 while the total financial subsidisation for Base Case 3 reduces from HK579m to HK$418m.

On the downside, a 15% increase in equipment cost leads to an increase in financial subsidisation of HK$103m for Base Case 2 whilst maintaining the target IRR at 10%. The total financial subsidisation for Base Case 3 increases from HK579m to HK$777m.

Sensitivity D: Selling price per tonne (+/-), keeping other Base Case assumptions constant, including cost of sales and other expenses

	1. Yard owner		2. Manufacturing company		3. Yard owner and manufacturing company combined	
Impact to ➔	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**	**Funding requirement (HK$m, NPV value)***	**Resulting IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**
-15%	724	5%	1,728	10%	3,056	7%
-10%	724	5%	1,152	10%	2,238	7%
-5%	724	5%	535	10%	1,409	7%
Base Case	**724**	**5%**	**-**	**10%**	**579**	**7%**
+5%	724	5%	-	19%	-	8%
+10%	724	5%	-	28%	-	12%
+15%	724	5%	-	36%	-	16%

* Refers to working capital shortfall i.e. amount required to avoid negative annual cash flow

Our analysis shows that movement in selling price per tonne has the largest impact on the overall results in Base Case 2 and Base Case 3. A 15% increase in selling price per tonne leads to a 26 percentage point increase in IRR in Base Case 2. Under Base Case 3, the combined development is independently financially viable (i.e. no financial subsidisation required) and is able to generate an IRR of 16%.

Sensitivity E: Sales volume (+/-), keeping other Base Case assumptions constant

	1. Yard owner		2. Manufacturing company		3. Yard owner and manufacturing company combined	
Impact to ➔	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Resulting IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**
-15%	724	5%	370	10%	1,174	7%
-10%	724	5%	247	10%	979	7%
-5%	724	5%	103	10%	773	7%
Base Case	**724**	**5%**	**-**	**10%**	**579**	**7%**
+5%	724	5%	-	13%	431	7%
+10%	724	5%	-	15%	249	7%
+15%	724	5%	-	17%	68	7%

Our analysis shows that a 15% increase in sales volume leads to a 7 percentage point increase in IRR, from 10% to 17% under Base Case 2. This upside also results in a reduction in funding requirement for Base Case 3, from HK$579m to HK$68m.

On the downside, a 15% decrease in sales volume leads to an increase in financial subsidisation of HK$370m for Base Case 2 whilst maintaining the target IRR at 10%. The total financial subsidisation for Base Case 3 increases from HK579m to HK$1,174m.

Sensitivity F: Labour cost (+/-), keeping other Base Case assumptions constant

	1. Yard owner		2. Manufacturing company		3. Yard owner and manufacturing company combined	
Impact to ➔	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Resulting IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**
-15%	724	5%	-	13%	398	7%
-10%	724	5%	-	12%	477	7%
-5%	724	5%	-	11%	523	7%
Base Case	**724**	**5%**	**-**	**10%**	**579**	**7%**
+5%	724	5%	-	10%	659	7%
+10%	724	5%	62	10%	716	7%
+15%	724	5%	103	10%	784	7%

Our analysis shows that a 15% increase in labour cost leads to an increase in financial subsidisation of HK$103m for Base Case 2 whilst maintaining the target IRR at 10%. This downside also results in an increase in funding requirement for Base Case 3, from HK$579m to HK$784m.

Sensitivity G: Selling, general, admin expenses (+/-), keeping other Base Case assumptions constant

	1. Yard owner		2. Manufacturing company		3. Yard owner and manufacturing company combined	
Impact to ➔	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**	**Funding requirement (HK$m, NPV value)***	**Resulting IRR (%)**	**Funding requirement (HK$m, NPV value)**	**Target IRR (%)**
-3%	724	5%	-	16%	171	7%
-2%	724	5%	-	14%	307	7%
-1%	724	5%	-	12%	443	7%
Base Case	**724**	**5%**	**-**	**10%**	**579**	**7%**
+1%	724	5%	82	10%	738	7%
+2%	724	5%	206	10%	908	7%
+3%	724	5%	329	10%	1,090	7%

* Refers to working capital shortfall i.e. amount required to avoid negative annual cash flow

Our analysis shows that a 3% decrease in selling, general and admin expenses leads to a 6 percentage point increase in IRR, from 10% to 16% under Base Case 2. The downside of 3% increase in expenses results in an increase in funding requirement for Base Case 2 from HK$0m to HK$329m and Base Case 3, from HK$579m to HK$1,090m.

Appendix E

Assumptions

Assumptions

Overview

This chapter outlines the key assumptions underpinning the Base Case analyses as presented in Chapter 7, and as used in the financial model to support our analyses. The calculation of the high level cash flow forecasts drew upon the following key parameters:

- General assumptions such as inflation and taxation rates, discount rate, and depreciation;
- Project timeline;
- Size or productivity;
- Development cost;
- Revenue;
- Cost of sales (applicable to manufacturing company only);
- Operating expense estimate ("opex") or selling, general, admin expenses;
- Equipment replacement cost;
- Working capital requirement (applicable to manufacturing company only);
- Financing structure and associated terms.

We describe in detail the approach, rationale, key assumptions and sources in each aspect in the following sub-sections.

Base Case 1: Yard owner

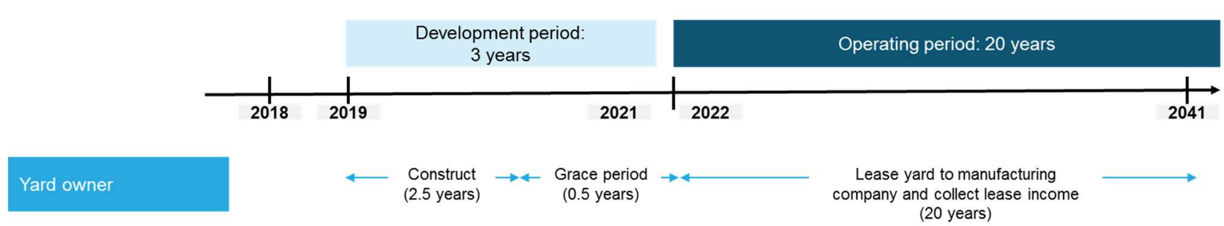
General assumptions

General assumptions that are applicable for the financial analysis are summarised below:

Key driver	Assumption	Source / rationale
Inflation rate	3.0% per annum	Based on Hong Kong long-term inflation rate as forecasted by The Long Term Financial Planning Working Group and reported in the Public Engagement Exercise on Retirement Protection Annex 4.
Corporate tax rate	Flat rate of 16.5% per annum	Hong Kong's corporate tax rate from 2009 onwards as published by Inland Revenue Department (IRD).
Discount rate	3.75%	Discount rate is used to determine the net present value (NPV) of the future cash flows of the Project, reflecting the project company's weighted average cost of capital (WACC) Source: Arup's analysis
Useful life / depreciation	1% - 5%	Based on straight line depreciation method ▪ **Yard/Building:** 5% per annum ▪ **Land:** 1% per annum Source: ▪ **Yard/Building:** EY Worldwide Capital and Fixed Assets Guide 2016 ▪ **Land:** Land lease assumption of 99 years

Project timeline

The figure below provides a high level view of the project implementation timeline for Base Case 1: Yard owner:



<table>
<tr><th>Key driver</th><th>Assumption</th><th>Source / rationale</th></tr>
<tr><td>Construction period</td><td>2.5 years
(30 months)</td><td>Estimates per Arup's technical team based on similar developments in Hong Kong:
<table><tr><th>Project name</th><th>Building area</th><th>Project duration[138]</th></tr><tr><td>HKTV Multimedia & E-Commerce Centre</td><td>30,000 sqm</td><td>30 months</td></tr><tr><td>China Unicorn Global Centre</td><td>38,000 sqm</td><td>40 months</td></tr><tr><td>NTT Financial Data Centre</td><td>35,000 sqm</td><td>28 months</td></tr><tr><td>Average</td><td></td><td>32</td></tr></table></td></tr>
<tr><td>Grace period</td><td>0.5 year</td><td>Provision of lease contract that allows lease rental payments to be received 6 months after the obtainment of Building Occupation Certificate to allow the tenant to proceed with installation of equipment.</td></tr>
<tr><td>Development period</td><td>3 years</td><td>Refers to the period required to construct the yard and to install all the required equipment before operation.</td></tr>
<tr><td>Operating period</td><td>20 years</td><td>The collection of lease income shall commence upon the completion of construction of the prefabrication yard. The operating period is assumed to be 20 years.</td></tr>
</table>

Development cost

The development cost for the development of prefabrication yard include (1) land cost, (2) construction cost and (3) consultant engagement and design fee.

(1) Land cost: Key assumptions to derive to the estimated land cost include:

Key driver	Assumption	Source / rationale
Land sale transaction	Early 2019	This is a high level assumption, It is assumed that the developer would need to pay 100% of the land cost before commencing the construction
Land size	19,000sqm	Based on comparable prefabrication hub projects in the region. Please refer to Section 4 for further details.

[138] Includes consultant engagement, design, works tender, construction and obtainment of Building Occupation Certificate

Key driver	Assumption	Source / rationale
Land selling price	HK$26,910 per sqm (HK$2,500 per sq ft)	There was no transaction for industrial type land use in Tuen Mun in the past 10 years. Given limited publicly available data on land price in Tuen Mun area, we have assumed that the average land price of HK$2,500 per sq ft. This is a simplified assumption – a next phase study, in particular on land valuation, is recommended once the potential site is confirmed. Source: Knight Frank
Land price escalation rate	3% per annum	Based on Hong Kong long-term inflation rate as forecast by The Long Term Financial Planning Working Group and reported in the Public Engagement Exercise on Retirement Protection Annex 4.

(2) Construction cost: Key assumptions to derive to the estimated construction cost include:

<table>
<tr><th>Key driver</th><th>Assumption</th><th>Source / rationale</th></tr>
<tr><td>Area / Gross floor area (GFA)</td><td>33,500 sqm</td><td>Based on Arup’s analysis. Please refer to Section 6.2 for further details.</td></tr>
<tr><td>GFA to Construction floor area uplift</td><td>20%</td><td>Based on “Estimating rules of thumb and design norms – GFA to CFA ratio” in Hong Kong.

Source: Arcadis Construction Handbook 2017</td></tr>
<tr><td>Unit cost of construction</td><td>HK$16,550 / sqm</td><td>Based on the average construction costs for industrial property in Hong Kong.
<table>
<tr><th>Type of building</th><th>HK$ / sqm</th></tr>
<tr><td>Landlord, high rise [A]</td><td>10,100 – 12,400</td></tr>
<tr><td>End user, low rise [A]</td><td>13,600 – 20,500</td></tr>
<tr><td>Owner operated factories, low rise [B]</td><td>18,800 – 23,900</td></tr>
<tr><td>Average</td><td>16,550</td></tr>
</table>
Source: (A) RLB Levett Bucknall - Hong Kong Construction Cost Update Report December 2017, (B) Arcadis Construction Handbook 2017</td></tr>
</table>

(3) Consultant engagement and design fee:

Key driver	Assumption	Source / rationale
Consultant engagement and design fee	Additional 8% of construction cost	Estimate per Arup's QS team based on similar developments in Hong Kong. We assume this cost to incur within the first 6 months of the development period.

Other assumptions: For the purposes of the financial analysis, we have applied price adjustment factors to the total development cost to derive to the MOD estimates. The adjustment takes into account the following:

Key driver	Assumption	Source / rationale
Construction cost profile	Year 1: 76% Year 2: 23% Year 3: 1%	Estimate per Arup's technical team based on similar developments in Hong Kong.
Construction cost escalation	6%	Based on Hong Kong's construction price adjustment factors per annum from 2017 to 2020. Source: Note for Public Works Subcommittee of Finance Committee, PWSCI (2016-17)6

Results:

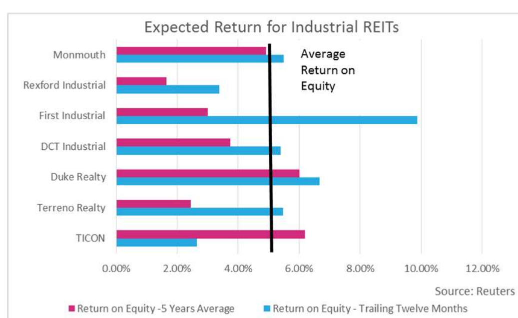
The resulting total development cost is approximately HK$905m in NPV terms or HK$978m in MOD prices.

Development	NPV (HK$m)	MOD prices (HK$m)
Land cost	504	542
Construction cost, including consultant engagement and design fee	754	819
Total development cost	**1,258**	**1,361**

Financing structure and associated terms

We assume that the yard owner would fund the development cost through a combination of debt and equity. The key financing assumptions are summarised as follows:

Key driver	Assumption	Source / rationale
Gearing (debt to total capital ratio)	60% debt	In line with real estate lending market. Actual gearing level will be a function of market dynamics at the time of development and would be a negotiated outcome.
Interest rate	3.5%	Comprising a base rate of approx. 1.5% p.a. (10-year HIBOR swap rate) and a credit risk margin of 2%. Interest is paid as incurred, but capitalizes during the construction period.
Loan repayment term	18 years (2 years financing tail)	The loan is repaid on a straight-line basis from completion of construction. Full repayment 2 years prior to the end of the operating period. Repayment terms to be tested further in the next stage of analysis.

Key driver	Assumption	Source / rationale
Expected return	5%	Based on publicly stated return on equity of industrial property investment funds between 4.0% to 5.6%. Our assumption is at mid-point (rounded).  Source: Reuters and selected industrial REIT's websites

Revenue

The main revenue stream of the yard owner is lease income from the manufacturing company. The key drivers to arrive to the revenue forecast include (1) gross leasable area, (2) expected occupancy rate, (3) lease rental unit rate and (4) lease rental escalation rate.

Key driver	Assumption	Source / rationale
Gross leasable area (GLA)	100% of GFA	Gross leasable area refers to the amount of floor space in a property available for rental. We assume 100% of the GFA would be available for leasing 33,500sqm.
Occupancy rate	100%	Occupancy rate refers to the ratio of the rented space compared to the total amount of available GLA. We assume a 100% occupancy rate for the prefabrication yard throughout the operating period.
Lease rental unit rate	HK$134.55 / sqm / month (2017 prices)	Lease rental unit rates refer to the average industrial use lease rental unit rate per sqm per month in Tuen Mun area (HK$10-15 per sq ft). Source: Knight Frank's data base
Lease rental escalation rate	2% p.a.	Based on Hong Kong's historical rental escalation rate from 1997 to 2016. Source: Rating and Valuation Department, Private Flatted Factories - Rental and Price Indices

Operating expenses

Key operating expenses ("opex") of the yard owner include repair and maintenance cost associated with the common area of the prefabrication yard.

Key driver	Assumption	Source / rationale
Opex	16% of revenue	Based on industry benchmark analysis. Developer / Landlord of industrial buildings would typically incur operating expenses of approximately HK$2.00 to HK$2.50 per sqft per month. This represents a 16% of the rental unit rates of HK$10 to HK$15 per sqft per month. Source: Knight Frank's data base

Base Case 2: Manufacturing company

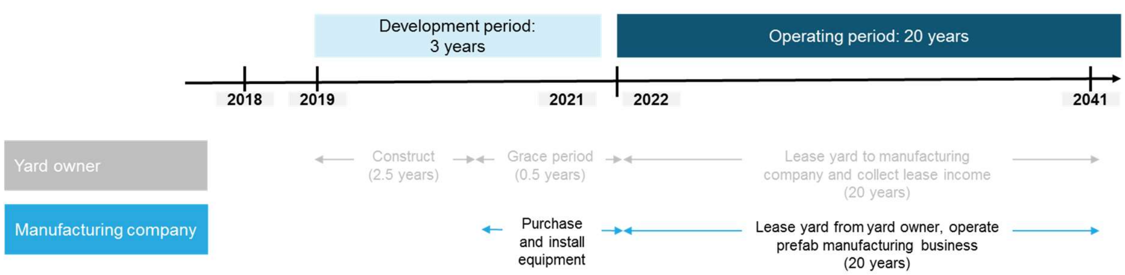
General assumptions

General assumptions that are applicable for the financial analysis are summarised below:

Key driver	Assumption	Source / rationale
Inflation rate	3.0% per annum	Based on Hong Kong long-term inflation rate as forecast by The Long Term Financial Planning Working Group and reported in the Public Engagement Exercise on Retirement Protection Annex 4.
Corporate tax rate	Flat rate of 16.5% per annum	Hong Kong's corporate tax rate from 2009 onwards as published by Inland Revenue Department (IRD).
Discount rate	6.85%	Discount rate is used to determine the net present value (NPV) of the future cash flows of the Project, reflecting the project company's weighted average cost of capital (WACC). Source: Arup's analysis

Project timeline

The figure below provides a high level view of the project implementation timeline for Base Case 2: Manufacturing company:



Key driver	Assumption	Source / rationale
Purchase and install equipment	0.5 year	The installation of equipment shall commence upon the obtainment of Building Occupation Certificate.
Operating period	20 years	The manufacturing activities shall commence upon the completion of the installation and testing of equipment.

Equipment cost

Under Base Case 2: Manufacturing company, we have assumed that the responsibility of purchasing, installing and maintaining the machinery / equipment rest with the manufacturer.

Key assumptions to derive to the estimated equipment cost is based on mid-point benchmark range as shown in table below:

Name	Size (sqm)	Development cost (SG$m)	Plant cost (SG$m)	Equipment cost (SG$m)	Equipment cost to plant cost ratio (%)
SEF SpaceHub	32,608	100[A]	53[D]	47	89%
Greyform Building	32,100	150[B]	59[D]	91	153%
Tiong Seng Prefab Hub	19,813	26[C]	12[E]	14	117%

Note	Source / Description
A	Source: The Business Times, Better quality control, faster production at SEF SpaceHub
B	Source: The Straits Times, BCA to give advance notice on building projects that need high level of prefabrication
C	Source: Building and Construction Authority news press, 4 January 2011, Tiong Seng's $26 million Prefab Hub – Singapore's 1st automated pre-cast facility and first to receive BCA funding
D	We have derived the plant cost based on the size of the plant and the average cost per sqm for heavy industrial building in Singapore as published by Singapore Construction Cost Handbook.
E	Source: Building and Construction Authority Construction Productivity Award 2013

Other assumptions: For the purposes of the financial analysis, we have applied price adjustment factors to the total development cost to derive to the MOD estimates. The adjustment takes into account the following:

Key driver	Assumption	Source / rationale
Equipment cost profile	Year 1: 0% Year 2: 0% Year 3: 100%	The purchase and installment of equipment is expected to happen in Year 3 of the development period.

Equipment cost escalation	6% p.a.	Based on Hong Kong's construction price adjustment factors per annum from 2017 to 2020. Source: Note for Public Works Subcommittee of Finance Committee, PWSCI (2016-17)6

Results:

The resulting equipment cost is approximately HK$760m in NPV terms or HK$990m in MOD prices:

Year	Equipment cost profile (%)	2017 price (HK$m)	Cost inflation (HK$m)	Equipment cost in MOD prices (HK$m)
2018	-	-	-	-
2019	-	-	-	-
2020	-	-	-	-
2021	100%	792	198	990
Total	**100%**	**792**	**198**	**990**
NPV: HK$760m				

Financing structure and associated terms

We assume that the manufacturing company would finance the equipment through a combination of debt and equity. The key financing assumptions are summarised as follows:

Key driver	Assumption	Source / rationale
Gearing (debt to total capital ratio)	70% debt	In line with market practice.
Interest rate	3.5%	Comprising a base rate of approx. 1.5% p.a. (10-year HIBOR swap rate) and a credit risk margin of 2%. Interest is paid as incurred.
Loan repayment term	10 years	The loan is repaid on a straight-line basis from the following year upon drawdown. Repayment terms to be tested further in the next stage of analysis.

Revenue

The main revenue stream of the manufacturing company is sales of prefabricated components. The key drivers of the revenue forecast include (1) production volume per built up area (tonnes/sqm), (2) selling price per tonne and (3) selling price escalation rate.

Key driver	Assumption	Source / rationale
Production volume per built up area	9.9 per sqm	Based on mid-point of benchmark range (refer to Section 4)
Selling price per tonne	HK$3,000 / tonne	Based on outcomes from our interviews with prefabrication concrete manufacturers in China and Hong Kong Source: Interview outcomes[139]
Selling price escalation rate	3.0% per annum	Based on Hong Kong long-term inflation rate as forecasted by The Long Term Financial Planning Working Group and reported in the Public Engagement Exercise on Retirement Protection Annex 4.

Cost of sales

Key cost of sales of the manufacturing company include (1) raw materials cost, (2) transportation cost, (3) cost for moulds and (4) labour cost.

Key driver	Assumption	Source / rationale
Raw materials cost	42.5% of revenue	Based on mid-point of interview outcomes.[140]
Transportation cost	11.5% of revenue	
Cost for moulds (project basis)	10% of revenue	
Labour cost:		

[139] Interviewees include Chinese contractor, prefabrication concrete manufacturers and construction company
[140] Interviewees include Chinese contractor, prefabrication concrete manufacturers and construction company

a) Worker density	75sqm per worker	Based on Planning Department of Hong Kong's guidelines for worker densities for Special Industrial Use – Industrial Estate category. Source: Planning Department of Hong Kong
b) Average salary per month	HK$15,913	Based on wages and labour earnings statistical reports published by Census and Statistics Department of Hong Kong as at 2017, indexing at annual inflation. Source: Census and Statistics Department of Hong Kong

Other expenses

In addition to cost of sales, the manufacturing company will also need to pay for (1) selling, general and admin expenses, (2) yard rental and (3) yard rental escalation rate.

Key driver	Assumption	Source / rationale
Selling, general and admin expenses	15% of revenue	Based on mid-point of interview outcomes.[141]
Yard rental	HK$134.55 / sqm / month (2017 prices)	Please refer to Base Case 1: Yard owner for further details.
Yard rental escalation rate	2%	Based on Hong Kong's historical rental escalation rate from 1997 to 2016. Source: Rating and Valuation Department, Private Flatted Factories - Rental and Price Indices

[141] Interviewees include Chinese contractor, prefabrication concrete manufacturers and construction company

Equipment replacement

We have included in our analysis an equipment replacement cost based on the following assumptions:

Key driver	Assumption	Source / rationale
Useful life	15 years	Source: United States Internal Revenue Service – 2017 Publication 946
Equipment replacement cost	HK$395m (NPV terms) / HK$1,388m (MOD prices)	Derived based on the following: **Initial equipment cost (2017 prices):** HK$792m. Please refer to Equipment cost assumptions above for further details. **Price adjustment factor:** Based on Hong Kong's construction price adjustment factors per annum: • 6% from 2017 to 2020 • 5% from 2021 to 2023 • 4.5% thereafter Source: Note for Public Works Subcommittee of Finance Committee, PWSCI (2016-17) 6
Equipment replacement funding and maintenance reserve account:		
Gearing	70% debt, 30% MRA	The manufacturing company would fund the equipment cost through a combination of debt and operating cash flow. In order to ensure that sufficient cash is set aside to fund these replacement costs, a maintenance reserve account (MRA) has been established in the financial model to set aside funds over the operating period.
Interest	3.5%	Comprising a base rate of approx. 1.5% p.a. (10-year HIBOR swap rate) and a credit risk margin of 2%. Interest is paid as incurred.
Loan repayment term	10 years	The loan is repaid on a straight-line basis in the following year after the drawdown of the loan.

Working capital

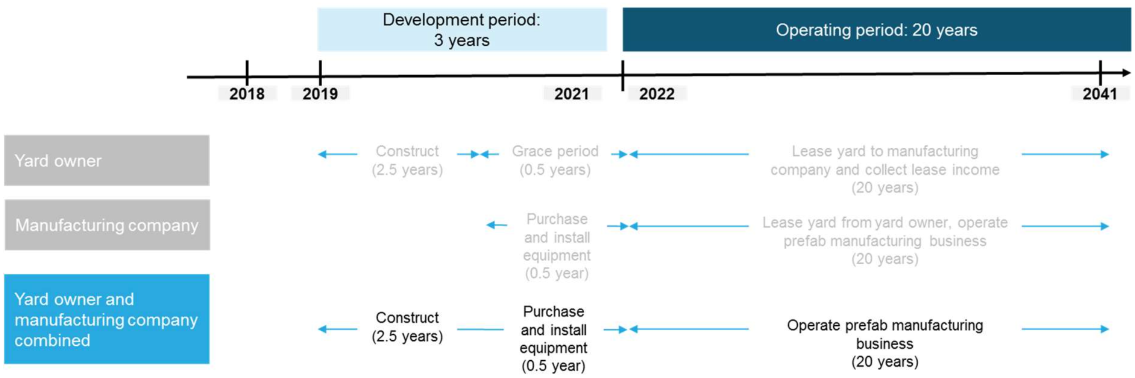
In order to ensure that sufficient cash is available during the first few months of the operation, we have included a working capital requirement for the manufacturing business. The assumptions for working capital include:

Key driver	Assumption	Source / rationale
Working capital requirement	Prior to operation of the yard	In order to ensure that sufficient cash is available during the first few months of the operation, we have included a working capital requirement for the manufacturing business.
Working capital amount	One quarter of first year's operating expenses	The working capital amount is set to be equal to one quarter (3 months) of the first year's operating expenses.
Working capital funding	100% equity	The manufacturing company would fund the working capital entirely through equity.

Base Case 3: Yard owner and manufacturing company combined

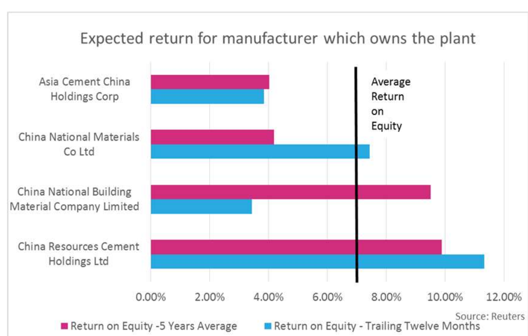
Project timeline

The figure below provides a high level view of the project implementation timeline for Base Case 3: Yard owner and manufacturing company combined:



Financing structure and associated terms

The key financing assumptions are summarised as follows:

Key driver	Assumption	Source / rationale
Expected return	7%	Based on publicly stated return on equity of manufacturing companies (which also owns the yard) between 6.1% to 7.5%. Our assumption is at mid-point (rounded).  Source: Reuters and selected industrial REIT's websites

Appendix F

Prefabricated Component Usage
in Public Housing Projects

	A		B	C = A x B	D	E = A X D
		60%	40%		20%	
Precast Elements	**Weight tonnes per precast element**	**Number of precast element per floor based on 60% usage**	**Number of precast element per floor based on 40% usage**	**Total Precast Elements per floor based on 40% usage (tonnes)**	**Number of precast element per floor based on 20% usage**	**Total Precast Elements per floor based on 20% usage (tonnes)**
Precast Facades	4.5	36	24.00	108.00	12.00	54.00
Semi-precast Slabs	4.5	118	78.67	354.00	39.33	177.00
Precast Staircases	4.5	4	2.67	12.00	1.33	6.00
Precast Partitions	4.5	8	5.33	24.00	2.67	12.00
Welded Walls (fully precast)	7	12	8.00	56.00	4.00	28.00
Semi-precast Walls	6	20	13.33	80.00	6.67	40.00
Precast Bathrooms	9	16	10.67	96.00	5.33	48.00
Precast Bathrooms-cum-kitchens	8.5	4	2.67	22.67	1.33	11.33
Precast Lift Cores	6.5	8	5.33	34.67	2.67	17.33
Precast Stair Cores	9	2	1.33	12.00	0.67	6.00
Precast Lintels	0.5	8	5.33	2.67	2.67	1.33
	Based on published data*					
			Precast Elements per floor (tonnes)	802		401
			Number of units per floor	16		16
			Precast Elements per unit based on 40% usage (tonnes)	**50.13**	**Precast Elements per unit based on 20% usage (tonnes)**	**25.063**

***Source:**
Green construction | Prefabrication and Precasting | Innovative Precasting and Prefabrication – Pilot Project in Kwai Chung Estate, including Arup's analysis