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Modular Integrated Construction for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment

Reference Materials on Roadmap for MiC Implementation in Hong Kong

香 港 大 學
THE UNIVERSITY OF HONG KONG

Centre for Innovation in Construction & Infrastructure Development

Modular Integrated Construction for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment

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Contents

1. Introduction

1.1. Background

Modular construction has been adopted in many jurisdictions including UK, US, Australia, Singapore and China. Worldwide there have been a few high-rise building projects completed or under construction, such as the 44-storey steel-framed modular building in Croydon, UK and the 40-storey residential building with precast concrete modules in Singapore (Pan et al., 2019). Modular construction has been proven as an innovative game-changing approach by using the Design for Manufacture and Assembly (DfMA) theory and advanced manufacturing and logistics technologies. Benefits achievable from using modular construction include faster construction, improved health and safety, reduced site labour, minimised construction waste, and enhanced construction quality (Lawson et al. 2014; Pan et al. 2007; 2019).

In Hong Kong, Modular Integrated Construction (MiC) has been recently adopted as a new policy initiative of promoting innovative construction (Chief Executive, 2017; 2018; 2020). MiC is based on but develops further from the modular construction approach. MiC embraces the theories of modularisation, value engineering and lean construction, and is defined by Pan and Hon (2018) as "*a game-changing disruptively-innovative approach to transforming fragmented site-based construction of buildings and facilities into integrated value-driven production and assembly of prefinished modules with the opportunity to realise enhanced quality, productivity, safety and sustainability*".

For the purpose of public works policy and regulatory building control, the Government of the HKSAR has defined MiC as a construction method that employs the technique of having freestanding volumetric modules (with finishes, fixtures, fittings, etc.) manufactured off-site and then transported to site for assembly (see PNAP ADV-36 and DEVB TC(W) No. 2/2020).

For Hong Kong where building high-rises is the norm, the approach of MiC offers an innovative solution with a high potential of enhancing quality, efficiency and productivity. Since the announcement of the MiC policy in 2017, there have been several MiC demonstration and pilot projects in Hong Kong. However, MiC is still in its infancy in Hong Kong with opportunities and risks co-existing. There is a need to comprehensively understand MiC and progressively establish supply chains for the successful adoption of MiC in various building sectors.

1.2. Research aim and objectives

This Roadmap Report is one of the deliverables of the research project entitled "*Modular Integrated Construction for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment*" which aims to improve the Hong Kong construction industry's understanding of MiC and to help de-risk MiC adoption in Hong Kong by identifying and analysing the challenges in establishing MiC supply chains for buildings in Hong Kong in order to enhance construction productivity, quality, safety and sustainability. The objectives of the research are:

(1) To improve the Hong Kong construction industry's understanding of MiC in terms of

(a) markets of different building sectors in Hong Kong such as hostels, housing, commercial, residential, (b) suppliers of different types of modular systems including steel-framed, concrete and hybrid modular systems, (c) logistics and quality assurance in terms of module supply, and (d) costs of manufacturing, transporting and installing modules.

(2) To investigate the issues and risks with delivering modular buildings in Hong Kong through factory visits, document analysis, and focus group meetings with MiC supply chains and industry stakeholders.
(3) To estimate the costs of manufacturing, transporting and installing modules and develop strategies for managing the uncertainties of the estimated costs through case study and industry consultation.
(4) To verify and disseminate the findings to the Hong Kong construction industry through stakeholder engagement and seminars to facilitate a better industry understanding and successful take-up of MiC in Hong Kong.

This Roadmap Report fulfils the following two sub-objectives:

(1) To recommend a Roadmap for implementing MiC in Hong Kong; and
(2) To provide recommendations on the parameters for setting up a local supply chain for MiC production in Hong Kong.

1.3. Project team

Table 1-1 provides the basic information about the project team, including the Principal Investigator and Co-Investigators. The project team also includes a team of researchers with expertise in MiC, cost analysis, and supply chain management.

Table 1-1 Project team

Role	Name	Position
Principal Investigator	Ir Prof Wei Pan	Professor and Executive Director, CICID, HKU
Co-Investigator 1	Ir Prof Thomas Ng	Professor & Associate Dean, Department of Civil Engineering, HKU
Co-Investigator 2	Ir Prof George Huang	Chair Professor & Head, Department of Industrial and Manufacturing Systems Engineering, HKU
Co-Investigator 3	Ir Prof Sam Chan	Associate Director, CICID, HKU
Co-Investigator 4	Ir Prof Francis Au	Professor & Head, Department of Civil Engineering, HKU
Co-Investigator 5	Ir KL Tam	Director, Estates Office, HKU
Co-Investigator 6	Dr Louis Chu	Assistant Director, Estates Office, HKU

1.4. Structure of the report

Following the introduction, Chapter 2 explains the methods adopted for developing the Roadmap and the associated action plans. Chapter 3 provides an overview of the status quo of MiC implementation in Hong Kong in terms of policy and regulation, supply chain network and representative MiC pilot projects. Chapter 4 presents the important drivers for and also some constraints to promoting MiC in Hong Kong, and outlines the overall Roadmap to guide

MiC implementation in short-, medium- and long-term, denoting the 0-3, 4-5, and 6-10 year timeframes respectively. Chapter 4 also recommends detailed action plans in accordance with the Roadmap, in terms of policy and regulation, supply chain development, and project delivery and performance. Chapter 5 concludes the Roadmap report and suggests strategic follow-ups for implementing the recommended Roadmap and the associated action plans.

2. Methods

This Roadmap Report was developed with a recommended Roadmap with action plans proposed to progressively enhance MiC implementation in Hong Kong. The Roadmap sets up strategic objectives within different timeframes, while action plans elaborate the key themes for different stakeholders to take relevant actions. The conceptual framework of the Roadmap is demonstrated in Figure 2-1 and explained thereafter.

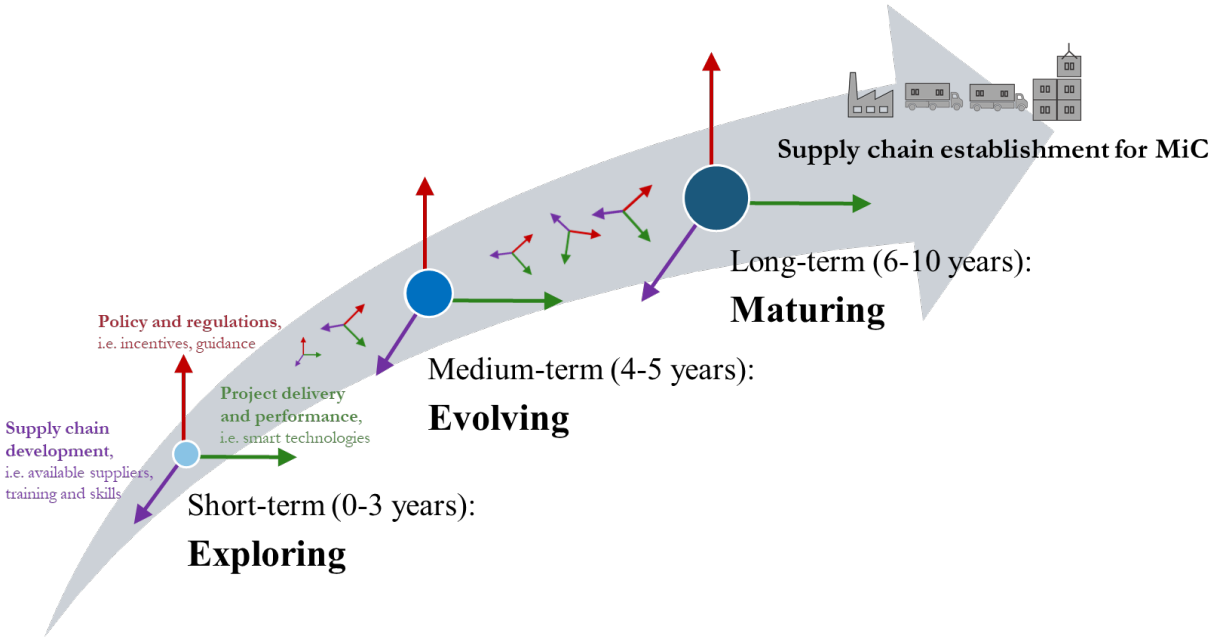


Figure 2-1 Conceptual framework of the Roadmap recommended for the implementation of MiC in Hong Kong

(*Note: The small arrows denote the dynamics and evolution embedded in the implementation of the Roadmap*)

First, the recommended Roadmap defines three strategic objectives in short-, medium- and long-term, as three milestones, drawing on the state-of-the-art development and market demand analysis of MiC. The short-, medium- or long-term timeframes denote 0-3, 4-5, and 6-10 years, respectively. Subject to policy drivers from the government and market drivers from various building sectors, the proposed strategic objectives for MiC implementation and development are captured with three general stages, i.e. "exploring", "evolving", and "maturing".

- The short-term strategic objective is to continuously **explore** and develop a comprehensive knowledge base of MiC methods, given the current infancy nature of MiC in the Hong Kong construction industry. The industry's knowledge of MiC is expected to grow comprehensively and solidly, with experiences being accumulated from the several MiC pilot projects.
- The medium-term strategic objective is to **evolve** towards more efficient, smart, and value-adding in MiC implementation. Meanwhile, the supply chain for MiC should be well established in and/or for Hong Kong to meet the rapid growth of the market demands.

- The long-term strategic objective is to step up a **mature** Hong Kong MiC industry, e.g. with world-leading practices and performance of MiC projects, extensive industry collaboration, comprehensive regulatory systems, and MiC supply chain network covering the Greater Bay Area (GBA).

Next, action plans were recommended for the Roadmap in terms of (1) policy and regulations, (2) supply chain development, and (3) project delivery and performance. These three themes are interrelated with each other and associated with different stakeholders.

- In terms of policy and regulations, the statutory and regulatory bodies should provide policy and regulations related support to generate a business environment that favours the development of MiC supply chains and safeguards MiC project delivery.
- In terms of supply chain development, the Hong Kong construction industry as a whole should work jointly to enhance knowledge sharing, skills, collaboration, and standardisation, to develop robust MiC supply chains for Hong Kong to realise benefits and overcome challenges.
- In terms of project delivery and performance, relevant decision-makers should have a comprehensive understanding of MiC, project-specific opportunities and risks, and thereby formulate suitable technical solutions and management strategies.

The research underpinning the Roadmap development was conducted through the use of combined methods of document review and analysis, expert consultation and focus group meeting.

Document review and analysis

A comprehensive review and analysis of relevant documents was carried out, aiming to understand the status quo and future development of MiC in Hong Kong. The reviewed documents included government and industry reports, published materials, and relevant websites accessible in the public domain, and also the reports delivered in this study including:

- Case Study Report (with leaflets)
- Supply Logistics Report
- Cost Estimates of MiC
- Stakeholder Seminar Report
- Market Analysis Report
- Practical Guide on MiC Adoption

Expert consultation

The Roadmap Report has gone through an intensive process of discussing with and commenting by CIC. In doing so, a number of meetings between CIC and HKU have been conducted, which enabled in-depth discussion on the contents of and issues addressed in the Roadmap Report. These consultation meetings mainly included the following agenda items:

(1) Briefing by the project team on the project progress, and main considerations for developing the Roadmap Report.
(2) Discussion on the contents of the Roadmap Report and the potential use of such a

Roadmap for MiC practitioners.

(3) Discussion on the recommendations for improving the Roadmap Report for better practicability and usefulness.
(4) Debriefing and summary session.

The Roadmap Report has also been circulated to relevant government departments and industry organisations for views and input, including the Joint Working Group on MiC, relevant Departments of the HKSAR government and parties (e.g., Architectural Services Department, Buildings Department, and Housing Authority), and CIC Committee on Productivity. Their comments have been addressed and integrated into the revised Roadmap Report.

Focus group meeting

A final focus group meeting was designed to further verify and enrich the Roadmap Report. The participants covered the key stakeholder groups of government, client, contractor, consultant and institution.

During the meeting, the project team first explained the developed Roadmap and action plans within the context of the project. The focus group participants raised enquiries and provided comments and suggestions. The focus group meeting lasted two hours for effective discussion. The discussion was audio-recorded with permission from the participants, and then transcribed. The transcript and notes taken during the focus group discussion were analysed using the thematic contents analysis methods.

3. Landscape of MiC in Hong Kong

3.1. Policy and regulations

Policy and regulations have been recognised as an important factor for MiC implementation. According to the recent MiC market survey[1], "*Gross Floor Area concession or bonus*" and "*MiC policy initiative and promotion*" were ranked the second and fourth most important drivers for MiC promotion, respectively. Meanwhile, "*limited available codes and standards*" and "*over-stringent regulations for MiC*" were ranked the first and the third most significant constraints to MiC promotion, respectively.

Since the Chief Executive' 2017 Policy Address that promoted MiC in Hong Kong, several regulations and guidance notes have been issued by relevant government departments to guide MiC implementation. The relevant policies and regulatory documents are summarised and illustrated in the timeline as shown in Figure 3-1.

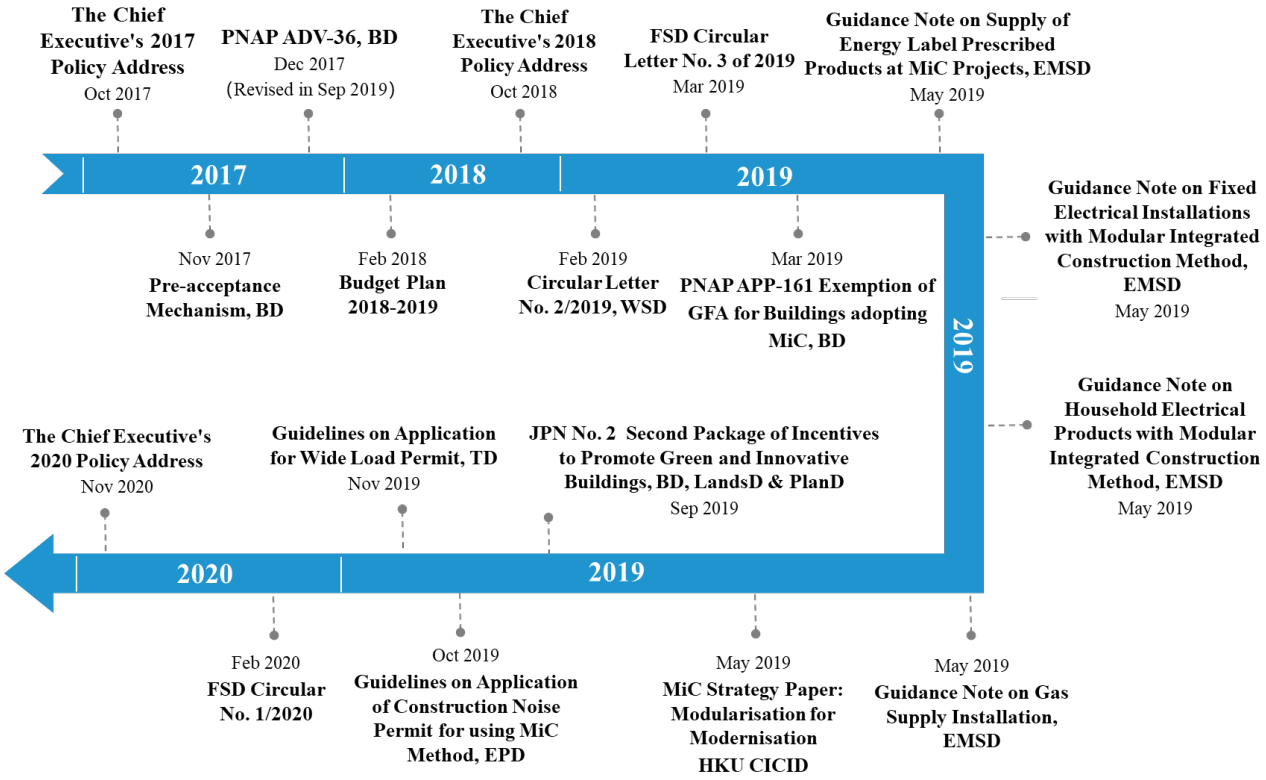


Figure 3-1 Policy and regulations for MiC implementation issued in Hong Kong (As of Nov 2020)

Chief Executive's Policy Address

The 2017 Policy Address promoted MiC in the Hong Kong construction industry as an innovative construction approach (Chief Executive, 2017: p.29):

[1] HKU CICID (2019). *MiC for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment: Market Analysis Report*. HKU CICID, CIC Research Fund.

"Promote and lead the adoption of Modular Integrated Construction (MiC) in the construction industry. By adopting the concept of "factory assembly followed by on-site installation" and the mode of manufacturing, labour intensive processes can be accomplished in off-site prefabrication yard with a view to enhancing productivity and cost-effectiveness."

The 2018 Policy Address continued to promote the wide use of MiC in Hong Kong and the Government has been actively supporting non-profit-making organisations to explore the feasibility of constructing prefabricated modular housing (Chief Executive, 2018: p.42):

"Continue to promote and lead the adoption of MiC in the construction industry. We will take the lead in piloting MiC in more public projects to further enhance the associated monitoring measures, provide funding support for the industry, consider the gross floor area concessions, as well as intend to study the feasibility of setting up local manufacturing facilities, for facilitating adoption of MiC in the construction industry."

The 2020 Policy Address further highlighted the advantages of MiC in quickly delivering quarantine centres amid the epidemic (Chief Executive, 2020: p.31):

"The speedy completion of the quarantine centre at the Lei Yue Mun Park and Holiday Village, with the use of the Modular Integrated Construction (MiC) method amid the epidemic, has been acclaimed by the Institution of Civil Engineers of the United Kingdom."

Budget Plan 2018-19

The Financial Secretary's (2018) Budget Plan earmarked Hong Kong $1 billion to have set up the Construction Innovation Technology Fund (CITF) for supporting the adoption of innovative construction technologies, with MiC being a priority theme:

"The Government will also take the lead in piloting Modular Integrated Construction (MiC) in public projects. We are considering extending the current gross floor area concessions for promoting green and innovation buildings to cover buildings adopting MiC. We are also conducting studies on relevant manufacturing facilities to promote the wider use of such a construction method in Hong Kong."

Development Bureau (DEVB)

In 2019, the Development Bureau (DEVB) together with HKU CICID released the MiC Strategy Paper entitled "Modularisation for Modernisation: A Strategy Paper Rethinking Hong Kong Construction", which elaborates on the MiC policy initiative by providing a definition and recommending strategies for the adoption of MiC in Hong Kong. In 2020, DEVB has set out the policy on the adoption of MiC for new building works with total construction floor area (CFA) larger than 300m^2 under the Capital Works Programme to be tendered on or after 1 April 2020 (Technical Circular (Works) No.2/2020). DEVB has also established a MiC Steering Committee to steer and oversee the MiC policy and the adoption of MiC, particularly in

government and government-funded building projects.

Buildings Department (BD)

The Buildings Department (BD) has set up a pre-acceptance mechanism for granting in-principle acceptance[2] to MiC systems/components. Along with this mechanism, the Practice Note (PNAP ADV-36) for Authorised Persons, Registered Structural Engineers and Registered Geotechnical Engineers outlines the relevant design considerations and requirements for compliance with the Buildings Ordinance (BO). The requirements listed in PNAP ADV-36 cover: fire safety, joints and gaps, structural design, provisions for maintenance, quality assurance scheme, quality and qualified supervision.

BD has also issued the Practice Note for Authorised Persons, Registered Structural Engineers and Registered Geotechnical Engineers APP-161 (PNAP APP-161) to promulgate the gross floor area (GFA) concession for new building projects adopting MiC in order to drive market demand:

(1) 6% of the MiC floor area of a new building may be disregarded from the GFA of the development upon submission of an application for exemption under section 42 of the Buildings Ordinance; and
(2) The disregarded GFA under item (a) above is not subject to the overall GFA cap of 10% under PNAP APP-151.

Electrical and Mechanical Services Department (EMSD)

The Electrical and Mechanical Services Department (EMSD) is committed to facilitating the implementation of MiC method and providing advice and guidance to the trade on how the method can comply with the Electricity Ordinance, Gas Safety Ordinance and Energy Efficiency (Labelling of Products) Ordinance. The guidance notes include:

(1) Guidance Note on Fixed Electrical Installations with Modular Integrated Construction Method;
(2) Guidance Note on Household Electrical Products with Modular Integrated Construction Method;
(3) Guidance Note on Gas Supply Installations; and
(4) Guidance Note on Supply of Energy Label Prescribed Products at MiC Projects.

Fire Services Department (FSD)

The Fire Services Department (FSD) has issued a guidance note (FSD Circular Letter No. 3/2019) for MiC to guide MiC practitioners to meet the standards and requirements of fire service installations and equipment in their MiC projects. More recently, FSD has revised the application procedure for inspection and testing of fire service installation and equipment (FSD Circular Letter No. 1/2020) to facilitate the application process and specify the respective areas of professional responsibility of authorised person (AP), registered professional engineer (RPE) and registered fire service installation contractor (RFSIC). Specifically, the current single application form has been divided into FSI/501 and FSI/501a to be completed by respective

[2] https://www.bd.gov.Hong Kong/en/resources/codes-and-references/modular-integrated-construction

parties. The revision streamlines the application process and thus could facilitate collaboration between different parties in MiC projects.

Water Supplies Department (WSD)

The Water Supplies Department (WSD) has issued Guide to Application for Water Supply to guide MiC developers on procedures for applications for water supply in new building projects adopting MiC method.

Based on the above document review, several key implications for policy and regulations for MiC are summarised as follows:

(1) The MiC market is expecting policy and financial support from the government and statutory bodies.
(2) Relevant regulatory bodies may further develop relevant codes and standards, formulate effective regulations, and simplify the permit approval processes for MiC projects.

Transport Department (TD)

During the project planning/design stage, a feasibility study should be carried out to assess and establish whether there is any route for transporting the modules from the MiC factory to the project site, taking into account ports and marine unloading points for marine transport, road conditions and constraints for road transport, and the need for traffic impact assessments at different stages of the project, etc.

'Just-in-time delivery' of the modules to the project site is the best approach. However, if this is not feasible, the feasibility study should include identification of temporary parking space and/or storage locations for the modules. Early advice from experienced logistics companies and trailer drivers on the logistics of delivery should be sought.

An assessment of the traffic impact on the proposed delivery routes should be carried out in consultation with the relevant Traffic Engineering (TE) Division/Regional Office of TD and the Road Management Office (RMO)/Hong Kong Police Force (HKPF).

In-principle approval of the proposed routes, and the conditions to be imposed on the use of the routes/vehicles, should be obtained. The approved routes and conditions should be included in the conditions of tender for reference by tenderers during the tendering process. This will give confirmation to the tenderers on the feasibility of adoption of MiC in the project, reduce risks and uncertainties to the project, and save cost and time (after CIC, 2020).

Environmental Protection Department (EPD)

The Environmental Protection Department (EPD) has issued guidelines for developers, architects and contractors on the application of construction noise permit for using MiC. Project stakeholders are suggested to plan for MiC to prioritise construction work during the daytime on weekdays and minimise works within the restricted hours (e.g. from 7 pm to 7 am). For example, modules design in terms of sizes and shapes are suggested to allow transportation in the daytime, thus to avoid noisy construction activities within the restricted hours.

An assessment of the noise impacts of the MiC works at the project site should be carried out in advance and the relevant Regional Offices of EPD may be consulted as necessary. The aims of the assessment are to establish the feasibility of carrying out the MiC works within the restricted hours, and to identify the potential noise issues that the project may face. The results of the assessment should be reviewed together with the traffic restrictions imposed by TD/HKPF to check if it is unavoidable to carry out the MiC works within the restricted hours.

If it is genuinely unavoidable, then recommendations should be made on the appropriate noise mitigation measures, such as use of the quietest practical construction equipment and methods, to eliminate or minimise the impacts.

In-principle approval of the assessment, the mitigation measures proposed and the conditions to be imposed on the MiC works carried out within the restricted hours should be obtained before the tendering. The information obtained from the assessment is useful for the planning and programming of the MiC works, and should be included in the conditions of tender for reference by the tenderers during the tendering process (after CIC, 2020).

3.2. Supply chain network

Given the infancy nature of MiC adoption in Hong Kong for the time being, there is yet no MiC supply chain fully established in Hong Kong. Meanwhile, there exist perceptions that the adoption of MiC in Hong Kong is constrained by the lack of capable supply chains which comprise qualified MiC vendors, experienced MiC contractors, designers with DfMA mindset and capability, and familiarity of regulatory bodies and appropriate regulatory procedures to facilitate the MiC projects in Hong Kong. It is inevitable for pilot projects to import MiC systems/products from outside Hong Kong. Consequently, the eligibility of MiC system suppliers, affiliated logistics feasibility, regulation and inspection issues, cost efficiency and schedule risks are all critical factors concerning the local stakeholders (Yang et al., 2019a).

This research drew on a comprehensive review of the global modular construction market and identified about 90 suppliers that are capable of supplying MiC products and services (e.g. ranging from consultation to installation) for building projects. These suppliers may have their own factories locally or partner with various manufacturers overseas for the reasons of cost and space. Nevertheless, this review focuses on eligible MiC suppliers that provide MiC products and services, rather than those that only produce modules.

As shown in Figure 3-2, most suppliers are from the UK (37%), followed by Singapore (29%) and Australia (15%), with a few from China (12%) and the US (7%).

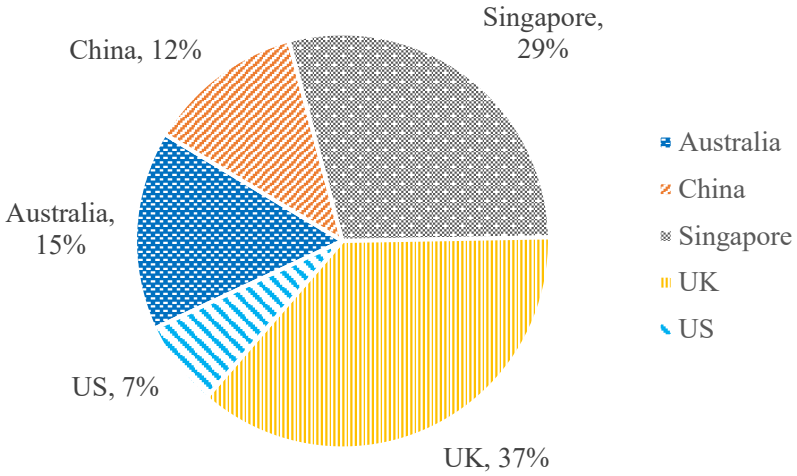


Figure 3-2 MiC suppliers' distribution by country (As of Oct 2019[3])

Figure 3-3 reveals the increasing number of module suppliers in the past two decades, indicating the growing demand and supply for modular construction in the global market.

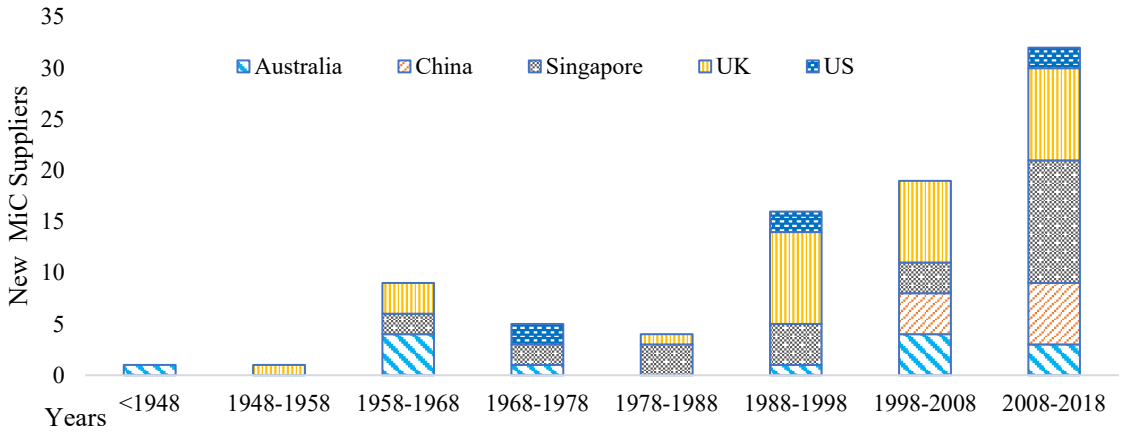


Figure 3-3 Increasing number of module suppliers (As of Oct 2019)

Despite the available supply of modules in precast concrete (PC), hybrid (e.g. steel framed modules with concrete floor) and timber materials, steel framed solutions appear to be the majority in the MiC supply market (Figure 3-4). Most of the UK suppliers (31 out of 33) and all of the Australian suppliers have a focus on steel framed solutions, given that steel framed modular building is a norm in these two countries. Similarly, in China, there are 10 suppliers providing steel framed solutions, but only 1 supplier provides PC solution. By contrast, in Singapore there are 15 accredited concrete PPVC suppliers, almost twice as many as steel PPVC suppliers (8), reflecting the preference of Singaporean clients to concrete modular solutions (Pan et al., 2018).

[3] HKU CICID (2019). *MiC for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment: Supply Chains Database with APPs*. HKU CICID, CIC Research Fund.

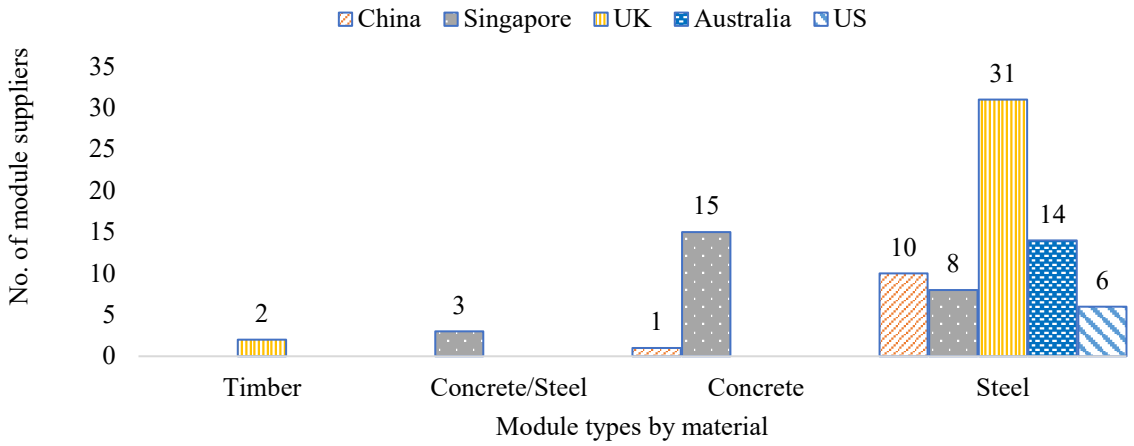


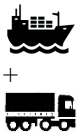
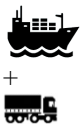
Figure 3-4 Module suppliers categorised by module material and by jurisdiction (As of Oct 2019)

When considering the suppliers' capability, previous research recognised that several established module suppliers in China provide their patented modular systems/products to be used and demonstrated in many high-rise modular buildings worldwide (Yang et al., 2019a). However, in other countries such as the UK where there are established module factories, their supply scope appears to focus on the domestic market. For Hong Kong, MiC systems accepted by BD will be shown on its website[4] for reference by the public and practitioners.

Based on the review of the module suppliers, six scenarios of MiC supply chain for buildings in Hong Kong are proposed with cross-scenario comparisons in terms of their pros and cons (Table 3-1). These scenarios are recommended considering the location of the module suppliers (i.e. China, overseas, or hypothetically a local factory within HK) and the mode of transport (i.e. by land or by sea-land).

[4]www.bd.gov.hk/en/resources/codes-and-references/modular-integrated-construction/mic_acceptedList.html

Table 3-1 Scenarios of MiC supply chains for Hong Kong[5]

Scenarios			Pros	Cons
Souring from Mainland China	Greater Bay Areas		• Short distance, fast delivery • Higher flexibility to programme changes • Established practice for prefabrication • No additional storage required at customs points	• Gate width of the checkpoint at customs may constrain module width • Time uncertainty related to road transportation • Road safety concerns
			• Higher flexibility to programme changes • Reduced delivery time • Potential time-saving and cost-saving from reduced customs inspection time • Potentially benefit from five-day free dock storage policy for cost-saving	• A bit slower than trailer transport • Additional handling and lifting modules may cause defects
	Yangtze River Delta region		• No additional storage required at customs points • Established practice for prefabrication	• Longer distance and consequent slower delivery and higher cost • Time uncertainty and safety concerns related to road transport • Gate width constraints
			• Well-established maritime industry in Hong Kong • Mid-stream operation and terminal operation are both available in Hong Kong	• Consideration of sea freight selection
Sourcing from foreign countries			• Well-established maritime industry in Hong Kong • Established MC system with experienced suppliers	• More complexities in logistics coordination and stakeholder's collaboration • Higher transportation cost • Constrained flexibility and efficiency to address uncertainties
Sourcing from local factories	Hong Kong		• Cost-saving and time-saving in logistics • Higher flexibility in achieving JIT • Better communication, and quicker action to uncertainties • Regulation compliance easier to achieve • Social value to Hong Kong such as providing employment • Build up a skilled workforce in HK • Establish pool of talents in construction innovation	Increased production cost due to high labour cost and high premium cost to build the factory

The review of module suppliers and logistics scenarios yields a number of implications for developing MiC supply chains in Hong Kong:

- Given the infancy nature of MiC adoption in Hong Kong as of the time of this study, the local suppliers and contractors have limited capability and capacity of producing,

[5] HKU CICID (2019). *MiC for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment: Supply Logistics Report*. HKU CICID, CIC Research Fund.

supplying and installing modules. It is thus inevitable to import modular systems/products from outside Hong Kong for the MiC pilot projects.

- The growing number of module suppliers, especially in Singapore and Mainland China, provides a good opportunity to develop a strong supply market for Hong Kong.
- It is significant to improve the understanding of various building sectors in Hong Kong about the eligible and capable module suppliers, the logistics, and the costs of manufacturing, transporting and installing modules.
- The development of local MiC supply chains in Hong Kong (e.g. local suppliers and factories) should be progressive to enable learning from the established supply chains in other jurisdictions.
- There exist significant advantages of souring available modular systems/products from other cities in the Greater Bay Area (GBA). Meanwhile, the development of the GBA during the next few decades will provide exciting opportunities for Hong Kong to establish the GBA-based supply chains for MiC adoption in Hong Kong.
- In the long run, setting up local factories for module production within HK should help to meet the increasing demand for module supply. Nevertheless, the need for a local factory will be mainly driven by the policy initiatives and the market demand for MiC.

3.3. MiC pilot projects

Since the announcement of the MiC policy in the 2017 Policy Address, there have been several MiC demonstration and pilot projects in Hong Kong. Figure 3-5 demonstrates representative MiC projects completed in 2020 and to be completed in the future 3-4 years.

All of the MiC pilot projects in Hong Kong so far rely on the module supply chains in the GBA. These projects adopt the modular systems that are available in the market with necessary adjustments to comply with the relevant planning and design requirements in Hong Kong.

In addition, there have been some other building projects under initial planning and design with the orientation of adopting MiC. Several observations on the progress of MiC implementation at the project level are as follows:

- To date, there is yet no modular building of 20 storeys or more completed or publicly announced in Hong Kong. One reason for that may be the perceived structural challenges to high-rise buildings in Hong Kong with the strong typhoon and stringent design code on wind effects.
- The high-density nature of developments in the urban built area imposes difficulties with the logistics of large-sized modules.

The procurement for MiC requires reengineering the existing project delivery process to enable the integration of design and supply chain.

Figure 3-5 Representative MiC projects completed in 2020 and to be completed in the future 3-4 years (as of Dec 2020)

To sum up, MiC is still in its infancy stage in Hong Kong. There is room for improvement in three strategic themes, i.e. policy and regulations, supply chain development, and project delivery and performance, which are further elaborated in the following chapter.

4. Roadmap and action plan

4.1. Drivers and constraints for MiC adoption

In terms of the drivers for and constraints to adopting MiC, the Government and statutory bodies play a critical role in driving the adoption of MiC while also relating to the most concerned regulatory issues. According to the market analysis[6] conducted by HKU CICID, the top five most important drivers for adopting MiC are identified to be (in descending order of importance):

(1) faster construction and shortened project duration;
(2) GFA concession or bonus;
(3) better quality control of products due to standardisation;
(4) MiC policy initiative and promotion; and
(5) improved health, safety and welfare for workers.

The top five most significant constraints to MiC adoption are revealed to be (in descending order of significance):

(1) limited available codes and standards;
(2) limited choice of capable suppliers and contractors in the market;
(3) over-stringent regulations;
(4) challenges in logistics due to safety, traffic condition and storage issues; and
(5) loss of saleable areas owing to the double-wall/floor issues.

Those identified drivers and constraints are associated with three main strategic themes (Table 4-1), which are policy and regulations (e.g. codes, standards, regulations, policy incentives), supply chain development (e.g. suppliers and contractors, logistics, workers), and project delivery and performance (e.g. quality control, project duration). To support the market potential of MiC in short-, medium- and long-term, actions should be well planned to provide strong drivers and address the constraints to MiC adoption in line with these three strategic themes, which are discussed in the following section.

Table 4-1 Drivers and constraints in relation to the strategic themes in the roadmap

Strategic themes	Related drivers	Related constraints
Policy and regulations	• GFA concession or bonus • MiC policy initiative and promotion	• Limited available codes and standards • Over-stringent regulations[7]
Supply chain development	• Better quality control of products due to standardisation	• Limited choice of capable suppliers and contractors in the market
Project delivery and	• Faster construction and	• Challenges in logistics due to

[6] HKU CICID (2019). *MiC for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment: Market Analysis Report*. HKU CICID, CIC Research Fund.

[7] The over-stringent regulations have been discussed in the Supply Logistics Report. These include size of a loaded vehicle limited to 2.5m(w) x 4.6m(h) (see Regulation 55 of the Road Traffic Regulations (Cap. 374G)) unless a Wide Load Permit has been applied for.

Strategic themes	Related drivers	Related constraints
performance	shortened project duration • Better quality control of products due to standardisation • Improved health, safety and welfare for workers	safety, traffic condition and storage issues • Loss of saleable areas owing to the double-wall/floor issues

4.2. Overall Roadmap

Considering the current status of and future demands for MiC in Hong Kong, action plans are proposed to progressively enhance MiC implementation. In general, the strategic objectives in short-, medium- and long-term, as three milestones, are defined drawing on the state-of-the-art development and market demand analysis[8]. The short-, medium- or long-term timeframes denote the 0-3, 4-5, and 6-10 year timeframes, respectively.

Subject to policy drivers from the government and market drivers from various building sectors, the proposed objectives for MiC implementation and development are captured with three general stages, i.e. "exploring", "evolving", and "maturing".

- The short-term objective is to continuously **explore** and develop a comprehensive knowledge base of MiC methods, given the current infancy nature of MiC in the Hong Kong construction industry. The industry's knowledge of MiC is expected to grow comprehensively and solidly, with experiences being accumulated from the several MiC pilot projects.
- The medium-term objective is to **evolve** towards more efficient, smart, and value-adding in MiC implementation. Meanwhile, the supply chain for MiC should be well established in Hong Kong to meet the rapid growth of the market demands.
- The long-term objective is to step up a **mature** Hong Kong MiC industry, e.g. with world-leading practices and performance of MiC projects, extensive industry collaboration, comprehensive regulatory systems, and MiC supply chain network covering the GBA.

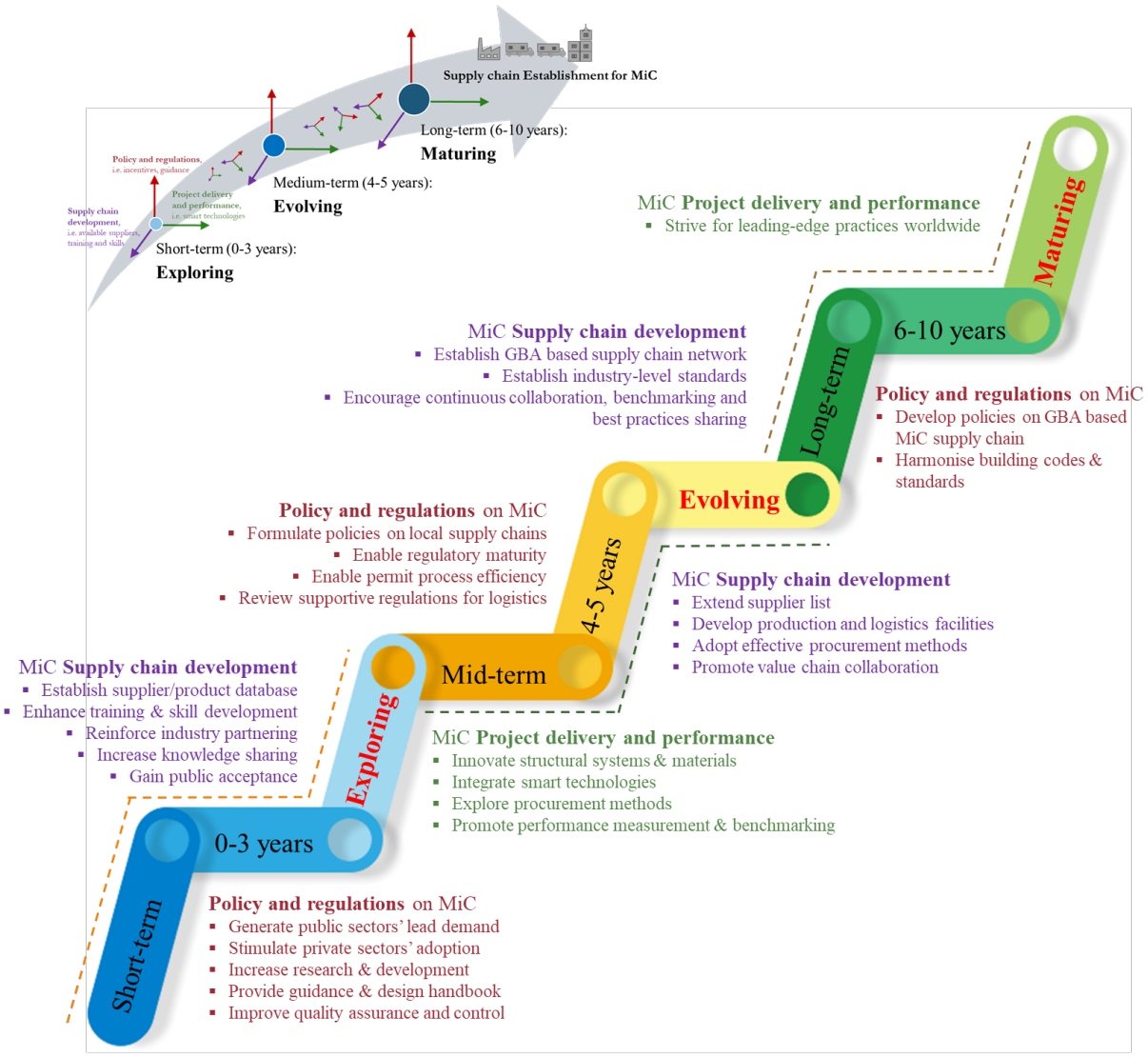
As outlined in Figure 4-1, the proposed action plans embrace the three strategic themes, namely, policy and regulations, supply chain development, and project delivery and performance. These three strategic themes are interrelated with each other and associated with different stakeholders.

- **In terms of policy and regulations**, statutory and regulatory bodies should provide policy and regulations related support to generate a business environment that favours the development of MiC supply chains and safeguards MiC project delivery.
- **In terms of supply chain development**, the Hong Kong construction industry as a whole should work jointly to enhance knowledge sharing, skills, collaboration, and standardisation, to develop robust MiC supply chains for Hong Kong to realise benefits and overcome challenges.
- **In terms of project delivery**, projects that adopt MiC, relevant decision-makers should have a comprehensive understanding of MiC, project-specific opportunities and risks, and

[8] HKU (2019). MiC for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment: Market Analysis Report. HKU CICID.

thereby formulate suitable technical solutions and management strategies.

The following sub-sections recommended critical actions to achieve strategic objectives in the short, medium and long term.



**The short-, mid- or long-term timeframes subject to policy drivers from the government and market drivers from various building sectors.*

Figure 4-1 Roadmap and action plans for MiC implementation in Hong Kong

4.3. Action plans for the Roadmap

4.3.1. Short-term recommendations

In terms of policy and regulations

(1) Generate sufficient lead demand from the public sector
   a. To prioritise the use of MiC approach in government-led projects when applicable.
   b. To examine the practicability of mandating the use of MiC in public housing projects.
   c. To encourage MiC adoption in Transitional Social Housing.

(2) Stimulate MiC adoption in the private sector
   a. To provide incentives and/or subsidies for private building projects that adopt MiC. The scale of such incentives and/or grants should be carefully determined with public engagement and consultation.
   b. To consider MiC adoption as one land sales requirement for the private sector.
   c. Reasonable incentives should be established and promoted to encourage the designers to adopt and accumulate MiC design experience, as well as to assist the MiC suppliers to get into qualified MiC supplier list by subsidising their cost to appoint AP and RSE to apply for In-Principal Acceptance.
   d. To explore the feasibility of bringing in medical modules for showing to Hospital Authority.

Example: Initiatives of the Singaporean government to promoting PPVC

The Building and Construction Authority (BCA) of Singapore has imposed the adoption of prefabricated prefinished volumetric construction (PPVC) as land sales conditions for developments sold under the Government Land Sale (GLS) Programme[9] since November 2014.

The BCA also provides financial supports to stimulate PPVC demand in the private sector. In the Productivity Improvement Project scheme (PIP), the Singaporean government could provide up to 70% co-funding for those contractors and manufacturers who will embark on innovative technologies (e.g. PPVC) to enhancing productivity.

(3) Increase research and development (R&D) on MiC
   a. To identify R&D subjects by consulting industry partners and the collaboration with regulatory bodies during the R&D process to ensure the outcome of R&D can be widely adopted in Hong Kong. It is recommended to utilise the current R&D facilities as well as planning for the new R&D facilities to meet the specific MiC research.
   b. To provide policy and financial support for establishing R&D facilities for MiC

[9] https://corenet.gov.sg/einfo/Uploads/Circular/CESS141031.pdf

related studies, such as research institutions and technology centres for new materials, structure system and digitalisation used in MiC. This will help to enhance the technical features and innovation in delivering high-rise modular buildings in Hong Kong.

c. To conduct regular evaluation of MiC related R&D projects (especially government-funded projects) and demonstrate the outstanding ones to the public for knowledge sharing.

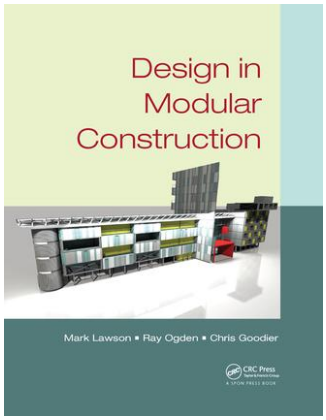
d. To encourage professionals and MiC suppliers to enter Hong Kong MiC market via providing CITF incentives.

(4) Provide practical guidelines and design handbook on MiC practices

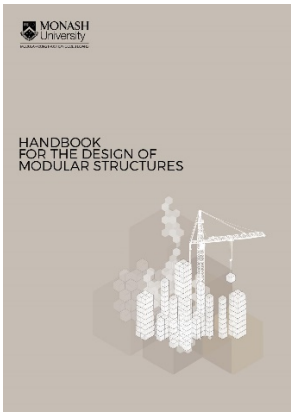
a. The Government should take the lead, or authorise relevant institutions, to provide MiC practical guidelines and design handbooks for MiC practitioners in Hong Kong. Such guidelines and handbooks will help to enhance industrial understanding of MiC and improve regulatory compliances. There are examples in other regions, such as the DfMA guideline in Singapore, design handbooks on modular buildings in the UK and Australia. Such MiC guidelines/handbook should cover the following issues:

- Design considerations
- Structure
- Building services
- Facades
- Architecture
- Materials and manufacturing
- Protection, transportation, installation
- Temporary works
- Construction and project management
- Inspection and verification
- Maintenance and renovation
- Disassembly and reuse

DfMA guideline in Singapore



Design handbooks in the UK



Design handbooks in Australia

(5) Improve quality assurance and quality control (QA/QC) for MiC

a. To tailor the present statutory inspection framework to suit the new MiC production arrangement.To provide comprehensive MiC QA/QC standards and guidance, to guide practitioners and inspectors to devise and execute QA/QC in the course of essential activities, including design, fabrication, transport and construction. For example, such guidance should define the responsibility of authorised persons and registered structural engineers (AP/RSE), the supervision on concealed engineering and connections check, etc.
b. Regulatory bodies should take the initiative to establish new or extend current construction material list for MiC. The purpose is to avoid the use of "unapproved" materials in MiC, save approval time for projects, ensure the structural quality of MiC buildings and underpin the healthy development of the MiC market in Hong Kong.
c. To work jointly with the industry to validate and refine MiC QA/QC systems, such as to collect feedback from pilot projects and to conduct industry consultation.
d. To encourage the utilisation of digital works supervision system and tools to facilitate QA/QC.

Example: Modular Construction QAQC Standard in Canada: CSA A277-16 Procedure for certification of prefabricated buildings, modules and panels

The Standard provides guidance for pre-approval of the manufacturers and their products at the factory.
The Standard gives requirements on four subjects related to the products, namely,
(1) Certification of the factory quality program;
(2) Certification of the prefabricated products;
(3) Auditing of the factory quality program and
(4) In-factory inspection of the prefabricated products.

Subject (1) is an essential part of quality assurance, under which a manufacturer is certified to demonstrate the manufacturer's ability in consistently maintaining the compliance of its products. Subject (2) is the major component of quality control. By certifying a product under (2) the product is verified for its compliance to governing building codes and regulations, and thus free from re-inspection on site. The certification of the quality program and the products will be carried out by a third-party certification body which is accredited.

Example: PPVC QAQC Practices in Singapore[10]

For a PPVC system to get approval under the Singaporean building regulations, the PPVC manufacturer shall first submit their plans and gain In-principle Acceptance (IPA) from the Building Innovation Panel (BIP), to demonstrate that the design and planning is in compliance with local regulations.

After getting IPA, the manufacturer shall also be accredited by the PPVC Manufacturer Accreditation Scheme (PPVC MAS). The scheme requires the manufacturers to be audited by the Accreditation Body. The Audit consists of two parts – Documentation Audit and Plant. PPVC systems that satisfy the auditing requirements will be granted a certificate, either provisional, conditional or full certificate depending on which stage the Audit is undergone. PPVC systems and the affiliated manufacturers that have obtained IPA will be listed on BCA's website as a public assessable information to all interested bodies (BCA, 2017).

To note, the certification granted under MAS does not assure that the manufacture's products are manufactured in compliance to all quality requirements. Clause 7.(1).(b) of Singaporean Building Control Act mandates fulltime supervision by Qualified Person or his/her representative(s) as appropriate for structural works of all building works (Building Control Regulations, 2003). The building's compliance to performance requirements is certified by the certification of completion of building works, which shall be provided by the Commissioner of Building Control Regulations (2003).

BCA issued the circular of "*Guidelines on Supervision of Structural Steelworks Fabricated Off-Site Locally or Overseas*" (ref. APPBCA-2015-12). The circular APPBCA-2015-12 aims to (1) remind the Qualified Persons (QPs) and Qualified Site Supervisors (QSS) of their supervisory duties, from materials inspection and testing to fabrication and erection, under the Building Control Act; and (2) provide guidance on the acceptable level of supervision for structural steelwork fabricated offsite/overseas. There are three major locations that the supervision and quality checking should cover: (1) overseas factory, (2) local holding yard, and (3) local construction site.

In terms of supply chain development

(1) Establish a demand/supply database

a. To promulgate the latest market demand volume on MiC from both private and public projects to attract the potential MiC contractors, suppliers and designers to go into the market.
b. To create a live database of MiC suppliers/products which are approachable to the Hong Kong market. This database could be visualised and accessed by the public via a web portal. This will facilitate clients, developers and contractors in identifying

[10] http://www.sisv.org.sg/Publications/CS_Circular/2%20Nov%2015%20Guidelines%20on%20Supervision%20of%20Steelworks%20Fabricated%20Overseas.pdf

eligible suppliers to partner with. It will also attract more suppliers to support the establishment of capable MiC supply chains for Hong Kong.

Example: The Construction Industry Council MiC resources centre[11]

The Construction Industry Council, drawing on input from this research, provides information on MiC in the MiC resources centre, covering supplier list, pilot projects in Hong Kong, and relevant projects around the world.

(2) Enhance training and skill development

a. To integrate MiC related trades into the current construction worker training systems provided by relevant institutions or companies.
b. To set up professional training courses for different disciplines, such as MiC design, manufacturing, construction, supply chain management, etc.
c. To emphasise MiC and digitalisation tools in undergraduate / graduate compulsory training programme to pave the way for medium- and long-term supply chain growth.
d. To beef up of trucking, cranage, and related skillful personnel for transportation, logistics and lifting.

Example: The BCA Academy of Singapore[12]

The BCA Academy offers PPVC related courses and workshops to the industry practitioners. Wide-ranging themes are covered, including general introduction of PPVC, details on design and engineering (e.g., structural connections, on-site installation works, mechanical connections and required tolerance, layouts, façade), management (e.g., typical scope of works for architect, engineers and suppliers), and construction (e.g., how to overcome logistics and lifting constraints).
As MiC is new to the Hong Kong construction industry, industry engagement and training should be encouraged to address the skills shortage and enable market acceptance and cultural changes.

(3) Reinforce contractor-supplier partnering

a. To encourage contractor-supplier partnering from the tendering stage, which should be driven by the contractor. Contractor-supplier partnering is essential for MiC adoption, particularly given that in Hong Kong, most contractors do not have enough experience in MiC and need to work with non-local MiC suppliers.

(4) Increase knowledge sharing and exchange

a. The industry, universities and government agencies to jointly promote knowledge sharing and exchange, e.g. via international conferences, forums, overseas visits,

[11] http://www.cic.hk/eng/main/mic/Download_Centre/
[12] https://bcaa.edu.sg/

training.

b. To conduct in-depth case studies with MiC pilot projects, and to demonstrate the benefits achieved, and challenges encountered for industry learning and sharing.
c. To integrate MiC related curriculum into higher education.

Increased knowledge sharing and exchange via MiC international conferences

Enhanced learning and sharing via in-depth case studies with MiC case projects

(5) Gain public acceptance for MiC
a. To enhance the public awareness and understanding of MiC and its associated benefits.
b. To encourage the general public to buy flat built by MiC with appropriate incentives.
c. To attract the younger generation on advanced technologies and create a better working environment in the construction industry.
d. To publish articles in professional journals to promote MiC.

In terms of project delivery and performance

The recommended actions on project delivery and performance cover the short- and medium-term considerations. This considers industry-wide learning from the pilot projects for the rest of the construction industry.

(1) Examine advanced structural systems and innovative materials used in high-rise modular buildings.
a. Industry and academic institutions should analyse and examine advanced structural systems for high-rise buildings (for an example see Shan et al., 2019). Typically, the solutions utilising innovative materials and system would require a longer period to get regulatory approval. In this regard, the solutions engineered and tested by professionals might facilitate the regulatory approval with evidence and thus help promote the adoption of MiC.
b. Companies could collaborate with universities and research institutions to investigate structural solutions, connection details and new materials for high-rise

modular buildings.

c. All-concrete module should closely resemble the common Hong Kong premises.
d. To design with reasonable flexibility for future addition and alteration.

(2) Integrate smart technologies into project delivery

a. In line with the industrialisation trend, smart project delivery solutions for MiC should be progressively developed (for examples see Yang et al., 2019b; Niu et al., 2019). For example, there is a need to utilising new technologies and digitalisation to provide a more robust QA/QC without the use of extra human resource and reduce human errors. In the early stage of MiC, project teams could integrate digital tools that have been relatively established in the construction industry, such as:
    - Building information modelling (BIM), e.g. for design and project management;
    - Visual reality (VR) technologies, e.g. for process risk detection and workers' training;
    - Geographic information system (GIS), e.g. for routing selection and logistics planning;
    - Internet of Things (IoT), e.g. for real-time monitoring of logistics.
    - Laser scanner, e.g. for QA/QC.
b. Client's leadership to adopting smart technologies.

Example: A framework of QA/QC processes for MiC using BIM and Laser Scanning

Errors can occur during module manufacturing, as a result of low production accuracy, workers' misinterpretations, equipment calibrating errors, etc. Thus, quality inspection should be performed at every milestone of module manufacturing, which however could lead to huge amount of inspection tasks to inspectors. To facilitate efficient and effective QA/QC in MiC, there is a need to integrate emerging technologies, such as BIM and Laser Scanner, into the inspection process. Figure 4-2 below presents a conceptual framework of QA/QC processes for MiC from module fabrication to installation.

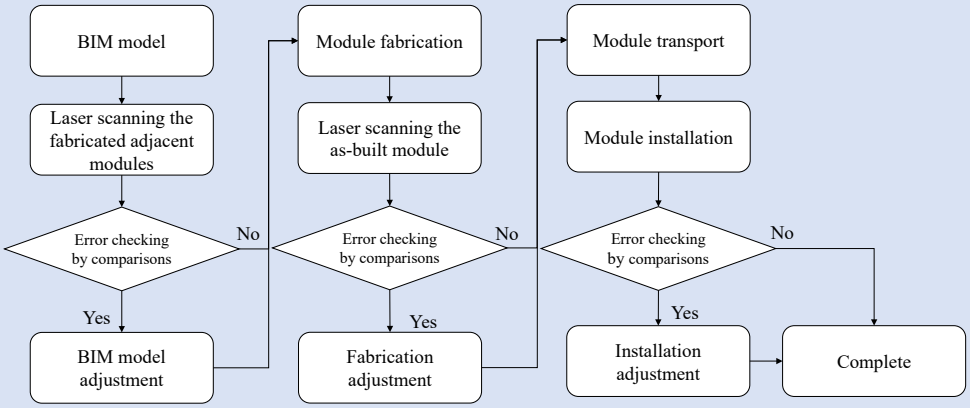


Figure 4-2 A conceptual framework of QA/QC process in MiC (adapted from Chi et al., 2015)

The conceptual framework encompasses a set of activities which are illustrated below (Chi

et al., 2015):

- During the planning and design stage, the BIM models of the building and individual modules should be established to inform module fabrication.
- Before fabricating a module X, the point cloud data of its adjacent modules should be collected and analysed using laser scanning. If any deviation, the BIM model of X should be modified, to ensure X could be well connected to its adjacent modules.
- After X is fabricated, the point cloud data of X and its adjacent modules installed on site should be collected and analysed using laser scanning. If any unmatched connection points detected, reworks upon X should be performed in factory.

After X arrives at site, site engineers and inspectors should perform a final checking with all the connection points among modules.

(3) Explore suitable procurement methods
   a. Stakeholders should assess projects and schemes' suitability for adopting integrated project delivery methods.

(4) Transfer MiC merits into tangible advantages
   a. All-concrete module should closely resemble the common Hong Kong premises.
   b. To design the layouts similar to conventional floor plans for for-sale products.
   c. To design with reasonable flexibility for future addition and alteration.
   d. To liaise with Transportation Authorities to streamline the transportation of oversized modules.
   e. Project stakeholders and universities to work jointly to develop systemic MiC performance measurement methodologies and key performance indicators (KPI) systems. This will support the industry's and the community's decision making of MiC system selection and evaluation for achieving optimal MiC performance.

4.3.2. Medium-term recommendations

In terms of policy and regulations

(1) Formulate policy initiatives on developing local MiC supply chain
   a. To identify and mandate the demands to utilise the local MiC supply chain.
   b. To allocate land for setting up the MiC factories in Hong Kong.
   c. To allocate land for setting up MiC storage yards in Hong Kong.
   d. To provide financial support to the set-up and operation of local MiC factories and holding yards.

Example: Considerations for the selection of land for MiC storage facilities[13]

With the development of MiC in Hong Kong, there is a need to set up local MiC storage facilities for the temporary storage of modules between module delivery to Hong Kong and

[13] HKU CICID (2019). MiC for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment: Supply Logistics Report. HKU CICID, CIC Research Fund.

module delivery to the construction site for installation. The suitability of possible areas as storage facilities should be carefully evaluated. In particular, three primary criteria, namely, location, land ownership and size, should be considered.

To illustrate how to apply the three criteria for area evaluation, an example is provided herein. This study refers to PlanD's "Report on 2014 Area Assessments of Industrial Land in the Territory" (2014 Area Assessments) to identify possible sites in the "I" zone in Hong Kong for developing temporary storage of modules. Through this evaluation one area out of the 26 alternatives (see PlanD's 2014 Area Assessments, and also Appendix I) was recommended for setting up a storage facility.

(1) Evaluation by location

The location of a temporary storage facility is very important as it acts to balance the demand and JIT supply of modules. There are a few necessary screening rules for identifying the appropriate location of the storage facility, including:

- The storage facilities should be conveniently accessible by the trailers from land crossing between Mainland and Hong Kong as part of the modules will be transported to Hong Kong by land.
- The storage facilities should also be convenient located for the modules that are transported to Hong Kong by sea, e.g. container terminals, medium-stream terminals and public cargo working areas.
- Trailers from the storage facilities should be able to reach the majority of the construction sites in Hong Kong quickly and cost-effectively.
- The storage facilities should be close to the major carriageways.

Following the above screening rules:

- Storage facilities on the Hong Kong Island (S1-S6, see Appendix I) are excluded because they are far from maritime terminals, and trailers to Kowloon and New Territories need to use the cross-harbour tunnel, which makes the transport more expensive.
- Storage facilities in Fo Tan (S14) are excluded because the Fo Tan area is connected to Kowloon via Lion Rock Tunnel, Eagle's Nest Tunnel, Sha Tin Heights Tunnel, Tai Wai Tunnel and Tate's Cairn Tunnel. The many tunnels would add another layer of risk of MiC transport because the rescue can be very difficult when module-detach happens in the tunnel.

Storage facilities in Fanling/Sheung Shui (S17-S19) and Kwai Tsing/Tsuen Wan areas (S9-S12) should be excluded because they are close to either the land crossings or container terminals, but are not convenient to both.

(2) Evaluation by land ownership

The land owned by the Government is prioritised because the development of MiC storage facilities should preferably be government-initiated. There could also be a delay when using

the private-owned land for the development due to the required time on re-zoning or other statutory procedures.

Following this rule, S7, S15 and S24 are excluded because they are private-owned.

(3) Evaluation by size of site

In the calculation of available storage areas that can be provided by the sites, vacant and temporary uses areas are considered in this study. The temporary uses areas include areas such as temporary car park and temporary storage. In addition, some sites are also partially owned by private owners, thus vacant and temporary areas that are private-owned are excluded. It is revealed that the site S23 could provide the largest area of about 36,000m^2 compared with other sites (Figure 4-3).

Through this evaluation one area out of the 26 alternatives (see PlanD's 2014 Area Assessments, and also Appendix I) was recommended for setting up a storage facility.

ID	S8	S13	S16	S20	S21	S22	S23	S25	S26
Vacant area (m^2)	N.A.	295	N.A.	0	0	0	0		3,098
Temporary area (m^2)	N.A.	0	N.A.	About 3,000	7,742	About 600	About 36,000		About 3,200
Total	N.A.	295	N.A.	About 3,000	7,742	About 600	About 36,000	About 4,000	About 6,300

Figure 4-3 Vacant/temporary uses areas in sites owned by the Government

(2) Enable mature regulations and efficient permit processes

a. Relevant regulatory departments should take the lead in the formulation of applicable regulations and the consultation and review of the regulations from experience built up from MiC pilot projects. A joint group of regulatory departments should be necessary to include all associated government departments (such as BD, FSD, WSD, EMSD, and TD).

b. Relevant regulatory departments to streamline the present permit and approval processes required for projects using MiC, and remove excessive red tape. This enables the promotion of MiC and other innovations in the construction industry to become more efficient.

c. Relevant regulatory departments to enhance inter-department collaboration to speed up the approval process.

d. To refine the In-Principle Acceptance system for ensuring the reliability and durability of MiC systems being adopted in local projects. For example, the Buildings Department may consider granting acceptance to not only the MiC system as a whole, but also to the types of modules.

Example: Building Innovation Panel (BIP) in Singapore[14]

The Building Innovation Panel (BIP) is an inter-agency platform set up by the Singaporean Government, in order to accelerate the development and implementation of feasible methods, processes, solutions, technologies or materials for innovative and productive construction.

The BIP consists of a number of regulatory and statutory bodies, which include the Building and Construction Authority, the Housing and Development Board, the Land Transport Authority, the Ministry of Manpower, the National Environment Agency, the Public Utilities Board, the National Water Agency and the Urban Redevelopment Authority.

(3) Review transport regulations in favour of MiC logistics

a. To benchmark the current regulatory requirements in Hong Kong with those in other jurisdictions such as Singapore. For example, the government may re-consider the current stringent regulations (e.g. the width limit of 2.5m) to support MiC adoption without harmful impacts imposed on road safety.

Example: revised the oversized vehicle movement regime in Singapore

Regulation makers should be aware of significant barriers to MiC adoption (e.g. height and width limits in transportation) and establish strategies to resolve them. The case of Singapore shows that flexibility in the regulatory framework could facilitate proactive actions to overcome some significant impediments related to the design and transportation of modules. According to the Land Transport Authority of Singapore:

The width requirement for permission has been revised from 'an overall width of more than 2.6 meters' to 'an overall width of more than 3.0 meters', except for the controlled roads (i.e. roads with narrow lanes).

The width requirement for auxiliary police escort was revised from 'an overall width of more than 3.0 meters' to 'an overall width of more than 3.4 meters'

In terms of supply chain development

(1) Extend the list of qualified suppliers

a. To attract more suppliers to enter into the Hong Kong MiC market.

b. To support the establishment of competitive MiC supply chains for Hong Kong.

(2) Set up local facilities for MiC production and logistics

a. To conduct a comprehensive feasibility assessment of developing local factories and storage yards, in terms of opportunities, risks and mitigation strategies. Foci of such feasibility assessment should at least cover the following issues:

- Location, e.g. where to locate the factory/storage yard.

[14] https://www.bca.gov.sg/cpc/building-innovation-panel-bip.html

- Product and service, e.g. the factory to fabricate entire modules from raw materials, or to only do fit-out works upon semi-finished modules procured from elsewhere.
- Stakeholders, e.g. stakeholders to invest, build, operate and regulate these facilities.
- Commercial viability.
- Technical issues, e.g. production lines design, automation deployment, staffing.

(3) Adopt effective procurement methods favouring MiC adoption
   a. The industry forms joint force to explore innovative business models and contractual framework suitable for MiC procurement.
   b. To promote knowledge sharing about innovative procurement and business models.

(4) Promote cross-industry collaboration along the value chain
   a. To enable MiC pilot project demonstration to the public for cross-industry learning.
   b. To enhance communication and engagement of relevant industries, e.g. high-tech, logistics, port/shipment industries, for developing smart MiC project delivery solutions.

Example: Supply chain of the 40-storey Clement Canopy project in Singapore[15]

In the Clement Canopy project, concrete modules were prefabricated and semi-finished in a Malaysian factory, transported by road to the fit-out yard in Western Singapore where they were fully finished and temporarily stored.

According to interviews, conducting internal finishing work in a local fit-out yard is essential to quality assurance. One significant reason was that overseas factories were not sufficiently capable of fulfilling clients' quality requirements.

4.3.3. Long-term recommendations

In terms of policy and regulations

(1) Develop MiC supply chains in the Greater Bay Area (GBA)
   a. Thanks to the close connection to the other cities in the GBA, Hong Kong faces enormous opportunities for the development of the MiC industry. The Government's leadership plays a significant role in helping the MiC industry grasp the opportunities and establishing MiC supply chain network with other cities in the GBA. For this, the Government may need to formulate policy Roadmap and action plans.

(2) Harmonise building codes and standards

[15] HKU CICID (2019). Modular Integrated Construction for High-rise Buildings in Hong Kong: Supply Chain Identification, Analyses and Establishment: Case Study Report, HKU CICID, CIC Research Fund.

a. To reinforce MiC related codes and standards and to support MiC implementation in Hong Kong and in the GBA at the cross-boundary level.
b. Building codes and standards need to be adaptable and up-to-date to appropriately reflect the growing market demand, environmental concerns and the emergence of construction innovations.

Example: Building codes and standards for precast concrete construction

In the 1990s, Hong Kong Housing Authority started to employ precast concrete construction in building structures and commenced the large-scale use of precast concrete in Hong Kong. However, the *Code of Practice for Precast Concrete Construction* and *Precast Concrete Construction Handbook* were not published until 2003 and 2015, respectively. The whole process took more than 10 years. Referring to the adoption of precast concrete construction, there are concerns about the formulation and implementation of codes and standards for MiC.

In terms of supply chain development

(1) Establish GBA-based MiC supply chain network
a. The industry as a whole should have a comprehensive understanding of MiC supply chains in the context of the GBA, e.g. in terms of regulations, suppliers, market, and business environments.

(2) Establish industry-level standards for MiC
a. Harmonising technical specifications of MiC products and services can effectuate MiC adoption. Moreover, industry-level standards are likely to shape the regulatory frameworks, directly or indirectly. Professional institutions, academia, companies and regulatory departments should work together to establish industry-level standards.
b. The industry as a whole should define key areas of standardisation to work on. Recommended areas for standardisation are as follows:
- Standardised interfaces between prefabricated modules and site-built components, for greater system compatibility, economies of scale, productivity, and industrialisation;
- Standardised lifecycle cost codes for greater comparability and compatibility among projects;
- Standards in information exchange protocols and interfaces among software systems, to facilitate the digitalisation of the industry; and
- Standards in machine code for robots and automated construction equipment.

(3) Encourage continuous collaboration, benchmarking and best practices sharing
a. It will be helpful for the industry to set up a platform to encourage extensive collaboration, benchmarking across MiC projects and regular sharing of best practices across the GBA and beyond.

In terms of project delivery and performance

(1) Strive for best/leading-edge practices worldwide

a. With the ten-year timeframe, it is expected that a few MiC projects in Hong Kong could represent best or leading-edge practices of high-rise modular buildings worldwide in terms of building height, innovation and performance, etc.

A summary of the recommended action plans in relation to the action parties is provided in Table 4-2. The actions recommended above provide a progressive Roadmap for the industry stakeholders and practitioners to effectively and efficiently adopt MiC in terms of policy and regulations, supply chain development, and project delivery and performance.

Table 4-2 Strategic themes of action plans for MiC implementation in Hong Kong

Themes	Sub-themes	Recommended Activities	Suggested action parties
Short-term development: *exploring*			
Policy and regulations	(1) Generate sufficient lead demand from the public sector	a. Prioritise MiC in government-led projects b. Examine the practicability of mandating the use of MiC in public housing projects c. Encourage MiC adoption in transitional social housing	Government departments and agencies
	(2) Stimulate MiC adoption in the private sector	a. Provide incentives and/or subsidies to encourage clients and developers to adopt MiC b. Consider MiC adoption as one land sales requirement for the private sectors c. Establish incentives to encourage designers and suppliers that adopt MiC d. Show the feasibility of using medical modules to Hospital Authority	Government departments and agencies
	(3) Increase R&D on MiC	a. Identify R&D subjects by consulting industry partners and collaborating with regulatory bodies b. Provide policy and financial support for establishing facilities for MiC related R&D c. Conduct regular evaluation of MiC related R&D projects and demonstrate the outstanding ones for knowledge sharing d. Encourage professionals and MiC suppliers to enter the Hong Kong market via providing CITF incentives	Government departments and agencies, universities and professional organisations
	(4) Provide practical guideline and design handbook on MiC practices	e. Provide MiC technical guidelines and design handbooks for MiC practitioners in Hong Kong	Government departments and agencies
	(5) Improve QA/QC system for MiC	a. Provide comprehensive MiC QA/QC standards and guidance b. Establish new or extend current construction material list for MiC c. Regulatory bodies work jointly with the industry to validate and refine MiC QA/QC systems	Government departments and agencies, universities and professional organisations

Themes	Sub-themes	Recommended Activities	Suggested action parties
		d. Encourage the utilisation of digital works supervision system and tools to facilitate QA/QC.	
Supply chain development	Establish a demand/supply database	a. Promulgate the latest market demand volume on MiC from both private and public projects b. Create a live database of MiC suppliers/products which are approachable to the Hong Kong market	Universities and professional organisations
	Enhance training and skill development	a. Integrate MiC related trades into the current construction worker training systems b. Set up professional training courses for different disciplines. c. Emphasise MiC and digitalisation tools in undergraduate / graduate compulsory training programme d. To beef up of trucking, cranage, and related skilful personnel for transportation, logistics and lifting	Universities and professional organisations
	Reinforce contractor-supplier partnering	a. Encourage contractor-supplier partnering from the tendering stage	Universities and professional organisations
	Increase knowledge sharing and exchange	a. Encourage international conferences, forums, overseas visits, training. b. Conduct in-depth case studies with MiC pilot projects, and to demonstrate the benefits achieved, and challenges encountered for industry learning and sharing. c. Integrate MiC related curriculum into higher education	Universities and professional organisations
	Gain public acceptance for MiC	a. Enhance the public awareness and understanding of MiC and its associated benefitss.. b. Encourage the general public to buy flat built by MiC with appropriate incentives. c. Attract the younger generation on advanced technologies and create a better working environment in the construction industry d. To publish articles in professional journals to promote MiC	Universities and professional organisations

Themes	Sub-themes	Recommended Activities	Suggested action parties
Project delivery and performance	Examine advanced structural systems and innovative materials used in high-rise modular buildings	a. Set aside sufficient time in the design stage for developing robust structural solutions b. Companies could collaborate with universities and research institutions to investigate structural solutions, connection details and new materials for high-rise modular buildings. c. All-concrete module should closely resemble the common Hong Kong premises d. To design with reasonable flexibility for future addition and alteration	Clients and developers, contractors, suppliers, consultants
	Integrate smart technologies into project delivery	a. Smart project delivery solutions (by utilising construction technologies and digitalisation) for MiC should be progressively developed b. Encourage client's leadership to adopting smart technologies	Clients and developers, contractors, suppliers, consultants
	Explore suitable procurement methods	a. Stakeholders should assess projects and schemes' suitability for adopting integrated project delivery methods	Clients and developers, contractors, suppliers, consultants
	Transfer MiC merits into tangible advantages	a. All-concrete module should closely resemble the common Hong Kong premises. b. To design the layouts similar to conventional floor plans for for-sale products. c. To design with reasonable flexibility for future addition and alteration d. To liaise with Transportation Authorities to streamline the transportation of oversized modules. e. Develop systematic MiC performance measurement methodologies and KPI systems	Contractors, consultants, universities and professional organisations
Medium-term development: *Evolving*			
Policy and regulations	Formulate policy initiatives on developing local MiC supply chain	a. Identify and mandate the demands to utilise the local MiC supply chain b. Allocate land for setting up local MiC factories c. Allocate land for setting up local MiC storage yards d. Provide financial support to the set-up and operation of local MiC factories and holding yards	Government departments and agencies

Themes	Sub-themes	Recommended Activities	Suggested action parties
	Enable mature regulations and efficient permit processes	a. Formulate applicable regulations, and review the regulations from experience built up from the pilot MiC projects b. Streamline the present permit and approval processes required for projects using MiC, and remove excessive red tape. c. Enhance inter-department collaboration to speed up the approval process. d. Refine the in-principle acceptance system	Government departments and agencies
	Review transport regulations in favour of MiC logistics	a. Benchmark the current regulatory requirements in Hong Kong with those in other jurisdictions	Government departments and agencies
Supply chain development	Extend the list of qualified suppliers	a. Attract more suppliers to enter into the Hong Kong MiC market. b. Support the establishment of competitive MiC supply chains for Hong Kong.	Universities and professional organisations
	Set up local facilities for MiC production and logistics	c. Conduct a comprehensive feasibility assessment of developing local factories and storage yards	Universities and professional organisations
	Adopt effective procurement methods favouring MiC adoption	a. Joint force to explore innovative business models and contractual framework suitable for MiC procurement. b. Promote knowledge sharing about innovative procurement and business models.	Universities and professional organisations, clients and developers, contractors, suppliers, consultants
	Promote cross-industry collaboration along the value chain	a. MiC pilot project demonstration to the public for cross-industry learning. b. Enhance communication and engagement of relevant industries for developing smart MiC project delivery solutions.	Universities and professional organisations, pilot project stakeholders
Project delivery and performance	Same as in the short-term development stage		

Themes	Sub-themes	Recommended Activities	Suggested action parties
Long-term development: Maturing			
Policy and regulations	Develop MiC supply chains in GBA	a. Formulate policy Roadmap and action plans for developing GBA-based MiC supply chain	Government departments and agencies
	Harmonise building codes and standards	a. Reinforce MiC related codes and standards and to support MiC implementation in Hong Kong and in the GBA at the cross-boundary level b. Adapt and update building codes and standards to appropriately reflect the growing market demand, environmental concerns and the emergence of construction innovations.	Government departments and agencies
Supply chain development	Establish GBA-based MiC supply chain network	c. The industry as a whole should have a comprehensive understanding of MiC supply chains in the context of the GBA, e.g. in terms of regulations, suppliers, market, and business environments	The construction industry and community
	Establish industry-level standards for MiC	a. Harmonising technical specifications of MiC products and services b. Define key areas of standardisation to work on	The construction industry and community
	Encourage continuous collaboration, benchmarking and best practices sharing	a. Set up a platform to encourage extensive collaboration, benchmarking across MiC projects and regular sharing of best practices across the GBA and beyond	Universities and professional organisations
Project delivery and performance	Strive for best/leading-edge practices worldwide	a. With the ten-year timeframe, it is expected that a few MiC projects in Hong Kong could represent best or leading-edge practices of high-rise modular buildings worldwide	The construction industry and community

* The short-, medium- or long-term timeframes denote 0-3 years, 4-5 years, and 6-10 years, subject to policy drivers from the government and market drivers from various building sectors.

5. Conclusions and way forward

MiC as a game-changing disruptively-innovative approach offers opportunities to enhance construction productivity, quality, safety and sustainability. This Roadmap Report has recommended a set of actions to support MiC implementation in Hong Kong in the short, medium and long terms. This Report should serve as a high-level plan for capturing the major milestones for achieving the successful implementation of MiC in Hong Kong.

The short-, medium- and long-term strategic objectives (align with "exploring", "evolving", and "maturing") and their relevant actions are summarised below:

- The short-term strategic objective is to continuously **explore** and develop a comprehensive knowledge base of MiC methods in Hong Kong. To achieve this objective, policy and regulations related actions should emphasise on the promotion of research and development and the publication of guidance and handbooks; supply chain development related actions should emphasise on the industry-wide information and knowledge sharing and professional training; project delivery and performance related actions should emphasise on the exploration and development of technical solutions for MiC implementation.

- The medium-term strategic objective is to **evolve** MiC adoption and implementation towards being more efficient, smart, and value-adding. To achieve this objective, policy and regulations related actions should outline clear policy initiatives and proposal of regulations for MiC; supply chain development related actions should target the establishment of an efficient supply chain for MiC; project delivery and performance related actions should further leverage smart technologies and innovation to achieve optimised performance in MiC project delivery.

- The long-term strategic objective is to step up a **mature** Hong Kong MiC industry. To achieve this objective, policy and regulations related actions should issue well-developed building codes and standards to support MiC implementation; supply chain development related actions should support the establishment of a mature MiC supply chain network and enhanced partnership and collaboration; project delivery and performance related actions should set out best practices of MiC for high-rise modular building for international recognition and learning.

This Report offers several practical implications which are summarised below:

- The actions on MiC implementation should be progressive and forward-thinking to enable learning from the short-term development to benefit medium- and long-term development.

- Given the infancy nature of MiC in Hong Kong, there is room for improvement in the

three strategic themes, namely, policy and regulations, supply chain development, and project delivery and performance. It is imperative to integrate these strategic themes in a systematic manner to enable successful and sustainable adoption of MiC in Hong Kong.

- Executing the recommended Roadmap requires a joint effort of stakeholders and practitioners in the MiC industry, including the statutory and regulatory bodies, clients and developers, contractors, suppliers, consultants and designers, professional institutions and academia of relevant disciplines.

This Report has laid a foundation for achieving the successful implementation of MiC in Hong Kong in the 0-3, 4-5, and 6-10 year timeframes. The timeframes are referred to the market demand estimation presented in the *MiC Market Analysis Report*. Future efforts are suggested to further discuss the strategic themes and actions in order to yield more specific suggestions and guidance. It is also suggested to evaluate the progress of achieving the strategic objectives. For these considerations, this Roadmap should be periodically reviewed and updated along with the rapidly-evolving process of MiC adoption in Hong Kong.

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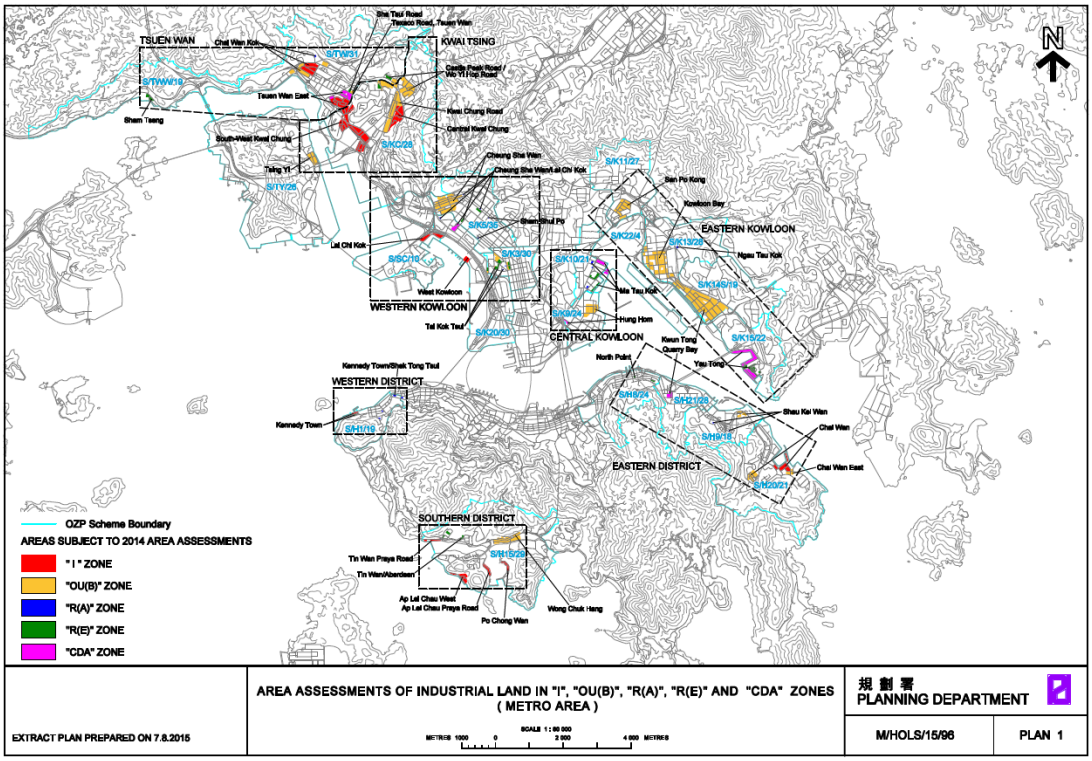
Appendix

Potential sites in the "I" zone for temporary storage facilities for MiC[16]

Region	Area
Hong Kong Island	Site S1 - Kennedy Town
	Site A2 - Chai Wan
	Site S3 - Po Chong Wan
	Site S4 - Tin Wan Praya Road
	Site S5 - Ap Lei Chau West
	Site S6 - Ap Lei Chau Praya Road
Kowloon	Site S7 - West Kowloon
	Site S8 - Lai Chi Kok
Kwai Tsing / Tsuen Wan	Site S9 - Southwest Kwai Chung
	Site S10 - Central Kwai Chung
	Site S11 - Tsuen Wan East
	Site S12 - Chai Wan Kok
Northeast New Territories	Site S13 - Tai Wai
	Site S14 - Fo Tan
	Site S15 - Siu Lek Yuen
	Site S16 - Sha Tin Area 65
	Site S17 - On Lok Tsuen
	Site S18 - Fanling Area 48
	Site S19 - Sheung Shui
Northwest New Territories	Site S20 - Tuen Mun Areas 9 and 12
	Site S21 - Tuen Mun Area 16
	Site S22 - Wu Shan Road, Tuen Mun
	Site S23 - Tuen Mun Area 40
	Site S24 - Tuen Mun Area 17
	Site S25 - San Hei Tsuen / Tong Yan San Tsuen
	Site S26 - Ping Shan

[16] Data and pictures adopted from Data and picture adopted from PlanD's 2014 Area Assessment



AREA ASSESSMENTS OF INDUSTRIAL LAND IN "I", "OU(B)", "R(A)", "R(E)" AND "CDA" ZONES
(METRO AREA)

EXTRACT PLAN PREPARED ON 7.8.2015

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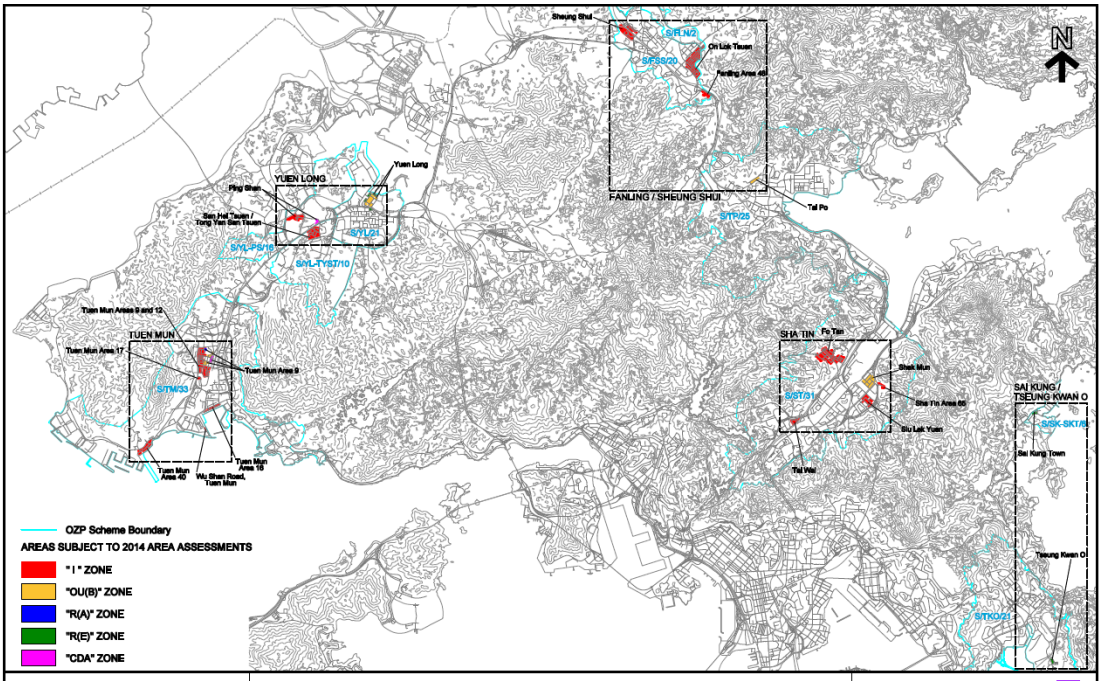

AREA ASSESSMENTS OF INDUSTRIAL LAND IN "I", "OU(B)", "R(A)", "R(E)" AND "CDA" ZONES
(NON-METRO AREA)

EXTRACT PLAN PREPARED ON 7.8.2015

規劃署
PLANNING DEPARTMENT

M/HOLS/15/96 | PLAN 2