

PREFABRICATED PREFINISHED VOLUMETRIC CONSTRUCTION (PPVC) IN SINGAPORE

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INTRODUCTION

With the aim of transforming Singapore's built environment to be more advanced and integrated through adoption of new game-changing technologies, the Singapore Government launched the Construction Industry Transformation Map (ITM) in October 2017. The Construction ITM is one of the 23 ITMs identified under a \$4.5 billion Industry Transformation Programme proposed by the Government's Future Economy Council (FEC). One of the 3 key approaches of the Construction ITM is Design for Manufacturing and Assembly (DfMA).

The concept of DfMA has been introduced since 2015 through the launching of the 2nd Construction Productivity Roadmap which set aside a funding of S\$450 million aimed to improve Singapore's construction productivity. It is a design approach that focuses on ease of manufacturing and efficient assembly, in the minimum time and lower cost. Some of the examples of DfMA concepts are Prefabricated Bathroom Units (PBUs), Mass Engineered Timber (MET) and Prefabricated Mechanical Electrical and Plumbing (MEP) System. In Singapore, Prefabricated Prefinished Volumetric Construction (PPVC) is one of the key products of DfMA due to the strong and continued Government's initiatives in generating the project demands.

WHAT IS PPVC AND WHY PPVC?

PPVC is a modular construction that adopts the concept of "factory assembly followed by on-site installation". It comprises integrated free-standing volumetric modules complete with internal finishes, fixtures and fittings that are manufactured in the factory, and then to be delivered to site for installation in a 'lego-like' manner. There are 3 types of PPVC systems available in the market, namely concrete, steel and hybrid of concrete and steel in which concrete PPVC modules are more commonly used in Singapore due to the climate and better maintenance.

With majority of the on-site construction works shifted to off-site controlled factory environment, adoption of the PPVC is envisaged with the following benefits:

- Improve productivity by up to 40% in terms of manpower and time savings, depending on the complexity of the projects;
- Better construction environment due to lesser construction works and manpower on-site, such as reduction of dust and noise pollution, lesser construction waste and better site safety; and
- Improve quality control as off-site fabrication can generate higher quality end products.

PPVC IN SINGAPORE

Government Regulation for PPVC

Besides monetary support, new mandatory conditions and requirements were also enacted as part of the Government's strong efforts in promoting the adoption of PPVC in the construction projects. For the private sector, stipulated as the mandated land sales conditions for new development sold under Government Land Sales (GLS) Programme from 1 November 2014, the Developer is required to adopt the PPVC for selected non-landed residential and hotel land parcels. An example of the imposition of the PPVC requirement in the GLS programme is enclosed herewith as [Appendix A](#).

Singapore's Building Construction Authority (BCA) stipulates the minimum requirements for PPVC which both the Developer and the Main Contractor shall comply with. Extracted from the *Code of Practice on Buildability 2017 (COP 2017)*, the minimum level of use of PPVC shall be 65% of the total super-structural floor area of the building or the component of the building that is to be used for residential or private dwelling purposes. The COP 2017 also clearly indicates the minimum level of finishing and fittings to be completed off-site for the volumetric modules (*see Table 1*). Should there be any deviation from these minimum levels is necessary, prior approval must be sought from BCA.

Table 1 Minimum level of finishing and fittings to be completed off-site
Source: BCA, 2017

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

A comprehensive acceptance framework was also being established in ensuring that all PPVC systems designed by different Consultants and Contractors are reliable, robust and meet minimum standards. The acceptance framework consists of two parts – acceptance by the Building Innovation Panel (BIP), followed by accreditation under and the PPVC Manufacturer Accreditation Scheme (PPVC MAS).

The Government also encourages the adoption of PPVC through formulating a master plan of the development of Integrated Construction and Prefabrication Hubs (ICPH) with a 30-year lease term. ICPH is a multi-storey automated and high degree mechanized manufacturing facilities which produce prefabricated components including PPVC modules.

Current Outlook of PPVC in Singapore

With the strong push by the Singapore's Government for the DfMA and PPVC, the DfMA adoption rate (in term of Gross Floor Area (GFA)) has increased from 19.2% in 2017, the year of the launch of Construction ITM, to 44% in 2021. It has surpassed the ITM target of achieving 40% in 2020 and Mr Desmond Lee, Minister of Ministry of National Development (2022) affirmed that the built environment sector is on track to meet its next target of 70% of GFA by 2025.

As of December 2019, BCA has also created 36 PPVC projects (34 residential sites and 2 hotels) through the GLS programme and envisioned 39 more in the following 2 years. If to include the PPVC projects in the public sector, which is 35% of the new public housing projects according to the Housing and Development Board (HDB), it is believed that more than 40 PPVC projects or close to 50 PPVC projects have been successfully generated as of end 2019.

To date, 34 nos of Concrete PPVC Systems and 17 nos of Steel PPVC Systems have been accepted by the BIP and 5 nos of ICPHs are constructed and in full operation. The full list of the approved PPVC systems and the operators of ICPH is enclosed herewith as Appendix B.

As most of the Government's released statistics on DfMA and PPVC are only available up to end 2019, an informal interview and a factory visit were conducted with two ICPH operators, namely CKR Contract Services Pte Ltd (CKR) and Soil-Build (Pte) Ltd (SoilBuild), to understand further on how COVID-19 pandemic has affected the progress and development of PPVC in Singapore in 2020 and 2021. The impact of COVID-19 shall be discussed in length at the latter part of this paper.

Design and Construction Constraints

PPVC requires huge land space for the production and storage of the volumetric modules. In the land-scarce Singapore, this has become a luxurious request and hence resulted in a unique arrangement of the modular construction process. Typically, the volumetric module will be fully fabricated within the same manufacturing factory for its structural, architectural and MEP components. For Singapore's PPVC, the fabrication process is split into two parts: structural carcass factory in neighboring country (i.e. Johor, Malaysia) and architectural and MEP fit-out factory in Singapore. Even with the successful implementation of the 5 ICPHs up to date, according to CKR and SoilBuild, they are only able to produce 20% of the total precast components required for the construction works and the industry is still highly reliant on Malaysia's factories for the remaining 80%.

Figure 2 Illustration of off-site factories in Johor, Malaysia and Singapore and the construction site



The other two deciding factors on the module design are transportation and hoisting limits. Logistics for module transportation from factory to site determines the maximum size and volume of each module design. In compliance to Land Transport Authority (LTA)'s traffic regulatory requirements, the ideal dimension of a single PPVC module shall be as follow:

- Height: < 4.5 metres (inclusive of truck height)
- Width: \leq 3.4 metres
- Laden Weight: < 80 tons

If exceeds the above controlling parameters, LTA permit and Auxiliary Police Escort are required for the module transportation from point to point.

The current available types of hoisting cranes (i.e. tower crane, mobile crane and crawler crane) have a similar lifting capacity of 25 tons to 40 tons, which dictates the maximum weight of a single PPVC module to be. As such, while making the layout plan design fully complies with regulatory requirements, the Designer and Contractor shall also ensure the PPVC module size allows transportation from factory to site and within the hoisting limits.

Figure 3 Type of Hoisting Cranes
Source: BCA, 2020



Characteristic of Crane	Tower crane	Mobile crane	Crawler crane
Crane Capacity	50 tons	700 tons	500 tons
Lifting Capacity	25 tons – 40 tons	25 tons – 40 tons	25 tons – 40 tons
Height of Equipment	120m	40m	80m
Radius of work	40m	40m	40m

Cost Implications

Being Singapore's first private PPVC building that was completed in 2016, the cost premium of adopting PPVC in Crown Plaza Changi Airport Hotel Extension was estimated to be 10 to 15% more as compared to conventional reinforced concrete construction (Today, 2016). With the launch of Construction ITM in 2017 and more PPVC players have come into the market, the estimated cost premium has been further reduced to 8% as of February 2020 (BCA, 2020). The estimated cost premium of PPVC is mainly driven by the following cost factors:

- **Precast Mould**

The PPVC module requires custom made mould which are unlikely to be recycled and reused for other projects. The higher number of the different modules in one PPVC project, the more precast moulds are required and hence, more cost to be added to the overall contract sum.

- ***Transportation***

Compared to the one time transportation of the conventional precast concrete component, the PPVC module requires two times transportation before reaching the construction site, i.e. from carcass factory to the fit-out factory and from fit-out factory to the construction site. Also, in the event that LTA permit and Auxiliary Police Escort is required as highlighted in the previous section, the application cost for the permit and escort shall constitute an additional cost to the overall contract sum.

- ***Hoisting Crane***

The PPVC module generally requires heavy-duty hoisting cranes for on-site installation. The initial cost and rental of such cranes is considerably higher than typical capacity cranes.

- ***Off-Site Yard***

PPVC requires two off-site fabrication yards: carcass factory and fit-out factory. Additional costs are incurred for setting up, operating and maintaining PPVC manufacturing factories in Malaysia and Singapore. Additional cost in sending off-site and overseas supervisors is also required in ensuring the product quality and full compliance to the COP 2017.

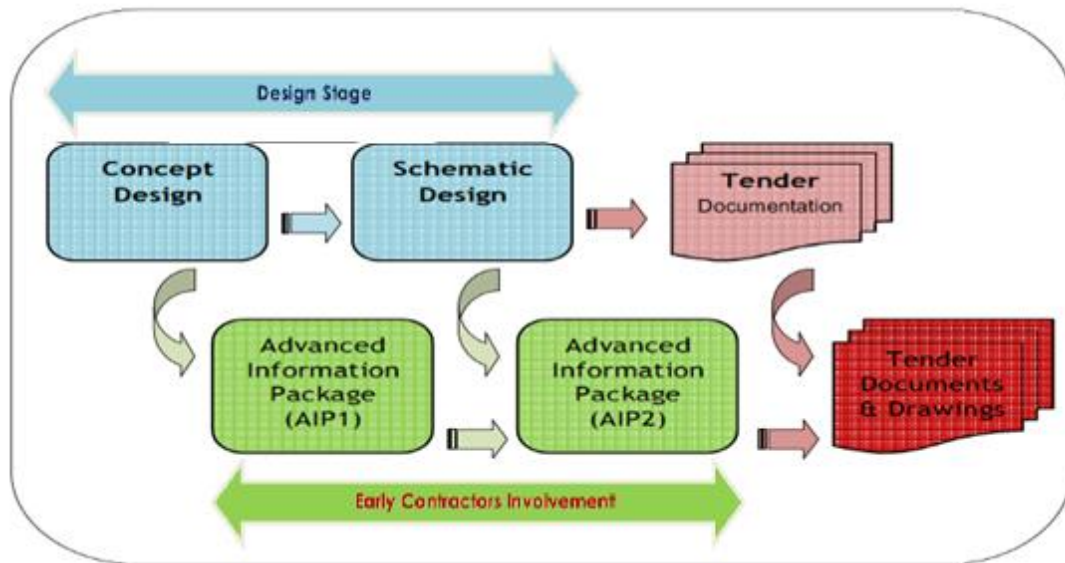
Contractual Framework

Early Contractor Involvement (ECI)

One of the key benefits of adopting PPVC is the significant construction time savings. For example, in The Clement Canopy, a 40-storeys high condominium took 7 days to construct a floor, compared to 14 to 21 days using conventional construction method. One of the learning points from this project was the early confirmation of designs and materials which led to a smooth production cycle that constituted time savings.

Particularly due to the complexity of the PPVC module and its own proprietary system, Developers are highly encouraged to engage the PPVC Manufacturers and Contractors early through the ECI approach. ECI is an approach where Contractors are engaged early during the design stage to facilitate integration of design and construction process, through early collaboration between the Developer, Consultants and Contractors. The PPVC manufacturers and Contractors can be engaged during the Concept Design stage and/or Schematic Design stage to provide their technical input in developing a more comprehensive design of structural, architectural and MEP. This helps in providing better and more effective technical solutions to the PPVC modules before the actual tender launch. In terms of procurement approach, Design & Build or Design Development & Build are also more preferred than the traditional Design Bid Build for construction projects involving PPVC.

Figure 4 An Overview of ECI in Design Stage
Source: Khoo, 2015



Progress Payment and Advance Payment Guarantee

Payment for material off-site is not a contractual provision in most standard forms of contract in Singapore. Hence, the immediate concern of most PPVC contractors is whether employers are willing to make payment for PPVC works that are mostly carried out at the off-site yards. To address the contractor's major concern on the construction cashflow, conditional payment schemes for off-site PPVC works have been developed.

Under the Public Sector Standard Conditions of Contract (PSSCOC), an Option Module of "Lump Sum Advance Payment for PPVC" has been introduced. An Advance Payment Guarantee is required to be submitted by the Contractor to the Employer (Developer) as a condition precedent to any Advance Payment to be made by the Employer. Within 28 days from the date of the receipt of the Advance Payment Guarantee and security deposit (performance bond) by the Employer, the Employer shall pay to the Contractor an advance payment of 20% of the PPVC costs, capped at 10% of the total construction sum unless otherwise stated in the Appendix of the PSSCOC. The Employer is entitled to recover the Advanced Payment by equal installments at the agreed intervals from the agreed recovery start date as specified in the Appendix, from the Contractor's submitted payment claimed amount.

Unlike the PSSCOC, the standard forms of contract used in the private sector, i.e. Singapore Institute of Architects Articles and Conditions of Building Contract and the REDAS Design and Build Conditions of Contract do not contain similar payment provisions as of today. Whilst a similar advance payment scheme has been adopted to some of the private PPVC projects, a milestone payment framework based on the agreed % has also been negotiated to facilitate the PPVC payment. The most common schedule for milestone payment is shown as follow:

- Upon completion of the PPVC carcass: 30%
- Upon completion of the off-site fit-out: 30%
- Final installation on site: 40%

Similarly, an Advance Payment Guarantee from the Contractor remains as a condition precedent prior to any milestone payment to be made by the Employer.

Insurances

Due to some off-site PPVC works to be carried out in overseas factories, the existing off-site storage and inland transit endorsement that have territorial limits in Contractor's All Risks Policy (CAR) are no longer sufficient. Additional Property All Risk Policy is required to cover off-site fabrication in another country. A proper Marine Cargo Insurance is also required to cover shipments or transit of the PPVC modules from another country to Singapore. Both insurance policies are to be issued in the joint names of both the Contractor and Employer so long the PPVC modules are stored overseas. As such, it is preferable for the Contractor to directly procure the insurance from the Employer's insurance broker in ensuring the Employer's full overseas insurance coverage is being well taken care of.

Nominated Sub-Contracts (NSCs)

With the adoption of the PPVC, some of the NSCs' products such as sanitary wares, wardrobes and switches shall be delivered to off-site fit-out yards instead of the construction site. Back-to-back provisions relating to payment, advance payment guarantee and insurances shall be provided and stipulated clearly in the NSCs' contract to ensure the water-tightnesses of the overall contract provision between the Main Contract and NSCs.

IMPACT OF COVID-19 ON PPVC DEVELOPMENT

The unexpected COVID-19 pandemic has affected economies and businesses around the world including the growing progress of the DfMA and PPVC development in Singapore. One example is the master plan of the development of ICPH. The Construction ITM has targeted to construct up to 10 ICPHs by 2020 but as of February 2022, only 5 ICPHs are completed and in full operation.

To further understand the impact of COVID-19 on PPVC development, an informal interview with the executive director of CKR Contract Services Pte Ltd (CKR) was conducted on 26 January 2022 and a factory visit to the ICPH owned and operated by Soil-Build (Pte) Ltd (SoilBuild) was scheduled on 19 February 2022. A list of questionnaires ([see Appendix C](#)) was sent to SoilBuild prior to the visit and a fruitful discussion and factory tour that lasted for about 2 hours was conducted.

Government Reliefs under the COVID-19 (Temporary Measures) Act (COTMA)

According to CKR, the border closure between Malaysia and Singapore resulting from the execution of Malaysia's Movement Control Order (MCO) and Singapore's Circuit Breaker (CB) has minimal impact on PPVC. Although the PPVC module transportation was put to halt at the beginning, such precast construction works had soon to be classified as critical and essential services and the delivery between both countries had resumed shortly after. What impacts the PPVC development the most is the shortage of construction workers, which is not unique to construction projects involving PPVC but the entire Singapore's built environment sector.

Against this backdrop, COTMA was enacted on 7 April 2020 aims to provide temporary reliefs to specific contracts that fall within the eligible period. These reliefs include universal Extension of Time (EOT) for construction contracts (Part 8A), co-share of certain costs between contracting parties (Part 8B) and reliefs for parties affected by the increase in foreign manpower costs (Part 10).

Government Support Measure for PPVC

Besides the reliefs provided under COTMA, upon the Contractors' submission and on a case-by-case basis, BCA has granted waivers to relax the minimum required level stipulated in the COP 2017 on the finishing and fittings to be completed off-site for the PPVC modules. One example is allowing full cabinetry works to be done on site instead of only restricted to door installation.

The Government has also further supported SoilBuild in providing a Temporary Occupational Land (TOL) at Punggol Pulau Timor as a temporary manufacturing and storage space for their precast components including PPVC modules. The bulky and heavy PPVC modules are unable to be stored on site and hence, Just in Time (JIT) delivery and installation are crucial for the smooth construction site progress. COVID-19 badly hit the site operation and many construction programme plannings were beyond the industry players' control. Therefore, the TOL space at Punggol Pulau Timor serves as an in-time aid to SoilBuild in resolving the PPVC modules' storage issue.

Innovation To Improve PPVC Design

SoilBuild highlighted that the cost premium of adopting PPVC has reverted back to the initial level of 15% during the pandemic period. A surge in the cost of material, shipping/ transportation, labour, etc. due to various COVID restrictions and shortage of resources are the contributing factors. The pandemic situation has further triggered the PPVC manufacturers to be innovative on how to improve PPVC design and production to achieve more time and cost savings. A research and development department was then set up in SoilBuild's ICPH. It is an incubation centre of engineering design through harnessing digital technology and introducing automation and robotics in DfMA.

According to their research, one potential improvement is the configuration of PPVC modules. Currently, the modules are configured by the Consultants according to the Architect's design layout. The number of the module size is highly dependent on the layout configuration which determines the required number of precast mould for one project. SoilBuild's proposed suggestion is through the ECI in the design stage, the PPVC manufacturers can provide a list of market available PPVC mould designs for the Consultants' consideration in configuring the unit layout plan. The project team can mix and match or adopt the similarity from the available PPVC systems in customizing their PPVC modules. This will increase the recycling and reusing rate of the precast mould which will help in reducing the cost premium.

CONCLUSION

With the strong support in terms of monetary fundings, regulations and even reliefs during the COVID-19 pandemic rendered from the Government to the adoption of DfMA and PPVC, the message is clear that Singapore's construction industry is determined to transform to be an advanced and integrated sector. Significant demands for DfMA projects have been generated since the launch of the Construction ITM in 2017. More PPVC players have entered the market since then which has brought down the estimated cost premiums of adopting PPVC from the initial 15% to less than 8% before the pandemic. The key cost drivers have been identified and discussed in length in this paper. Comprehensive contractual frameworks for PPVC projects such as Early Contractor Involvement during the design stage and milestone payment scheme for off-site PPVC works have also been developed over the years to address the design and construction constraints highlighted in this paper.

Whilst COVID-19 inevitably slows down the progress of PPVC development and increases the cost premiums, and the adoption of PPVC is still imposing design and construction challenges to the project team, the industry players see the opportunity in harnessing the digital technology and robotics in PPVC to further reduce the construction time and increase cost savings. It is also believed that by adopting more innovation and game-changing technologies in the built environment sector, it will attract and retain more local young talents in the industry. With the experiences gained and the lessons learnt from all the completed and on-going projects, it will certainly help to smoothen the implementation process for the built environment sector to reap the full benefits of DfMA and PPVC in the near future.

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APPENDIX A – EXAMPLE OF THE PPVC REQUIREMENT IN THE SELECTED GLS PROGRAMME (RESIDENTIAL DEVELOPMENT LAND PARCEL AT DAIRY FARM WALK)

Dated 21 October 2021

**SALE OF SITE
FOR RESIDENTIAL DEVELOPMENT
LAND PARCEL
AT DAIRY FARM WALK

TECHNICAL CONDITIONS OF TENDER**

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5.3	Prefabricated Prefinished Volumetric Construction (PPVC)	
5.3.1	For the purpose of adopting the PPVC method of construction, the successful tenderer is required to set aside some space within the Land Parcel for storage and/ or holding area for PPVC modules. No additional space outside the Land Parcel will be granted on TOL basis for this purpose.	
5.4	CONQUAS Assessment of Construction Quality	
5.4.1	The successful tenderer shall be required to refer and submit the proposed development to the Building and Construction Authority (BCA) to be assessed for the construction quality of the building works under the Construction Quality Assessment System (CONQUAS).	
5.4.2	The successful tenderer shall for the purpose of this Condition comply with all requirements, procedures, directions and request of BCA and shall pay all fees, charges and other amounts payable to BCA for and in relation to the assessment of the construction quality of the proposed development under CONQUAS. The successful tenderer shall also render his full co-operation to BCA, its officers, employees and agents in relation to such assessment under CONQUAS.	

APPENDIX B1 – LIST OF PPVC SUPPLIERS / MANUFACTURERS WITH THE APPROVED PPVC SYSTEM

Concrete PPVC System

S/N	Supplier / Manufacturer
1	Excel Precast Pte Ltd
2	SPP System Pte Ltd
3	Integrated Precast Solutions Pte Ltd
4	Vico Construction Pte Ltd
5	Dragages Singapore Pte Ltd
6	Prefab Technology Private Limited
7	CS Corp Pte Ltd and ICPH International Pte Ltd
8	Mod Prefab Private Limited
9	Qingjian International (South Pacific) Group Development Co Pte Ltd
10	Sembcorp EOSM Pte Ltd
11	China Construction Realty Co. Pte Ltd
12	HL Building Materials Pte Ltd
13	G & W Precast Pte Ltd
14	Sunway Concrete Products (S) Pte Ltd
15	Moderna Homes Pte Ltd
16	Robin Village Development Pte. Ltd and Robin Village International Pte Ltd
17	Nakano Singapore (Pte) Ltd
18	Kimly Construction Private Limited
19	United Tec Construction Pte Ltd
20	TK Modular Pte Ltd
21	K&H Innovative Systems Pte Ltd
22	BHCC Construction Pte Ltd
23	Sim Lian Construction Co (Pte) Ltd
24	VC Modular System Pte Ltd
25	CNQC Engineering & Construction Pte. Ltd
26	Welltech Construction Pte Ltd
27	CCL Precast Private Limited
28	Hua Siah Construction Pte Ltd
29	Ssangyong Engineering & Construction
30	China Jingye Engineering Corporation Ltd (Singapore Branch)
31	Gammon Pte. Limited
32	Master Contract Services Pte Ltd
33	Lian Beng Construction(1988) Pte Ltd
34	Wee Hur Construction Pte Ltd

Source: BCA, 2022

Steel PPVC System

S/N	Supplier / Manufacturer
1	Unitised Building Pty Ltd
2	Sembcorp EOSM Pte Ltd
3	Moderna Homes Pte Ltd
4	AM Modular (Singapore) Pte Ltd
5	CIMC Modular Building Systems Holding Co. Ltd.
6	Tiong Seng Contractors Pte Ltd and Steeltech Industries Pte Ltd
7	Dragages Singapore Pte Ltd
8	TTJ Design and Engineering Pte Ltd
9	Quicksmart Technology (Singapore) Pte Ltd
10	Mod Prefab Private Limited
11	iMax Modular Pte Ltd
12	TK Modular Pte Ltd
13	Lightrus Pte Ltd
14	Tong Hai Yang Construction Private Limited
15	Qingjian International (South Pacific) Group Development Co Pte Ltd
16	Australian Robotic Building Technologies Pte. Ltd.
17	CNQC Engineering & Construction Pte. Ltd

Source: BCA, 2022

APPENDIX B2 - LOCATION AND OPERATORS OF THE 5 ICPH

S/N	Location	ICPH Operator
1	Kaki Bukit Road 6 (KB 1)	CKR Contract Services Pte Ltd
2	Kaki Bukit Road 6 (KB 2)	Straits Construction Singapore Pte Ltd
3	Airport Road (Defu 1)	Soil-Build (Pte) Ltd
4	Airport Road (Defu 2)	Teambuild Engineering & Construction (Pte) Ltd
5	Pulau Punggol Barat (PPB 1)	HL-Sunway JV Pte Ltd

Source: BCA, 2020

APPENDIX C - LIST OF QUESTIONNAIRES FOR SOIL-BUILD (PTE) LTD

1. How many PPVC projects SoilBuild has currently?
2. What is the PPVC market in the past two years (i.e. 2020 & 2021) in the built environment industry?
3. Does ICPH help to improve the construction productivity of precast components? If yes, how does ICPH help?
4. Is ICPH able to produce all the precast components that SoilBuild needs for the construction project on hand? If not, what is the manufacturing rate of ICPH compared to the factory in Malaysia or other place/ country?
5. How does COVID-19 impact the precast component manufacturing process (eg. material, labour, shipping)?
 - a. What is SoilBuild's mitigation plan on the above COVID-19 impact?
 - b. Besides COTMA, any other government support on the COVID-19 impact to the precast component manufacturers?