

Pre-Fabricated Pre-Finished Volumetric Construction (PPVC) For Residential Projects

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Threesixty Cost Management Pte Ltd is a member of the Surbana Jurong Group which specialises in cost management and contractual administration from project inception to completion.

EXECUTIVE SUMMARY

Over the last 2 years, in response to BCA's roadmap for construction productivity, the industry has seen an upsurge of game-changing technologies and the adoption of innovative building methods. Perhaps one of the more talked about is PPVC (pre-fabricated pre-finished volumetric construction), or more commonly known as "Lego" building. The perceived benefits are well documented, but a common misconception about PPVC is the overall time savings that it can achieve. Generally, construction on-site takes comparatively lesser time because many wet trades are shifted off-site where the modules are constructed, but consideration of the additional time required up-front for detail planning and co-ordination are often overlooked. PPVC do come with its own set of challenges and at a cost premium; however, the additional cost can be off-set by a reduction in construction time and savings on labour cost.

With PPVC modules manufactured and fitted-out off-site, majority of the cost are up-front and contractors may have cashflow issues if a payment mechanism for materials off-site is not in place. As each PPVC supplier works with their own Professional Engineer, issues pertaining intellectual property might arise. There are cases where contractors engaged their own QP and this might affect the novation of consultants in modified Design and Build projects. As with most systems, there is no 'one size fits all' and PPVC is still at a very infant stage. This article will further look into the pros and cons of PPVC, the element driving PPVC costs, and the challenges from a procurement perspective.



PHOTO 1: PPVC INSTALLATION IN PROGRESS

PHOTO CREDIT: DRAGAGES

WHY PPVC?

Pre-cast construction is nothing new in Singapore. For years, especially in HDB projects, pre-cast components like ledges, gable end walls, service ducts, staircases, Civil Defence shelters, and more recently – pre-fabricated bathroom units (PBU) have been adopted extensively. As precast construction now assumes a more defined and critical role in our relentless drive for increased productivity, the advent of pre-fabricated pre-finished volumetric construction (PPVC) method would provide the much needed impetus for the industry to embrace productivity in its design and construction process. Pioneered in Nanyang Technological University’s North Hill Residence Hall back in mid-2013, PPVC modules are manufactured off-site and are complete with internal wall/floor/ceiling finishes, fixtures and fittings, and transported to site for installation. Mandated in selected Government Land Sales (GLS) sites from 1 November 2014, not fewer than 10 sites have since been earmarked to adopt the minimum level of use of PPVC, all as part of the government’s initiative to push the use of Design for Manufacturing and Assembly (DfMA) in the private sector.

The construction sector is one of the least productive industry in Singapore. Heavily-reliant on manpower, many perceived the industry as boring and ancient, and the sector is struggling to retain and attract new talents, with the younger generation choosing “Fin Tech” (financial technology) and start-up entrepreneurship over the construction industry. In June 2015, the Building and Construction Authority (BCA) rolled out the 2nd Construction Productivity Roadmap to push the industry to adopt smart and productive measures to reduce the reliance of manpower, and placed a great emphasis on DfMA.

There are now more than 15 completed/on-going projects that have adopted the PPVC method. The first PPVC project at NTU necessitated a colossal 1,900 different steel PPVC modules, in which 6 – 8 modules are delivered to the site each day. While the project was completed in a shorter time frame, it costs 18% more than it would have, had it been built using traditional cast-in-situ method. The Changi Crowne Plaza Hotel extension project, the first private sector commercial building completed using PPVC, shaved off construction time by approximately 17%, and reduced manpower on site by a staggering 40%, albeit at a 10-15% cost premium. Another noteworthy first, the Brownstone Executive Condominium (the first large-scale residential project to adopt the technology) used more than 4,000 different modules for the 638-units project, and is arguably the world's largest application of PPVC modules. The usage of PPVC in the project is expected to improve productivity by up to 40%, which is about 55,000 man-days. Numerous government projects have been known to adopt PPVC in the design. BCA also has just recently rolled out the tender for the Phase 2 Intensification Works at BCA Academy that mandates the use of PPVC in one of the buildings. As DfMA gathers momentum and the industry players are paying more attention to PPVC, developers and contractors who adopted PPVC in their projects are beginning to reap the benefits: -

- **Time** – the pioneer projects that adopted PPVC have reported shorter construction duration, savings between 2 to 6 months
- **Manpower** – less trade sub-contractors are required on site which means better sequence of work and a less crowded construction site during project peak. A lower manpower usage also means reduced idling time (workers waiting for Alimak, etc.) and reduced down time due to inclement weather
- **Safety on site** - as there are less workers working on site and workers are spending less time on site due to shortened construction period, correspondingly it reduces the chances of work injuries. Less work-at-height also reduces fall from height incidents
- **Quality** – fabrication/production in a controlled environment ensures appropriate supervision and consistent quality, and immediate rectification can be carried out
- **Sustainability** – “green” and lean construction with reduction of construction material wastage. Has the flexibility to incorporate “green” features i.e. green concrete, etc.
- **Environment friendly** – minimises construction noise and dust. As fabrications are in an industrial environment, most yards can operate longer hours for optimum production, at minimal disruptions

- **Incentives and co-funding** –under BCA’s PIP scheme (Productivity Innovation Projects), “subsidies” for cost premium. Assistance for the contractors/PPVC suppliers come in the form of the Construction Productivity and Capability Fund (CPCF)
- **Flexibility** – while no PPVC projects in Singapore has been demolished, it is expected that the PPVC modules can be easily “detached” and demolished. This flexibility also enables a building to undergo future addition and alteration works with ease

At the time of writing this article, there are more than 20 PPVC suppliers who have successfully obtained an In-Principle Approval (IPA) from the Building Innovation Panel (BIP) for their PPVC system, and 2 suppliers are already fully accredited under the Manufacturer Accreditation Scheme. With majority of the PPVC suppliers assembling the carcass in an overseas yard (Malaysia or China) before transporting them to Singapore for fitting-out, BCA believes that there will be a greater adoption of precast components in the industry, through the setting up of more Integrated Construction and Prefabrication Hub (ICPH) via the Land Intensification Allowance scheme.

COST DRIVERS

In any one project, owners/developers are invariably concerned with the project cost. While some expect a saving with modularisation (given that the construction period can be reduced), there are other associated works that drive up the PPVC cost. Although modular, in truth all PPVC modules are “custom-made” to suit the project. So how much more do owners/developers need to pay for PPVC? Contractors are generally indicating a broad 10% - 20% range (incremental), or 15% - 25% for steel PPVC (incremental), which is equivalent to \$210sqm to \$260sqm of the Gross Floor Area based on the current market price, depending on the system (no. of modules, modules standardisation, etc.) and its complexity (site location, building height, site access, etc.). However, with a shift in supply and demand, we predict that the cost will reduce, albeit at a slow pace.

The cost savings from a shorter construction duration are typically offset by other cost drivers: -

- **Precast Mould** - as each different module requires a different mould, the higher number of different modules will drive up the cost. Once used, the moulds are unlikely to be recycled and reused for another project. In addition, the higher number of different modules will also mean more installation work on site (grouting, jointing, etc.).
- **Transportation** – as PPVC modules are manufactured and assembled off-site, the modules need to be transported to Singapore (most PPVC suppliers’ pre-fab yard is in Johor, Malaysia)

for fitting-out, before being transported to site for on-site installation. Transportation of the modules are based on per trip basis, and the truck can only load limited number of modules at any one time, depending on the size of the modules. There are also LTA restrictions with regard to the usage of public roads. A typical non-landed residential project that requires say 2,000 modules will need at least 1,000 trips, if 2 modules are loaded onto the truck at one time.

- **Hoisting** – tower crane with higher capacity is required, with concrete PPVC modules weighing as much as 25 – 30 tonnes. The initial cost and rental of 30-tonnes tower crane is considerably higher than typical capacity tower crane. In addition, the scarcity of 30-tonnes tower crane in Singapore market will push the cost up. Some contractors may consider investing in higher capacity tower cranes, but the amortised cost can only be realised after a few more PPVC projects, before the savings can be passed on to owners/developers.
- **Manufacturing & holding yard** – high cost of setting up and maintaining a PPVC manufacturing & holding yard. Once shipped to Singapore, the modules are then whisked away to a holding yard where the modules are fitted out. Certain project sites have limited storage space on site therefore PPVC modules need to be stored elsewhere (note that most GLS project sites prohibits the use of Temporary Occupation Licence of State Land (TOL) for storage of PPVC modules).
- **Additional TOL** – site offices and other ancillary buildings might need to be housed in a TOL nearby, to make space for storage of PPVC modules on site.
- **Supervision** – additional off-site / overseas supervision is required to ensure that consistent quality and compliance to local code.

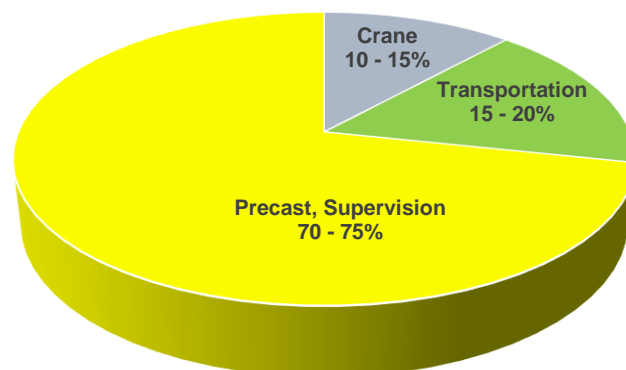


FIGURE 1: PPVC COST DRIVERS

S/N	Description	Amount	Amount
	Tower	Base Cost	PPVC Cost Drivers
1.0	Piling	√	
2.0	Superstructure		
	Conventional Cast In-situ Concrete (m3) - 35%	√	
	65% PPVC (m3) - Carcass of PPVC Modules		
	Precast Module		√
	Manufacturing & holding yard		√
	Additional TOL		√
	Additional Supervision		√
3.0	Architectural Works		
	Roof drainage and finishes	√	
	Internal Walls	√	
	Windows / fixed glass, façade frame, horizontal fins	√	
	Doors & Ironmongery	√	
	Finishes	√	
	Touch and Feel Items		
	Wardrobe and DB cabinet and Kichen Cabinet	√	
	Vanity cabinet, mirror cabinet and solid surface	√	
	Sanitary wares, fittings and accessories	√	
	Kitchen Appliances	√	
4.0	Fittings, Fixtures and Furnishing		
	Metal works	√	
	Signages	√	
	Feature wall	√	
	Shower Screen	√	
5.0	Aluminium and Glazing Works (Façade)		
6.0	Mechanical and Electrical		
7.0	Preliminaries	√	
	Additional Transportation		√
	Premium on Hoisting		√

FIGURE 2: BASE COST & PPVC COST

Given that PPVC was mandated fairly recently and the lack of economy of scale in number of projects, PPVC suppliers will find it difficult to keep the cost down, and pass the savings on to the owners/developers, without any sustainable form of demand, as they lack the bulk purchasing power to negotiate with their supply chain. As PPVC systems are only limited to residential, student accommodation, workers' dormitory, and healthcare projects, there is a shortage of public sector projects that are suitable to adopt DfMA technology. Although not short of PPVC suppliers in the local market, there is a lack of competitiveness in PPVC pricing, as many owners/developers are only willing to work with the few contractors/PPVC suppliers that possess the relevant track records. The yards are ready, but many suppliers are eagerly waiting for PPVC orders to fly through the door.

PROGRESS PAYMENT

An aspect up for debate on PPVC is the payment for work done. Payment for materials off-site is not typically practised in Singapore and contractors are paid as works are completed on site progressively, but because the whole PPVC module is completed off-site and then transported to site for installation, most owners would only pay when it is fully completed, delivered and installed on site. What this mean is contractors would have to finance the high up-front cost of fabrication and fitting out of the modules in the factory, and only claim for it when it is delivered to site and fully installed. To overcome this anomaly, contractors could be provided with a form of advance payment or stage payment upon award of the contract. The contractor will then subsequently be paid fully when the PPVC modules are delivered to site and installed. This arrangement should help alleviate downstream payment issue, and ensure that the fabrication of the modules is not delayed. Conversely owners will need to be more financially prepared and ready in the early stages of the project to facilitate the payment of PPVC modules as the fabrication of PPVC often can commence early on, even before the piling works are completed. The contractor should provide appropriate insurances and indemnity against any loss or damages to the PPVC modules to mitigate the risks borne by the owner for the payment of off-site PPVC. To further protect the interest of the owner, a mechanism to recover payment made for any PPVC should be enforced in the contract, if the PPVC modules are not delivered to site as scheduled, or became defective after installation, etc.

PROCUREMENT

One of the biggest advantage that PPVC brings to the project is the ease of construction that translates to a shorter construction period. On the Crowne Plaza Hotel extension project, the actual time taken to complete construction from Level 2 onwards up to the roof was only 4 months, compared to 12 months had conventional construction method been adopted instead of PPVC.

The construction time saved meant that the hotel could open its doors to hotel guests and generates revenue earlier. However, there is a lengthened design development stage as PPVC construction requires a higher level of detail and planning, particularly if the project team is not familiar with the PPVC process or system. As such, a close partnership between the PPVC supplier, contractor and design team is required at the outset of a project, so that both the PPVC supplier and contractor can provide buildability input to the design, and vice versa. In a PPVC project, the owner and design team should identify and shortlist suitable PPVC suppliers and contractors very early on, and engage them to see how their system intertwines with the design. If the proposed systems are suitable, the owner should proceed with a competitive bidding process and appoint the main contractor as soon as possible. This process also enables the application of the relevant building permissions from URA/BCA in a timely manner. With a longer design period, the procurement process should be fast-tracked so that the project can take full advantage of the time savings achievable in the construction stage. One of the more important aspect for a fast-tracked procurement is to ensure that the design team begins with a PPVC-friendly design, rather than tweaking the design at a later stage to accommodate PPVC.

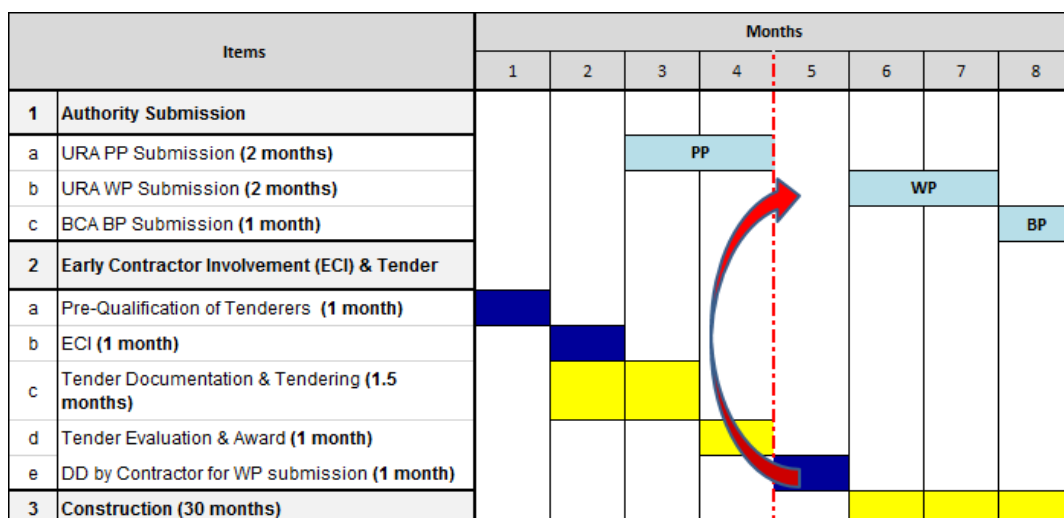


FIGURE 3: FAST-TRACKED PROCUREMENT FOR PPVC PROJECTS

INTELLECTUAL PROPERTY

While PPVC systems are generally similar in nature (concrete/steel/hybrid), there are distinctive differences (i.e. connections between modules, joints, etc.) and some PPVC suppliers see the need to patent their systems. As some contractors/PPVC suppliers have concerns over intellectual property rights, some may not be willing to work with certain design consultants/Qualified Person (QP), which in turn could affect the novation of and the procurement process. Alternatively, owners/developers could directly engage the structural consultant to provide only design intent drawings and design brief, and to review and check the contractor's designs.

As Design and Build contractors would normally prefer to engage their own Professional Engineer to carry out design development, it would mean they are likely to engage the same structural consultant who is also the Professional Engineer (PE) for the PPVC system that is being adopted in the project. This arrangement is ideally suited to PPVC projects since the structural consultant understands the design and is familiar with the PPVC system proposed.

CHALLENGES

PPVC unavoidably comes with its own set of issues and challenges. With steel PPVC homes, the mandatory post-construction periodic inspections for corrosion issues could lead to privacy and accessibility issues for the owners. To minimise the impact, architects need to ensure that the homes are designed in such a way that future periodic inspections can be carried out in a less invasive manner. Another design "constraint" is notably the reduced floor-to-floor height. Without the luxury of ceiling space, most ducts and pipes are embedded in the slab and therefore early co-ordination and planning must be allowed for services routing. When designing and selecting floor finishes to the bedroom and/or living/dining, the design team should also take into consideration that timber floor finishes are easily warped when the temperature in the holding yard is hot and humid, while marble floor finishes are heavy and may impact the overall PPVC carcass weight. There are also interfacing issues particularly at areas where the modules connect with pre-cast slab or cast-in-situ slabs/columns. On site, contractor must ensure that verticality issues arising from stacking of the PPVC modules do not result in a slanted structure, especially in super high rise projects (>40 storeys high). The biggest hurdle and perhaps the most difficult to overcome, is to change the industry mindset and practices. Often, a project is delayed due to the sheer number of design changes. In projects where many different user groups are involved, the changes become insurmountable. To embrace PPVC, the norm needs be thrown out, and owners/developers must lock in their design preferences and decisions early to avoid abortive works and costs, once the PPVC modules are in production. While changes are inevitable, it

should be at a minimal and only where necessary, and only when the owner/developer is prepared to pay for the changes. Even the slightest change to the position of a switch may mean wholesale changes at the PPVC production and fitting out yard.

CONCLUSION

While the advent of PPVC is recent, it would undeniably be the harbinger of productivity increase and would slowly but relentlessly become an inherent part of our work. As the industry forges ahead with PPVC, there are underlying fears from the smaller-sized contractors that they could miss the train. PPVC is not a matter of if, but when. Developers and contractors alike must bite the bullet or risk being left behind. For businesses who traditionally build everything on site, the quantum leap from conventional method to PPVC requires a new and paradigm shifting business model and brand new skillsets. They are, in effect, no longer construction companies but a hybrid of construction and manufacturing. Most acknowledge and agree that it is the right direction for the industry, but they are also worried about the high cost of embracing technologies like DfMA, Virtual Reality (VR) and robotics. They want to remain competitive and upgrade, but for now, the impediment of a gap too wide to bridge should be ameliorated. Nevertheless, the government's on-going efforts in forging new paths for the industry should be lauded, and the industry must now work together closely to realise the objective.

A PRACTITIONER'S SUMMARY

At Threesixty Cost Management Pte Ltd, we are working on a few PPVC projects and believe that we may soon be seeing a downward trend in PPVC prices. With more than 10 new residential GLS sites to be released from now up till Q4 2017/Q1 2018, the demand for PPVC will ramp up. That being said, supply still outweighs demand at present, and we believe that contractors/PPVC suppliers who are hungry to win their first PPVC project may be looking to offer very competitive prices to land that exclusive PPVC track record. Contractors who are not yet on board will be eyeing to invest in PPVC, while those who are already on board will be interested to look at ways to bring PPVC cost down, and pass on the savings to developers and clients. As more and more ICPH are being set-up, we also anticipate that productivity shall increase, which will result in a lower labour cost.

DEVELOPER'S AND CONTRACTOR'S PERSPECTIVE

“Our primary concern has always been to construct residential units in the best interests of the residents and this will necessarily mean that the overall construction must be watertight, structurally durable and safe. With more and more designers and contractors having PPVC competencies, our concerns are very much addressed and as such we are much more comfortable in adopting the PPVC methodologies.” – **Sing Holdings Limited**

“PPVC is very challenging but very satisfying once you have successfully delivered the project. Early Contractor's Involvement is the first key to the success of a PPVC project, teaming up with the client and consultants. PPVC dramatically improves construction productivity, safety, and quality. A strong builder is very important in achieving high level of efficiency and success in PPVC. Fixed factories is a key element for PPVC's sustainability. The government plays an important role in this aspect to nurture more PPVC projects to allow contractor's continuity and to overlap projects.” – **Dragages Singapore Pte Ltd**

ABOUT THREESIXTY COST MANAGEMENT

Threesixty Cost Management Pte Ltd is a member of Surbana Jurong Group and currently comprises senior practitioners in quantity surveying practice whose experience spans over 3 decades under the leadership of Mr Seah Choo Meng; a respected practitioner in the construction industry. All the team members have extensive track records and expertise in both the private and public sector and are well placed to provide in depth cost management and contractual administration to the Client from project inception to completion stage. Our Cost Research unit is specialised in providing reliable cost estimate and cost benchmarking and publication of cost research paper on the market trend and new technologies in the construction market.

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