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SINGAPORE’S CONSTRUCTION PRODUCTIVITY JOURNEY

Hugh Lim
CEO, Building and Construction Authority (BCA), Singapore
SCOPE OF PRESENTATION

i. Singapore’s Construction Productivity Journey

ii. Design for Manufacturing and Assembly (DfMA)

iii. Integrated Digital Delivery (IDD)

iv. The Way Forward
Singapore’s Construction Industry is Transforming

Key Trends driving our transformation

Greater Urbanisation and Increasing Manpower Squeeze
- Need to adopt more advanced construction technologies (e.g. DfMA)

Gearing towards Digital Revolution
- Integrated Digital Delivery (IDD) as key enabler of DfMA adoption

Dealing with Climate Change
- Greater focus on sustainable construction practices
Singapore’s Construction Industry Transformation Map (ITM)

1. Design for Manufacturing and Assembly (DfMA)
   - Prefabrication
   - Assembly

2. Integrated Digital Delivery
   - Design
   - Facility Management/Operations
Moving work offsite will improve productivity in 3 ways:

- **Controlled** factory environment
- Greater scope for **automation**
- Options for **offshoring**

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- Adopting Prefabrication
  - **Modular Design**
### DfMA Changes the Way We Build

**Continuum of DfMA technology**

<table>
<thead>
<tr>
<th>Components: Incremental Improvement...</th>
<th>...Integrated Assemblies: Game-Changing Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prefab components</td>
<td>Advanced Prefab Systems</td>
</tr>
<tr>
<td>Structural</td>
<td>Structural Steel / Advanced Precast / Hybrid</td>
</tr>
<tr>
<td>Architectural</td>
<td>On-site Dry Applied Finishes</td>
</tr>
<tr>
<td>MEP</td>
<td>Flexible Water Pipe / Sprinkler Dropper</td>
</tr>
</tbody>
</table>

40% DfMA Changes the Way We Build

Digital Engineering
Establishing a Robust DfMA Ecosystem

Key Objectives:

1. **Increase adoption** to improve productivity
2. **Reduce cost premium** for sustained adoption
3. **Sufficient capacity and capabilities** to support adoption

**A**

Creating sufficient lead demand quickly is critical for sustainable DfMA adoption

**B**

**SUPPLY CAPACITY & CAPABILITIES**
(e.g. developers, consultants, contractors, suppliers, logistics)

Creating Economies of Scale & Competition

Lower Cost for DfMA Technology Adoption

**Key Strategies:**

A  Build sustained demand
B  Build supply capacity & capabilities
Creating Lead Demand for DfMA

Taking the lead - Public sector projects adopting DfMA

**Prefabricated Prefinished Volumetric Construction**
- 16 projects
  - (4 completed, 12 on-going)

**Mass Engineered Timber**
- 11 projects
  - (3 completed, 8 on-going)

**Prefabricated Mechanical, Electrical and Plumbing**
- 2 projects
  - (on-going)

**Structural Steel**
- 11 projects
  - (2 completed, 9 on-going)
Creating Lead Demand for DfMA

Public sector taking the lead, in close collaboration with industry

Championing productive technology adoption and processes

<table>
<thead>
<tr>
<th>DfMA Technology</th>
<th>Integrated BIM</th>
<th>Procurement Methods</th>
</tr>
</thead>
</table>

Advisory panel of industry experts for DfMA projects

DfMA project implementation
Creating Lead Demand for DfMA

**Government Land Sale (GLS) Sites**

Specifying DfMA technology adoption

<table>
<thead>
<tr>
<th>Technology</th>
<th>GLS Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPVC</td>
<td>20 residential GLS sites</td>
</tr>
<tr>
<td>Structural Steel</td>
<td>2 commercial GLS sites</td>
</tr>
<tr>
<td>Productivity</td>
<td>1 residential GLS site</td>
</tr>
</tbody>
</table>

**Total number of sites to date**

**Private developments**

Voluntary DfMA technology adoption

<table>
<thead>
<tr>
<th>Type</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPVC hotel</td>
<td>Crowne Plaza Extension, Brownstone</td>
</tr>
<tr>
<td>PPVC residential</td>
<td>Singapore Sustainability Academy</td>
</tr>
</tbody>
</table>

**Funding support for voluntary DfMA adoption by private sector**

Note:

- PPVC – Prefabricated and Pre-finished Volumetric Construction
- MET – Mass Engineered Timber

**Outcomes**

Pilot Concept & Price tender approach
Competent Suppliers

Accredited suppliers listed on BCA’s website

**Building Innovation Panel (BIP)**
- Ensuring *design* complies with regulatory requirements

**PPVC Manufacturer Accreditation Scheme (MAS)**
- Ensuring high *quality* in PPVC production
Suppliers Capabilities Established

Highly automated facilities for production, quality ensured

- Multi-storey prefabrication hubs with automation and mechanization
- Improved quality control in factory production
- Considerably reduce labour usage on-site for higher productivity

Automated Steel Reinforcement Fabrication
Automated Pallet Circulation Plant

Courtesy of: GREYFORM
Competent Suppliers

24 SUPPLIERS (Through Building Innovation Panel)

1) Unitized Building
2) Moderna Homes
3) Sembcorp EOSM
4) Integrated Precast

Steel PPVC
5) AM Modular
6) CIMC
7) Tiong Seng
8) Dragages
9) Mod Prefab
10) TTJ
11) Quicksmart
12) Kong Hwee
13) Imax
14) TK Modular
15) Lightrus
16) SPP System
17) Excel Precast
18) Vico
19) Dragages
20) Mod Prefab
21) Prefab Tech
22) CS Corp
23) Qingjian
24) China

Concrete PPVC

2013 2014 2015 2016 2017
**PPVC – Most Promising DfMA Technology**

**PPVC yields significant productivity improvement**

**Components: Incremental Improvement…**

<table>
<thead>
<tr>
<th>Structural</th>
<th>Advanced Prefab Systems</th>
<th>Integrated Sub-assemblies</th>
<th>Fully-integrated Integrated Assemblies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precast</td>
<td>Structural Steel / Advanced Precast / Hybrid</td>
<td>Mass Engineered Timber (MET)</td>
<td>Prefabricated Prefinished Volumetric Construction (PPVC)</td>
</tr>
</tbody>
</table>

| Architectural | | |
|---------------| | |
| On-site Dry Applied Finishes | Prefinished Surfaces | PBUs |

| MEP | | |
| Flexible Water Pipe/ Sprinkler Dropper | Prefab Ceiling Module/ Prefab Plant | Prefab Module with Platform/ Catwalk |

**Components: Incremental Improvement…**

**Integrated Assemblies: Game-Changing Improvement**

- PPVC yields significant productivity improvement

- Components: Incremental Improvement
- Integrated Assemblies: Game-Changing Improvement

- **Components:**
  - Structural Components: Precast, Structural Steel / Advanced Precast / Hybrid, Mass Engineered Timber (MET)
  - Architectural Components: On-site Dry Applied Finishes, Prefinished Surfaces, PBUs
  - MEP Components: Flexible Water Pipe/ Sprinkler Dropper, Prefab Ceiling Module/ Prefab Plant, Prefab Module with Platform/ Catwalk

**PPVC – Most Promising DfMA Technology**

**Digital Engineering**

40% PPVC – Most Promising DfMA Technology
Prefabricated Prefinished Volumetric Construction (PPVC)

What is PPVC?

1. Modules manufactured, fitted out in Factory
2. Transport to site
3. Easy Installation on-site

Courtesy of: Moderna Homes

Courtesy of: Teambuild

Courtesy of: OUE
Completed PPVC Unit

No different from conventional construction, but better quality finishes

Living Room

Kitchen View From Living

Kitchen

Common Area Within Unit

Bedroom

Bathroom

Courtesy of: Teambuild

Digital Engineering
Types of PPVC

1. REINFORCED CONCRETE PPVC MODULE
   - Wall: Concrete
   - Floor: Concrete

2. STEEL PPVC MODULE
   - Wall: Steel frame with lightweight walls
   - Floor: Concrete or Lightweight Flooring System

Courtesy of: ADDP
PPVC

- 31 projects
  (6 completed, 25 on-going)

Development types:
Hostel, Nursing Home, Hotel, Dormitory and Residential

Singapore PPVC Projects
Wide range of project types done in PPVC

Residential

- 10-Storey Brownstone Executive Condo (COMPLETED, Photo: CDL)
- 12-Storey Wisteria Commercial & Condo (ON-GOING, Photo: Moderna)
- 36-Storey Parc Riviera Condo (ON-GOING, Photo: EL Development)
- 40-Storey Clement Canopy Condo (ON-GOING, Photo: UOL)
- 13-Storey NTU Hostel (COMPLETED, Photo: NTU)
- 9-Storey Dormitory JTC Space @ Tuas (COMPLETED, Photo: JTC)
- 9-Storey Woodlands Nursing Home (COMPLETED, Photo: MOHH)
- 10-Storey Crowne Plaza Hotel Extension (COMPLETED, Photo: OUE)
**Case Study 1**

**West Terra, Public Housing**

Minimal finishes, incomplete modules, with extensive wet joints

*2013*

**The Brownstone, Executive Condo**

**Greater modularization** with less wet joints, but still minimal finishes and no floor slab

*2015*

**Valley spring, Public Housing**

Construction in progress

*2016*

**Parc Riviera, 36 storey condo**

Construction in progress

*2018*

**15% manpower savings**

**20% manpower savings**

**Minimal finishes, incomplete modules, with extensive wet joints**

**Greater modularization** with less wet joints, but still minimal finishes and no floor slab

Complete 6-sided, **fully prefinished** modules
Crowne Plaza Airport Hotel Extension

• Made possible by a strong project team, comprising architect, engineer, contractor and fabricator

Developer:
OUE Airport Hotel Pte Ltd

Architect:
WOHA Architects Pte Ltd

Structural Engineer:
RSP Architects & Planners Pte Ltd

M&E Engineer:
Surbana International Consultants Pte Ltd

Main Contractor:
Dragages Singapore Pte Ltd

PPVC Supplier:
Unitised Building Consulting (Aust) Pty

One of Singapore’s pioneer PPVC projects

6 months time savings, 44% manpower savings
Industry Breakthroughs in PPVC

• PPVC for high-rise developments

Clement Canopy Condominium

Construction ongoing

40-storey condominium
(World’s tallest concrete PPVC building)

Developer:
Singland Homes & UOL Venture Investments

Architect:
ADDP Architects LLP

Structural Engineer:
Tham & Wong LLP

M&E Engineer:
J Roger Preston (S) Pte Ltd

Main Contractor:
Dragages Singapore Pte Ltd

PPVC Supplier:
Dragages Singapore Pte Ltd
Industry Capabilities developed in PPVC

Modularisation

Offsite fabrication

Onsite Assembly

Clement Canopy Condominium

Case Study 3

Courtesy of: Dragages

PPVC Video
Industry breakthroughs in PPVC

Designing open-concept PPVC systems

Consultants design capabilities made open-concept PPVC design possible

Woodlands Nursing Home

Developer: MOH Holdings Pte Ltd (MOHH)
Architect, Structural Engineer, M&E: Surbana International Consultants
Main Contractor: Dragages Singapore Pte Ltd
PPVC Supplier: Dragages Singapore Pte Ltd

3 months time savings,
24% manpower savings

JTC Space @ Tuas

Developer: JTC Corporation
Architect: SAA Architects Pte Ltd
Structural Engineer: Aecom Singapore Pte Ltd
Main Contractor: Tiong Seng Contractors Pte Ltd
PPVC Supplier: Tiong Seng Contractors Pte Ltd

16% manpower savings
Open concept PPVC systems

Woodlands Nursing Home
Modular system for various bedroom functions

JTC Space @ Tuas (Dormitory)

Typical Bedroom

Modular Layout

Courtesy of: Dragages

Courtesy of: Tiong Seng
PPVC projects achieving variety of building forms

• With capable architects on board, creative building features can be achieved

Oversea PPVC Projects

Habitat 67, Canada (Residential)
By Arch Moshe Safdie

Victoria Hall, London

Crowne Plaza Hotel Extension

Wisteria Condominium

Mixed residential and commercial

Singapore PPVC Projects

12 STOREYS

19 STOREYS

10 STOREYS

12 STOREYS
Prefab Mechanical, Electrical and Plumbing (MEP) Systems

Components:
- Incremental Improvement

Sub-assemblies:
- Include MEP services only
- Integrate with architectural/structural components

Integrated Assemblies MEP PPVC
- Complete assembly

Prefab Components
- Pre-insulated plastic piping

Prefab horizontal services / vertical riser modules

Prefab horizontal module with ceiling board

Prefab vertical riser module with catwalk

Prefab plant room
Benefits of Prefab MEP Systems

**Better Health and Safety**
- Neat and tidy factory

**Improved Quality and Productivity**
- Upfront detailed design
- Working in a factory environment and at ground level improve productivity
- Easy to install (lifting one subassembly instead of multiple ducts, pipes, etc.)

Photograph courtesy by Crown House Manufacturing
Photograph courtesy by DSG Modular, Newcastle, England, UK
Case Study - Global Switch Data Centre

**Up to 70% productivity improvement**

**Developer:**
Global Switch Singapore

**Architect:**
AWP

**M&E Engineer:**
Aurecon

**Main Contractor:**
Gammon

**MEP Module Supplier:**
Gammon

**Project Period:**
October 2017 – November 2018

**Adopted Prefab MEP Systems**

- Horizontal module
- Roof cooling tower modules
- Riser modules
- Plant room modules
- External modules with catwalk
Championing of DfMA is supported by Digital Engineering.

**Digital Design**
Collaborative and coordinated DfMA design using BIM/VDC or other computational tools.

**Digital Assembly**
Using real-time Info-Comm Technology (ICT) to deliver and install on-site.

Digital Manufacturing and Fabrication
Integration of BIM/VDC for off-site production through automation, robotics.

**Note:**
IDD – Integrated Digital Delivery
Digital Design - components

- Use of Intelligent Objects
- Computational & Rule-based design
- Automated Code Compliance Checker
- Tender Release & Handover
- BIM Quality Checks
- AR-VR

DESIGN BIM MODEL
Digital manufacturing and fabrication - components

- Fabrication Model Creation (e.g. Detailing & BBS)
- Production Management System (e.g. from BIM to machinery)
- BIM to Shop Floor (e.g. using mobile device)
- Robotics installation
- Quality Control
- Storing & Tagging (e.g. using RFID linked To BIM)
- Delivery (e.g. Fleet Tracking)
An IDD Scenario

Architect uses BIM to generate design options

Engineers perform analysis

Contractor, Fabricator give early input on constructability

Developer uses VR tool to visualise building

Contractor uses BIM to plan construction

PM monitors site using drones

Contractor uses BIM-to-Field technology for setting out

Crane Operator operates smart crane

Supervisor monitors activities in central control room

DfMA modules delivered just-in-time to site

Digital IDs embedded in DfMA modules

Digital data and robotics to drive machinery

Fabricator uses digital DfMA model for production

Fabricator uses digital DfMA model for production

Contractor uses BIM to plan construction

Assembly

IDD Platform: Data Storage, Data Exchange, Data Processing, Data Mining, Analytics Engine/Machine Learning
CHANGING THE WAY WE BUILD

Where to next?

DfMA
More projects to adopt DfMA

From conventional construction...
..to offsite manufacturing
and onsite assembly

IDD
Pilot adoption of IDD

Digital Design
Digital Manufacturing
Digital Assembly

Developing full suite of digital solutions and capabilities

Collaboration
Require close Partnership & Collaboration among Stakeholders
Thank You