Joint Symposium 2022 23 November 2022

CITY FOR FUTURE

Journey to Carbon Neutral Building

Apply design for manufacture and assembly (DfMA) thinking and offsite techniques to building services systems to enable future lean construction

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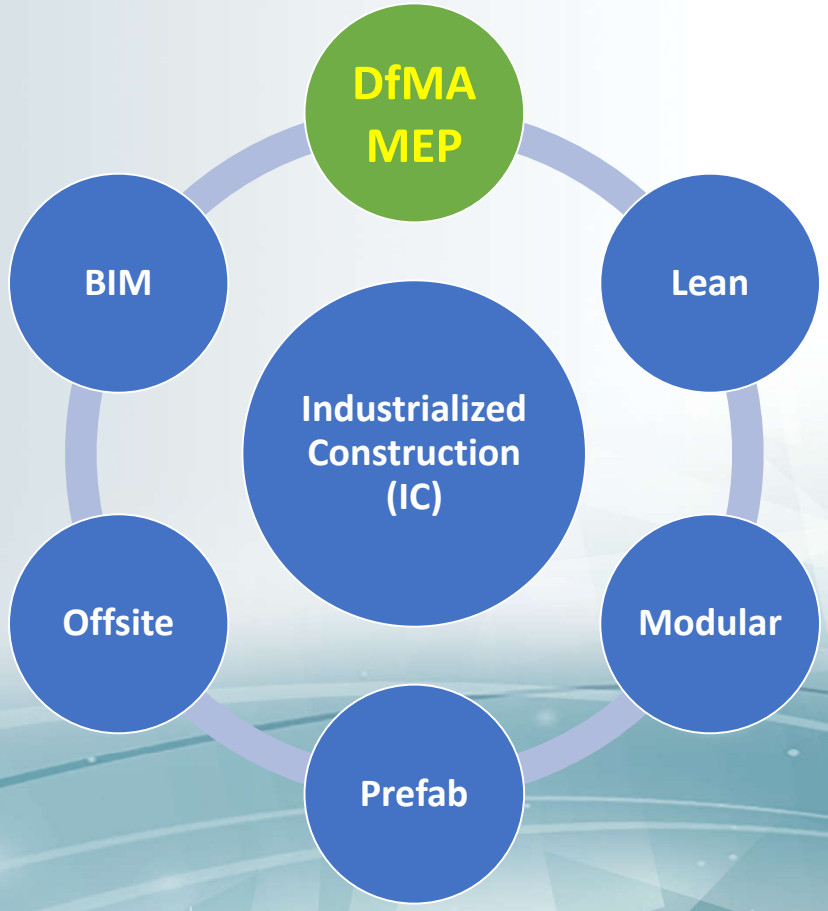


1. Introduction

- Design for manufacture and assembly (DfMA):
  - A set of principles for enabling a design process that facilitates the optimisation of all manufacture and assembly functions and contributes to the minimisation of cost and delivery time and the maximisation of quality and customer satisfaction
  - Originated from production industries, DfMA is considered an effective strategy for the construction industry to enhance productivity, quality, safety and sustainability
  - When DfMA is integrated with offsite techniques and applied to building services systems, it can support rapid-speed and efficient construction of building elements and components

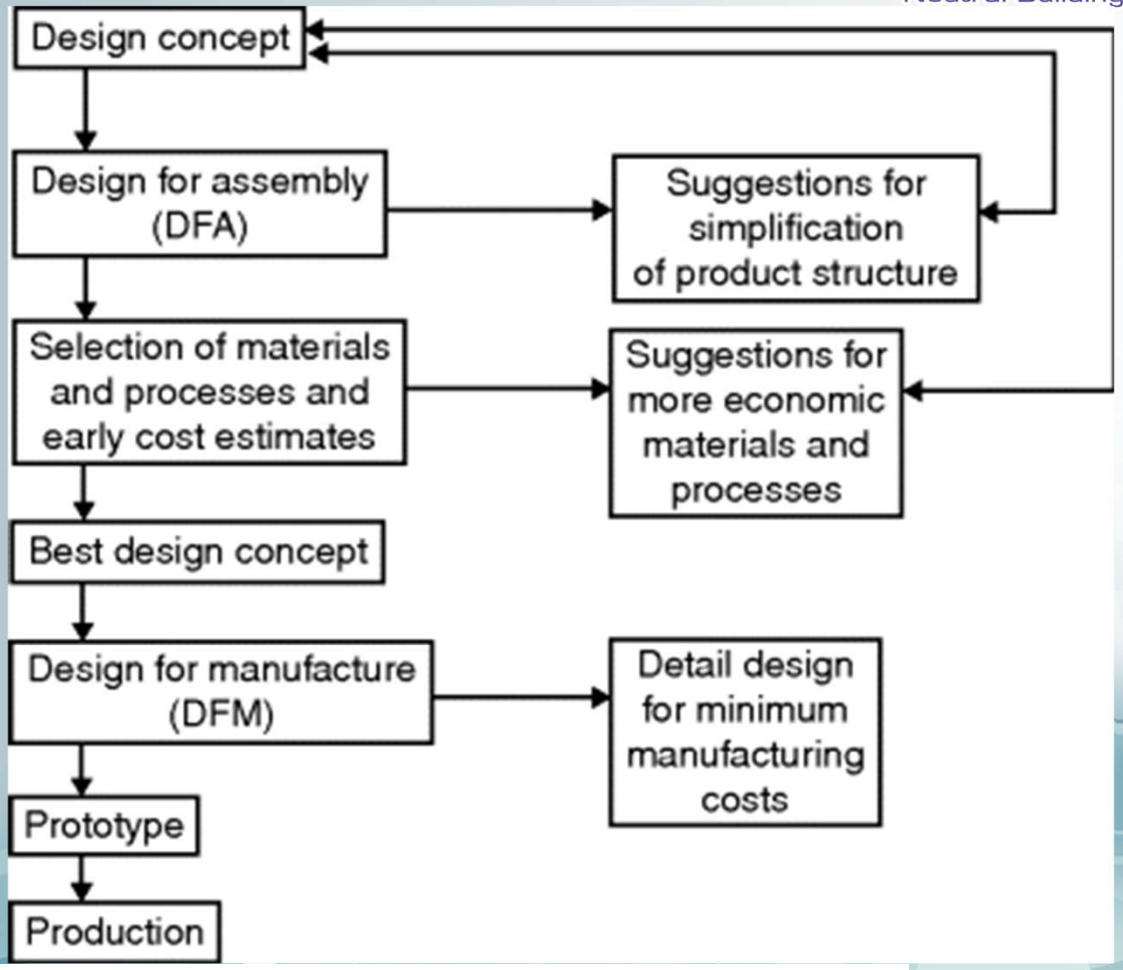
2. DfMA and Offsite Techniques

- History and Basic Principles of DfMA
  - Design for X (DfX) with the goal to optimise the manufacturing and assembly phase of a product
  - Originated during World War II when Ford and Chrysler applied it as a principle in their weapon production processes
  - In the 1980s, DfMA software and tools were developed by Boothroyd and Dewhurst and applied in various manufacturing companies and sectors, such as automobile and aerospace industries
  - A mature design system and thinking philosophy which can be applied to other sectors to reduce costs and increase profits

Basic concepts and procedures of DfMA

DFA - reduce the number of components that make up an assembly and making their assembly easy and mistake-proof in order to reduce assembly costs

DFM - simplify component designs to make them easier to manufacture in order to reduce component and product costs



Key principles of DfMA: **Minimisation**, **Standardisation**, and **Modularisation**

Source: (Boothroyd *et al.*, 2011; BESA, 2015)

2. DfMA and Offsite Techniques

- DfMA in Construction
  - It enables offsite manufacture of high-quality components and efficient assembly of the components onsite in a cost-effective manner
    - DFA: design for minimising work onsite
    - DFM: make significant construction elements in a factory environment
  - Can work with virtual design and construction (VDC) to assess the efficiency of manufacturing and assembly
  - Embraces the prefabrication and modular construction technologies
  - Applications range from one-off small-scale to large-scale projects

Categories of offsite construction

Category		Definition
1	Component manufacture & subassembly	Prefabricated units made in a factory and not considered for onsite production
2	Non-volumetric preassembly	Pre-assembled units which do not enclose usable space (e.g. timber roof trusses, flat panel units and panelised systems)
3	Volumetric preassembly	Pre-assembled units which enclose usable space and are typically fully factory finished internally, but do not form the building structure (e.g. toilet and bathroom pods)
4	Modular systems or buildings	Pre-assembled volumetric units which also form the actual structure and fabric of the building (e.g. prison cell units and hotel rooms)

Source: (Arif *et al.*, 2012; Gibb, 1999)

2. DfMA and Offsite Techniques

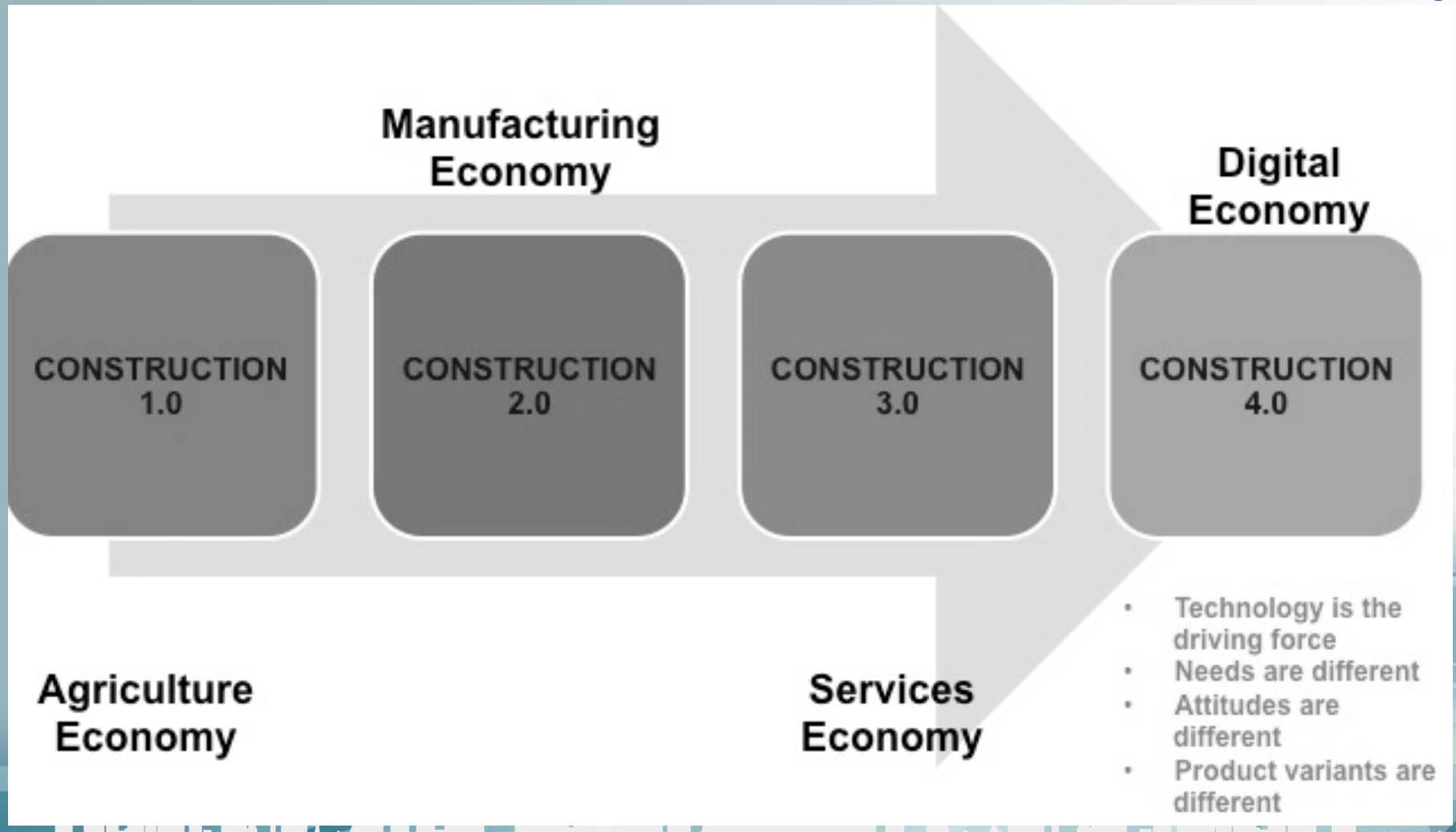
- Offsite Construction Techniques
  - DfMA-oriented design on modular and prefabricated construction
  - Major constraints: value, processes, supply chain and knowledge
  - Main drivers: cost, time, quality, health and safety, and sustainability

  - Offsite fabrication: An industrial process and strategy which incorporates prefabrication, preassembly, standardisation and modularisation, with the aim to change the orientation of the project process from construction to manufacture and installation

2. DfMA and Offsite Techniques

- Global trends
  - The construction industry is currently being transformed into a more integrated production to develop standardisation of products
  - Three transformative processes:
    - (a) Product transformation
    - (b) Digital transformation
    - (c) Transformation in project delivery processes & related business processes
  - Synergies of BIM, DfMA and lean thinking will continue to grow and will bring up new changes in technology, processes and people

Evolution of Construction 4.0



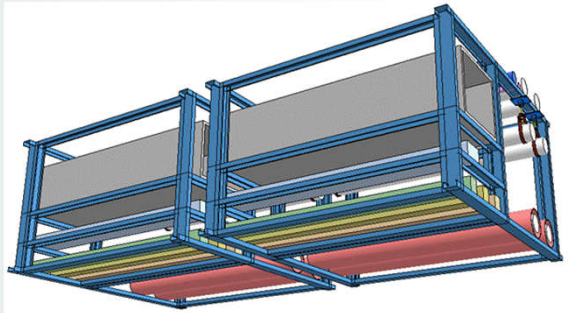
Source: (Sawhney, Riley & Irisarry, 2020)

2. DfMA and Offsite Techniques

- Situation in Hong Kong
  - Adoption of Modular integrated Construction (MiC)
  - A new construction method for MEP works known as Multitrade integrated Mechanical, Electrical and Plumbing (MiMEP)
    - Offsite prefabrication and inspection
    - Multi-trade integration and module maximisation (i.e. volumetric assembly with multi-trades integration)
    - Plug and play (maximising efficiency of onsite installation works)
  - Evaluation of the barriers to wider DfMA adoption in Hong Kong

3. Application to Building Services Systems

- Prefabricated MEP adopts the DfMA concept (e.g. Singapore)
- Potential Benefits:
  - Shorter construction time
  - Improved workmanship and quality control
  - Economy of scale for mass production or mass customisation
  - Simplified manufacturing and assembly processes
  - Increased reliability, efficiency and productivity
  - Reduced onsite works and impacts to the environment
  - Reduce waste and environment impact
  - Positive impact on workplace health and safety



Major building services elements suitable for prefabrication

Building services systems	Major elements
Mechanical ventilation and air conditioning	- Air duct system - Water pipework and fitting - Refrigerant pipework and fitting - Air conditioning equipment (e.g. air handling unit)
Fire services	- Water pipework and fitting - Pump sets and fittings - Smoke extraction system - Automatic fire detection & fire alarm systems
Plumbing and drainage	- Water supply pipework and fitting - Drainage pipework and fitting - Pump sets and fittings - Bathroom and toilet sanitary fittings
Electrical services	- Cable and busbar trunkings - Conduits and wiring - Power outlets and telecommunication - Electrical switchgear - Emergency generators

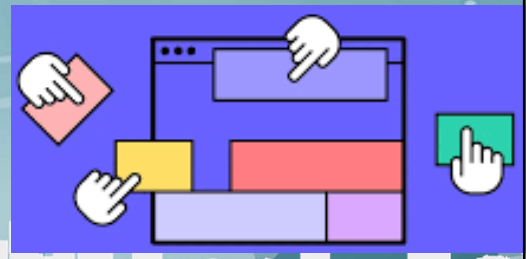
Source: (Hui & Or, 2005)

3. Application to Building Services Systems

- Major Considerations:
  - MEP works is a less-explored area in prefab construction
  - A critical need to modularise MEP systems in prefab buildings
  - A combination of DfMA and offsite construction technologies
  - DfMA approach requires a change in the relationship between design and construction/installation
    - Component-driven, modularisation and standardisation approach
    - Optimise design for offsite fabrication of components and onsite assembly
    - Close collaboration among members of the design team, contractors/subcontractors, suppliers/manufacturers, and assemblers

4. Discussions

- From Manufacturing to Construction Process
  - A business process “re-engineering”
    - Manufacturing (product-based) vs Construction (project-based)
  - Need to break down construction into sub-sectors with distinctive missions
  - Combine the BIM capabilities in DfMA with mass customisation
  - Digitally enabled DfMA and integrated project delivery (IPD)
  - DfMA encourages multidisciplinary collaborations in product development



4. Discussions

- Lean Construction (LC)
  - Manage construction projects with the aims to minimise the waste of materials and time and to generate the maximum value
  - Integration of BIM, DfMA, LC and sustainability
  - Applying DfMA enables the identification, quantification and elimination of waste or inefficiency in the manufacture and assembly of building components or systems
  - It can also be used as a benchmarking tool to study and select the most cost-effective materials, products or processes

BIM (tools)

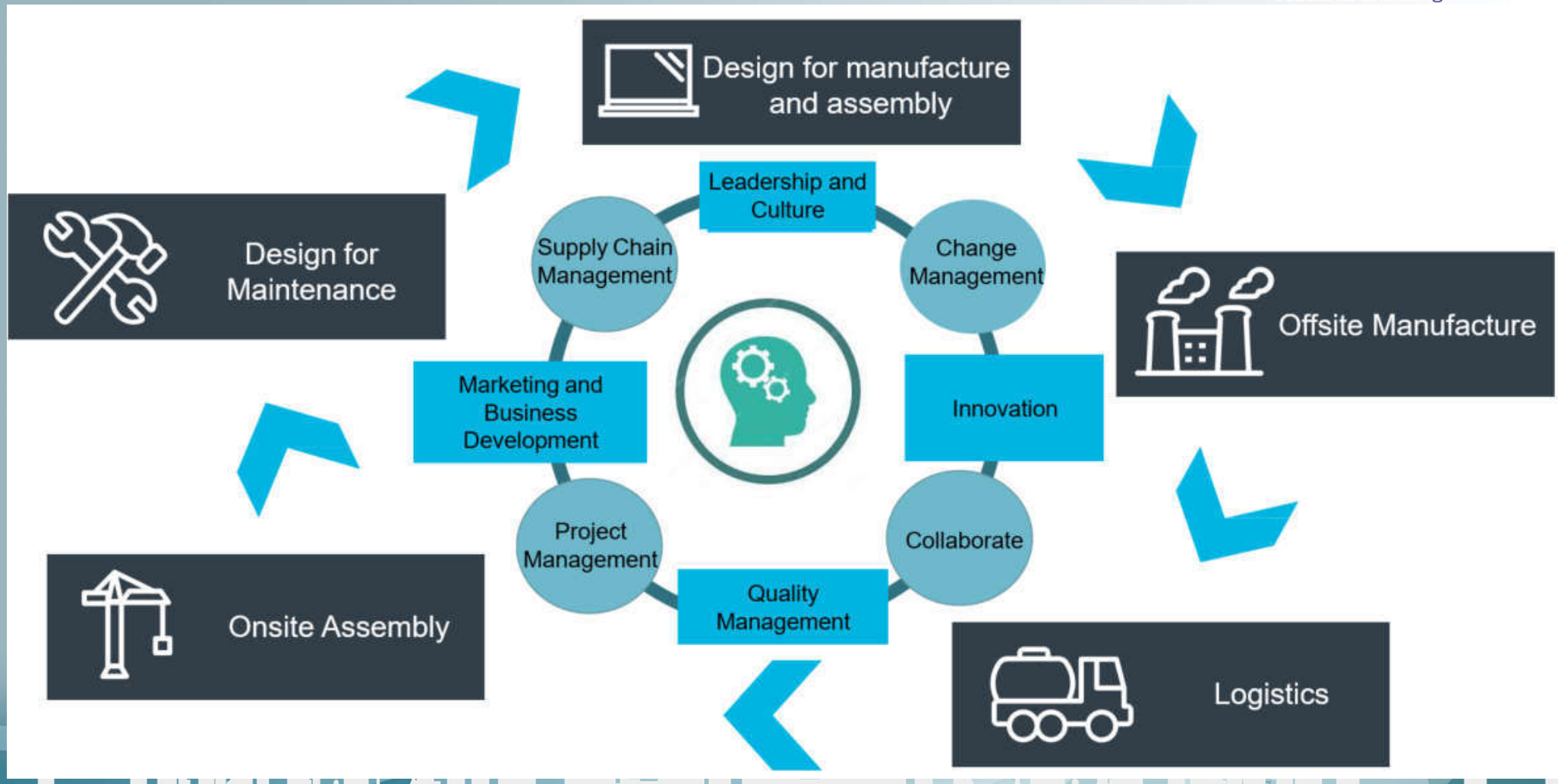
DfMA (innovate)

Lean (processes)

4. Discussions

- Recommended strategies to drive DfMA adoption
  - Raise awareness by education and promotion
  - Engage stakeholders to create the demand
  - Enhance supply chain collaboration/ecosystem
  - Build up local capability and skills
- Useful practical guidelines from Construction Industry Council (CIC):
  - Adopting DfMA for MEP Works (A Concise Guide) [PDF]
  - https://www.cic.hk/eng/main/aboutcic/publications/reference_materials/

DfMA mindset and the construction industry



Source: CIC, 2022. *Adopting DfMA for MEP Works (A Concise Guide)*

5. Conclusions

- DfMA philosophy is an important basis and enabler to industralised construction
- To realise full potential of DfMA and offsite techniques, it is important to promote digital transformation, lean thinking and industrialised construction across the whole construction industry
- Application of DfMA to building services systems requires a paradigm shift not only in design methodology but also in professional practice process

Thank You