

DIGITAL ROADMAP FOR BUILDING COMPLETION AND FINISHING



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ABBREVIATION

AI	Artificial Intelligence
AR	Augmented Reality
BIM	Building Information Modelling
BNM	Bank Negara Malaysia
CBOR	Client Brief of Recommendation
CCC	Certificate of Completion and Compliance
CIDB	Construction Industry Development Board
COBEPN	Construction & Built Environment Productivity Nexus
CREAM	Construction Research Institute of Malaysia
DfMA	Design for Manufacturing Assembly
DOSM	Department of Statistics Malaysia
HDS	High-Definition Surveying
HVAC	Heating, Ventilation and Air Conditioning
IDD	Integrated Digital Delivery
LiDAR	Light Detection and Ranging
MPC	Malaysia Productivity Corporation
MR	Mixed Reality
PPVC	Prefinished Prefabrication Volumetric Construction
PVM	Prefabricated Volumetric Modelling
QLASSIC	Quality Assessment System in Construction
SMAC	Social, Mobile Analytics and Cloud
STEM	Science, Technology, Engineering and Mathematics
USA	United States of America
VR	Virtual Reality
WBS	Work Breakdown Structure

PREFACE

Digital Roadmap for Building Completion and Finishing is developed as a guide to enable Government, industry and academia within the construction industry to respond to the rapid changes towards the Fourth Industrial Revolution (IR4.0). This document aims to provide guidance to digitally transform Malaysian construction, with focusing on roles and responsibilities of industry players in construction towards the next industrial revolution.

This document consists of Malaysia's construction industry overview, that includes current trends impacting today's construction industry and overview on roles and responsibilities of industry players in construction. This document is also highlighting 12 disruptive technologies identified by The Construction 4.0 strategic plan that can be adopted within working scope of building completion and finishes working inside construction industry, pointing out example on area or activities where these technologies can be applied and pointing out solutions that are already available in the market and technologies that are under development that could be available in the near future.

This digital roadmap addresses 1 out of 4 key enablers that support the Construction 4.0, which is construction industry players. This document highlights what needs to be done on each enabler, enhancing them in preparing for digital transformation.

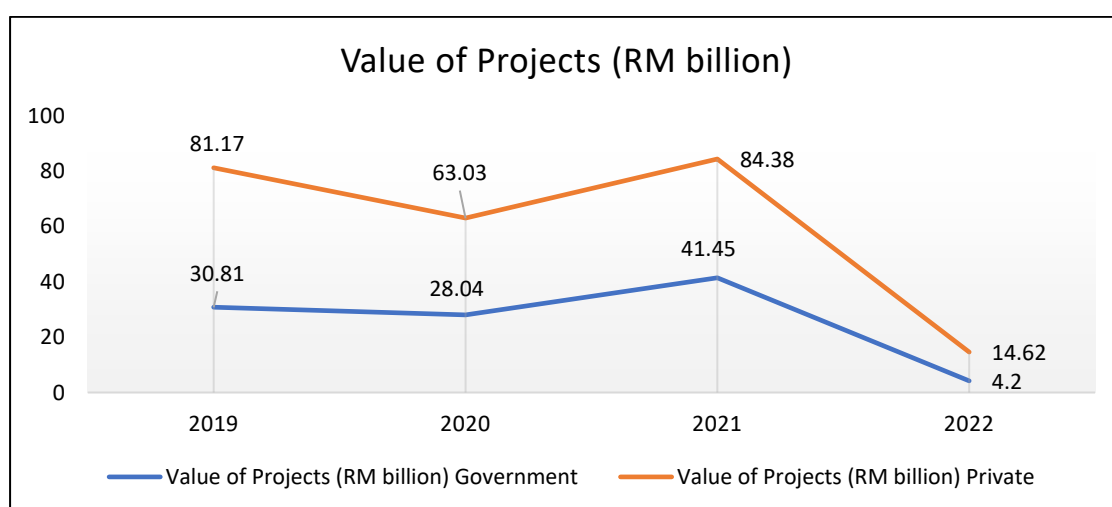
This document provides guidance in the construction industry on how to react with disaster recovery plans should the industry be experiencing acts of nature or cyberthreats. The roadmap also provides guidance on how to get started with digital transformation, highlighting initiatives and funding support provided by government agencies in launching the industry towards embracing digitalisation. The roadmap also highlights challenges that may face during the transformation and possible solutions to overcome it.

Digital transformation is affecting the construction industry faster than ever before due to rapid advancement in technologies, bringing along many benefits such as cost reduction, improved collaboration and increased productivity. Embracing digital transformation is no longer an option, industry players that are involved in construction must start adopting digital tools in every aspect of their work scopes in order to be on par with other industries. This document is expected to assist industry players in the construction industry in adopting emerging technology and moving ahead towards the next construction industry revolution, The Construction 4.0.

CONSTRUCTION INDUSTRY IN MALAYSIA

CONSTRUCTION INDUSTRY OVERVIEW

The construction industry recorded a decline of about 12.9% in the fourth quarter of 2021, with the value of construction work amounting to RM27.6 billion (Figure 1). The construction sectors are dominated by the private sector with a share of 58.7% compared to the public sector with 41.3% with a value of completed construction works of RM16.2 billion and RM11.4 billion respectively (DOSM), 2022).

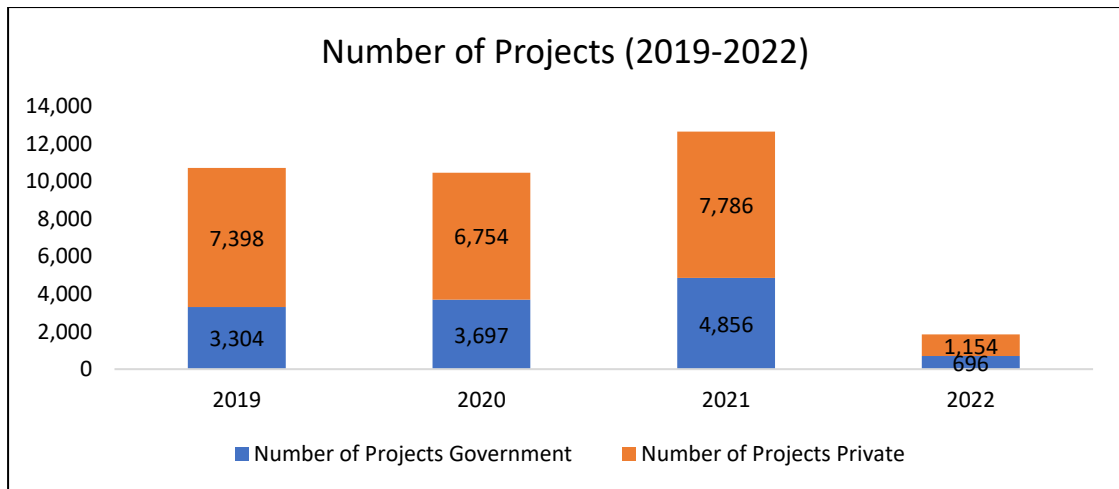


Note: as of March 2022

Source: CIDB (2022)

Figure 1: Value of Projects

In March 2022, the number of projects recorded is 696 for government projects and 1,154 for private projects. From 2019 to 2021 there is an increase in both government and private projects (Figure 2).

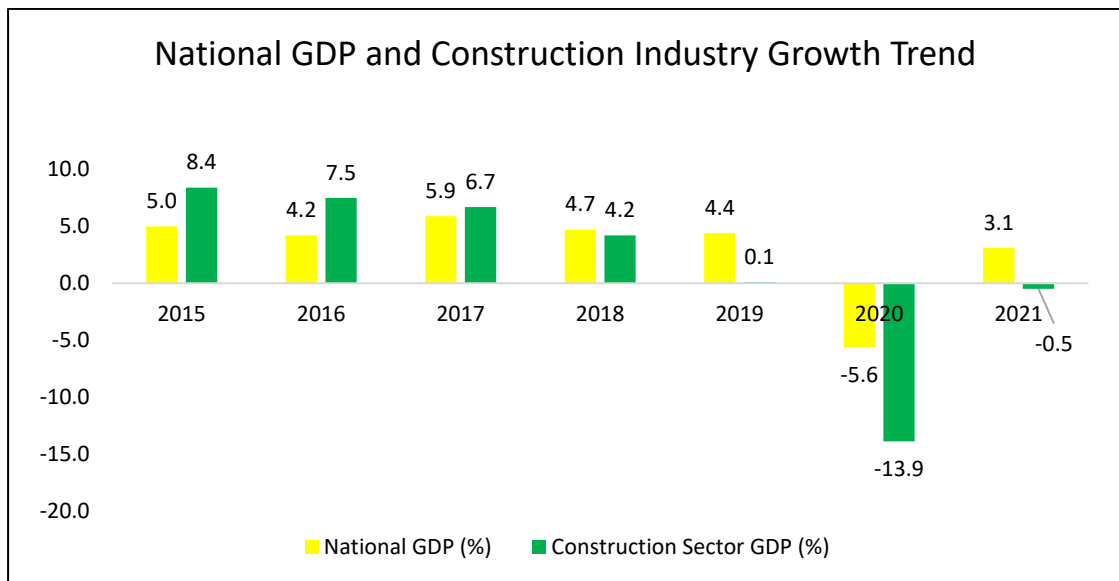


Note: as of March 2022

Source: CIDB (2022)

Figure 2 (a): Number of Projects (2019-2022)

As reported by Bank Negara Malaysia (BNM), there is a positive trend in national GDP growth in 2021 compared to 2020, indicating the impact of the COVID-19 pandemic. Table 1 shows the national GDP and the growth trend of the construction industry (Bank Negara Malaysia (BNM), 2022).



Source: Bank Negara Malaysia (BNM) and Department of Statistics Malaysia (DOSM)

Figure 2 (b): National GDP and Construction Industry Growth Trend

Table 1: National GDP and Construction Industry Growth Trend

Year	2015	2016	2017	2018	2019	2020	2021
National GDP (%)	5.0	4.2	5.9	4.7	4.4	-5.6	3.1
Construction Sector GDP (%)	8.4	7.5	6.7	4.2	0.1	-13.9	-0.5

Source: Bank Negara Malaysia (BNM) and Department of Statistics Malaysia (DOSM)

Overall, labor productivity increased by 1.7% in Q4 2021 to a record value added per employment of RM 24,006 per person. However, the construction industry is known to be the lowest productive producer compared to other sectors. As reported by the Department of Statistics Malaysia (DOSM), the Construction Department recorded a declining percentage of minus 11.2% in the fourth quarter of 2021 and minus 18.8% in the third quarter of 2021 for the value added of labor productivity per employment. Although labor productivity per hour worked increased with a growth of 1.3%, data on labor productivity per hour worked showed a declining trend in the construction sector from minus 5.7% in Q3 2021 to minus 11.2% in Q4 2021 2021 quarter (Table 2).

Table 2: Labour Productivity

Period	Labour Productivity, Value Added Per Employment		Labour Productivity, Value Added Per Hour Worked	
Q4 2021	RM 9,063	-11.2%	RM 15.50	-11.0%
Q3 2021	RM 8,597	-18.8%	RM 16.90	-5.7%

Source: DOSM (2021)

Building Completion and Finishing

Completion and completion of the building is the final part of the construction process before the developer receives the Certificate of Completion and Compliance (CCC). Finishing work can be defined as that phase of construction that provides a pleasing, finished appearance and protects the building. Finishing work includes enclosing interior walls and ceilings, installing finished floors, cabinets, doors, moldings, capping interior and exterior surfaces, and finishing plumbing, heating, ventilating, and air conditioning (HVAC), electrical, and communication systems.

Current developments and state of the Malaysian construction industry

In recent years, industry's interest in digitization and reindustrialization has increased. For digitization to make way, every party in the industry should be electronically connected so information can flow both ways and the information can be used as input for decision-making at all levels of the industry.

In the Malaysian construction industry, the use of digitization in construction completion and finishing is not yet widespread and is still in the phase of slow adaptation. However, it is believed that in the future Malaysia will learn and use the technological knowledge used by developed countries like Singapore.

The level of mechanization in the construction industry can be categorized into onsite and offsite construction. Four (4) levels have been identified for on-site construction:

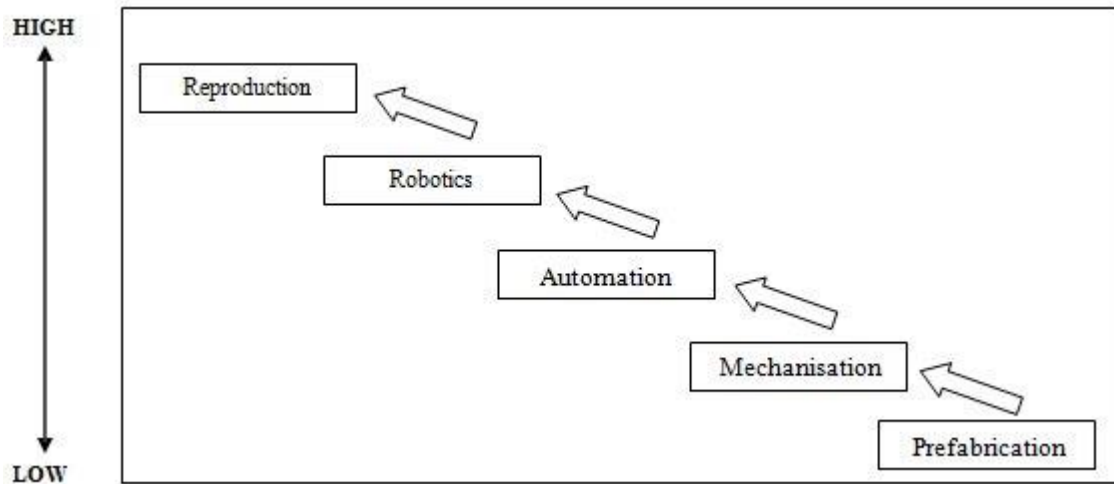
Level 1: Simple and non-complex

Level 2: Enhancement of existing plant and machinery

Level 3: Task specific and dedicated machine

Level 4: Intelligence and cognitive machine

One of the most important studies on industrialization concepts in construction was the work of Roger-Bruno Richard (2005). In his research, Richard found that the large number of components in the design are subassemblies; Therefore, construction is still a construction site-intensive craft. As a result, the degree of industrialization should be an indicator to measure the degree of adoption of industrialization in construction. The level of industrialization discussed in Richard's research is shown in Figure 3.



Source: Richard (2005)

Figure 3: Degree of Industrialisation

There are five degrees of industrialization. The first four are prefabrication, mechanization, automation and robotics. They duplicate the conventional construction process and merely transfer the task from human labor to the machine. The fifth degree, reproduction, implies the research and development of innovative processes, truly capable of simplifying production. The following are the elaborations of the five degrees of industrialization by Roger Bruno Richard.

Level 1: Prefabrication

“Pre” in prefabrication means “before” or “elsewhere”. In the construction industry, prefabrication means components are manufactured in a factory very similar to those found on a traditional construction site, using the same on-site materials and processes. For example, most modular prefabricated home manufacturers in the United States use timber frame panels with automated equipment very similar to that used on the construction site. Prefabrication reduces construction costs by up to 15% when the factory is producing at full capacity and in mass production. Other advantages of prefabrication are:

- Weather protection (factory control)
- Specialised tooling and handling equipment
- Semi-skill labour
- High-quality control

Prefabrication could limit the flexibility of a building's design. The benefits to commercial enterprises, contractors, and their stakeholders outweigh the little reduction in flexibility, though. Several advantages include:

- i. **Reducing Labor Risk:** Although it is already challenging for contractors to locate workers, construction must nevertheless be done. Fragmented building on-site significantly diminishes labour productivity and increases the likelihood of errors. Prefabrication enables businesses to complete projects more quickly and more productively because less manpower is needed on the jobsite. As on-site construction goes on in pieces, labour productivity is reduced even further. Prefabrication enables firms to shorten deadlines, maximise on-site labour, increase efficiency, and compete successfully in the market.
- ii. **Increased Safety:** Prefab is typically noted for decreasing congestion on the jobsite and enhancing safety due to the regulated and cleaner offsite environment. By shortening the duration of a building site, you also shorten the window during which the site is open to theft or damage.
- iii. **Cost-Savings:** Moving parts and units from the fabrication factory to the job site for assembly results in higher labor productivity and lower costs. The jobsite's safety is improved and mistakes are reduced thanks to the efficiency realized by managing less-needed trade personnel. Transporting partial assemblies from a plant is also less expensive than transporting pre-production materials to every location. As labour productivity rises, personnel-related expenditures also decrease.
- iv. **Saving Time:** Prefabrication is credited with many reports and case studies' large schedule savings, which result in a significant return on investment for all stakeholders, including the owner. This is crucial for minimising delays due to inclement weather and other factors. The rainy season is all about timing, and prefabrication will enable you to work within more constrained time frames.
- v. **Quality control:** Factory tools can provide additional quality assurance when compared to repeated building on-site. On-site safety is also increased by streamlining manufacturing and assembly procedures. Using factory tools rather than doing the same work on-site might increase quality assurance. Additionally, regular indoor factory environments minimise the impact of weather on manufacturing, and streamlined production and manufacturing increase overall job site safety.
- vi. **Lessening environmental impact:** The regulated atmosphere of a fabrication shop allows for a more precise distribution of materials to the jobsite and substantially lowers waste. Reduced emissions and work disturbance are the results of accelerated off-site part production. This minimises local flora and fauna disturbance and protects surrounding wetlands or protected areas. Modular building uses less water because of the controlled, dry atmosphere and permits recycling of scrap and other resources. Additionally, with less on-

site traffic and simplified transit, fossil fuel use falls. Due to the fact that various components of a structure are finished in the factory, there is significantly less truck traffic, machinery, and material suppliers at the final construction site. Therefore, the disruption caused by typical workplace irritants like noise, pollution, garbage, and others is negligible. This method of organised design provides a far more conducive atmosphere for work and eliminates unwelcome interruptions and disruptions characteristic of building sites.

- vii. Flexibility: Modular construction is simple to deconstruct and transport to different locations. This significantly lowers the demand for raw materials, uses less resources, and saves a lot of time. The design of the structure can be flexible thanks to modular construction, opening up an endless range of options. Prefabricated building units' neutral appearance can be paired with practically any type of construction because they can be employed in a variety of settings.

Level 2: Mechanisation

Mechanization is the term used whenever machines or machines are engaged in work such as the use of power tools, mobile cranes and other machines. Usually, prefabrication is accompanied by mechanization. For example, to lift the 3D volumetric or modular units, a mobile crane is used to lift the 3D modular units. Mechanization is the transition from doing work mostly or entirely by hand to doing it using machines. Building projects are growing more demanding and complex, and if traditional construction methods are followed, projects would be delayed. Mechanisation mostly applied in the highway projects, irrigation, buildings and power plant and other applications. In general, mechanisation can be divided into two (2) categories which are onsite mechanisation and offsite mechanisation (industrialisation).

When machinery is used to reduce the workload of the labourer, mechanisation is involved. This is frequently true anytime there is extensive prefabrication. Automation, which replaces human employees with machines, is a state of having a highly technological implementation or the act of executing the control of equipment with cutting-edge technology, typically requiring electronic gear.

The characteristics of mechanisation includes:

- Machineries operate by operators;
- Related to systematic flow process of production;
- Reduce tradesmen and improve productivity, efficiency and profitability (results);
- Implement product standardisation;
- High product quality and standard;
- Ease and fast production;
- Optimum use of material, manpower and finance;
- Mass production; and
- Better working condition

The following construction activities required extensive application of mechanisation:

- Steel structure fabrication;

- Roof trusses fabrication & assembly;
- Block, bricks tiles (Roof, floor and wall tiles);
- Pavers, wall panels, slab panels;
- Manual job at site including; concreting and bricklaying
- Plastering;
- Shell structure (involving reinforcement, formwork and concreting), also foundation

Motives for Construction Industry Mechanization

- The job may be completed quickly, preventing time and expense overruns.
- Because a lot of materials may be handled, the project's size can be enlarged.
- The intricate tasks utilising premium materials.
- The ability to sustain high standards.
- A timetable can be maintained.
- Best possible use of resources, including money and labour.
- A lack of effective and skilled labour.
- To employ mechanised equipment instead of the conventional way when planning building projects in order to reduce time and expense consequences.
- Lower insurance prices for contractors.
- Work that is simpler and safer for construction workers.
- Long-term sustainability improvement of a building.
- Minimal to no construction trash at the site

a) Onsite Mechanisation

On-site mechanisation is the use of mechanical and electrical machinery and equipment to support labour-intensive building tasks. It helps the construction process. Common machineries and equipment which are used onsite are as follows:

- Mobile cranes;
- Poker vibrators;
- Excavators and other earth moving equipment;
- Roller compactors;
- Fork lift;
- Backhoe;
- Hauling equipment;
- Hoisting equipment;
- Aggregate and concrete production equipment;
- Pile driving equipment;
- Tunnelling and rock drilling equipment;
- Pumping and de-watering equipment

Level of mechanisation for onsite mechanisation are:

- Simple and non-complex machinery – The use of simple and traditional construction machines and equipment in aiding construction activities undertaken by labour and to improve the construction process.
- Enhancement to existing construction plant and equipment – The enhancement can be done through the attachment of sensors and navigation aids, so as to provide improved feedback from the machines to the operative. The performance of traditional construction equipment over entirely manual controlled methods can be significantly enhanced. Laser control, Radio Frequency Identification (RFID) and ultrasound are commonly used.
- Task specific, dedicated machine – Most of construction machines and robots have been developed in Japan construction “big five” company; Shimazu, Obayashi, Takaneka, Taisei and Kajima. They can be categorised into:
 - i. Machines and robots for structural work, such as concrete placing and power floating and steelwork lifting and positioning
 - ii. Machines and robots for finishing or completion of work such as exterior wall spraying, wall and ceiling panel handling, positioning and installation
 - iii. Machines and robots for inspection work, for example window and ceiling clearing. Task specific, dedicated robot generally under tele-operation and program control. The operative control is positioned outside the immediate vicinity of the machine, with the instructions transmitted to the machine via controller.
- Intelligent (or cognitive) machine – This category is a combination or hybrid of category 2 and category 3. This hybrid type of mechanisation and robotics application will be distinctively construction oriented, supported by a high degree of autonomy and knowledge base, in which to resolve the wide range of construction problems.

b) Off-site Mechanisation

Prefabrication, the utilisation of industrialised components, and IBS are all examples of off-site mechanisation. Even while IBS calls for a significant portion of the components in construction projects to be manufactured, site-intensive handicraft is nonetheless always a part of construction. The amount of industrialization should therefore be a gauge for the adoption of IBS in the construction industry in order to advance toward labour reduction. The indicator shows how far industrialization adoption has advanced.

Level 3: Automation

The term "automation" refers to a self-regulating process carried out by programmable devices to complete a number of activities. Another kind of automation is when a machine entirely performs the laborer's previous work. The foreman is still present,

and the engineer and programmer are nearby even though the tooling is taking over. According to a study on Swedish wood frame panels put together by automation, there is a 27% cost savings over conventional building techniques.

However, it was determined that the previous emphasis on employing automation just to boost output and cut costs was short-sighted because it is also required to supply competent personnel who can maintain the machinery and do repairs. Additionally, the upfront expenses of automation were significant and frequently could not be made up for when completely new manufacturing processes took the place of the outdated ones.

With automation, the tool completely takes over the tasks performed by the human. A supervisor is still there, although the industrial engineer and the software or computer engineer are essential supervisors of the participants.

Level 4: Robotics

In robotics, the tool has the same function as automation and has the multi-axis flexibility to handle even diversified tasks. The fields of robotics and mechanical engineering share similarities with artificial intelligence. Robotics is the ability of a single piece of machinery with multi-axis flexibility to carry out a variety of activities on its own.

The robot is too expensive for nailing wooden studs and laying bricks. However, it is still possible and applicable to use the robot for construction work. The future of robotics is related to computer-aided manufacturing (CAM). CAM generates complex shapes that vary from unit to unit, opening the way to individualization with mass production, opening the way to mass customization.

Level 5: Reproduction

The wording is taken from the printing technique. From now on, the analogy to printing serves to extrapolate a methodology that brings productivity and economy to architecture. Reproduction is the introduction of an innovative technology capable of simplifying the duplication of multi-piece goods. The purpose of reproduction is to abbreviate the repetitive linear operations that are the hallmarks of the artisanal approach, such as laying bricks, plastering walls, and others.

Compare with the other level of industrialization that invests directly in machinery; Reproduction is more towards research and development for ideas to produce a simplified process. Reproduction is not necessarily an option; it may also accompany some of the other degrees of industrialization. The real message of reproduction is to prioritize ideas over machines.

The product is expected to have a clear idea of performance. The ability to envision a simplified topology and knowledge of the processes currently available will result in solutions capable of delivering high quality architecture to the vast majority of people.

Reproduction means that creative process development and research are actually capable of making the production process simpler. Reproduction requires a lot of creativity since it streamlines the manufacturing of complicated things using a new

technology and achieves greater economies of scale than mechanising, automating, or robotizing old construction techniques. Reproduction directly satisfies the industrialization's goal, where quantity justifies an investment in streamlining manufacturing.

The following are already in the market products produced using the concept of reproduction:

- **Hollow core slab:** Extrusion of concrete along a line of pre-stressed cables; rather than building (and dismantling) formwork, installing the reinforcing, delivering and pouring the concrete on the site; the cheapest way to produce a structural slab
- **Multifunctional lightweight precast panel:** Casting or pressing or moulding a monolithic panel integrating thermal & acoustical insulation, air & vapor barrier, structural or bracing capacity, cladding and texture as well as the jointing geometry; then spraying a coating to achieve waterproofing; rather than putting up a stud wall with insulating blankets, air and vapor barrier membranes, exterior sheeting and cladding as well as interior finish.
- **Toilet pod / modular toilet system:** incorporating all the components (bath/washbasin/shower/even toilet bowl) and facilitating the maintenance (round corners and no tile joints) in composite, through deep-drawing, covering or even centrifugation; rather than laying & grouting tiles on a waterproof backing. Or producing the same shell in metal through electro-deposition.

Challenges in Adopting Digital Technology in Construction Industry

Although the adoption of digital technology in the construction industry is quite significant nowadays, the industry has had to overcome some challenges in order to realize it. Some of the highlighted challenges are:

- i. Reluctant to change
- ii. The construction industry has an aging workforce making it more difficult to accept the technology
- iii. The industry is struggling to attract younger generations to participate in the construction industry

Many awareness programs and training courses should be created for the different generations to realize that the current trends in the industry are moving in the direction of digitization.

Besides that, construction industry has known as its uniqueness which each project has various and different requirements. Some of the issue can't be resolved repeatedly using the same solution. This situation makes the construction industry more challenging and require expensive start up to adopt digitalization. The digitalization adopted must tailor with their project needs.

Moreover, implementing digital in the construction industry require extra coordination because construction industry involves many parties at different stage of construction

life cycle. The issue of digital maturity also common as different parties has different level of technology maturity adoption.

Adopting digitalization in an organization require a skilled and knowledgeable workforce on the technology. It must be suited with the current age of the worker in the organization and attitude towards accepting technology and digitalization. Some of the workers aged above 40 reluctant to change towards technology and rather to use manual, commonly used. On top of that, to hire new staff and sending for training is quite expensive and could also time consuming.

It is undeniable that adopting digitalization and technology in an organization require high initial investment. Initial investment including equipment, software, training etc. Though we know the usage of digitalization could fasten the process, however, it took some time to get the Return on Investment (ROI). It may be no problem for big company, however, for SME and small company, it would affect them to implement their operation. Thus, to encourage the organization to implement digitalization and technology especially small company, an initiative related to the high initial investment must be created.

Motivation in Adoption Digital Technology in Construction Industry

i. Evolving client expectations

Customers, impacted by other rapidly changing markets (like B2C with platforms that have sparked new relationships, tailored products and powerful service levels) now expect the same from their homes, offices, commercial buildings and infrastructure to make their connected lives even more powerful create a reality. Constructions must be increasingly individual, modular, connected to the Internet of Things (IoT) and enable, for example, targeted performance tracking, energy optimization and improved safety and health parameters. Customer requirements are rapidly increasing and becoming more complex, with expectations increasingly being placed on usage rather than the product itself.

Currently, client does expect involvement of technology and digitalization rather than previous practices. The adoption of digitalization could reduce time and in the long term, can also reduce cost of operation. Client's foresee the usage of digitalization could give many benefits in the future.

ii. New technological capabilities

Sensors and various hardware and software have seen cost reductions and efficiency gains in recent years, opening the way to new possibilities. The technologies available on the market are more numerous than ever (such as virtual and augmented reality, drones, robotics and additive printing), so there is an urgent need to separate the more valuable from the mere novelties. New technology can provide services that manual practices can do. In this sense, it could be the motivation to the company to adopt digitalization and technology related to the company's operation.

iii. New generation of craftsmen and professionals

Technological know-how is spreading in the construction industry, which has traditionally been resistant to change, accelerating the adoption of digital tools. Innovative university curricula train the younger generation for emerging technology-related professions. In the coming years, the introduction of new tools and processes will create many new, previously unknown jobs. Currently, those who have skills especially in digitalization or technology for an example, big data, IoT and others has great demand from the bigger companies. It is an opportunity for the younger generation to take this chances to upskills their self and contribute their knowledge and skills to the market. Lot of training centres are provided training on the technology usage and digitalization.

iv. Booming start-up environment

Startups have seized the market opportunities induced by some of these trends to fill newly created value creation gaps. Oliver Wyman has identified nearly 1,200 real estate and construction startups worldwide since 2010.

v. Supportive legal frameworks

Governments, particularly in the Nordic countries and the UK, are tightening their carbon and energy efficiency regulations and raising their targets. Digitization offers a great opportunity to reduce the environmental impact of construction projects. Increased requirements will also be placed on data use and cyber security in buildings and infrastructures in the future, which must be analyzed in detail (General Data Protection Regulation). Importantly, labels and groups are increasingly being created to help the market move in a common direction and support innovation.

vi. Launch of large infrastructure projects

The market need is huge in terms of new infrastructure networks between cities (such as the Grand Paris Express with 200km of new automated metro lines in France, the High Speed 2 in the UK or the Rastatt Tunnel in Germany) as well as in terms of the modernization of some old existing structures.

TRENDS IMPACTING CONSTRUCTION INDUSTRY

The construction becomes digital. A few key areas are likely to have a major impact on the construction industry in the coming years. Some of the trends that will affect the construction industry in the future are as follows:

Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR)

This technology allows the human to feel the situation on the construction site without actually having to go there. Virtual reality allows us to switch to digital content as the actual work on site is overlaid with the physical or digital model.

AR and VR are quite different in their application. AR deals with the integration of real objects with a computer-generated image. Meanwhile, VR is a way to simulate an entire environment or scenario. VR is widely used in construction to show clients a picture of what a proposed project will look like once completed.

AR is a great tool for interacting with complex information. With the help of AR, real objects can be overlaid with information for the end user. Also, we can anticipate the introduction of technologies that will integrate sensory information such as sound, mixed and assisted reality.

Effective communication is crucial during the course of a construction project. Virtual Reality offers an exciting solution that literally brings collaborative teams to the field without even being on site. VR simulates an environment by creating an exact rendering in a computer. Using VR headsets, participants can enter the simulation and explore the floor plan of a building.

This enables various teams to organize and plan for the efficient and effective execution of the work long before the construction project begins in earnest. By creating a virtual and immersive environment, architects can have an accurate measure of spacing, layout and materials from start to finish. Being able to see work in progress without a physical building being there helps you make informed decisions with confidence.

In addition, architectural firms can easily make changes, e.g. B. changing materials within the same design. This saves a lot of time and clearly shows customers the options so they can also make informed decisions based on their aesthetic preferences and budget. Essentially, VR enables the entire project team to easily navigate through the complexities and requirements that are typical sticking points in the construction industry. Combined with AR, mixed reality solutions significantly improve the performance of construction teams.

Digital models as legal documents

Some of the developed countries like the United States of America (USA) have used digital models in federal courts along with state courts. It is said that the digital models as legal documents are the beginning of the data revolution.

However, several aspects need to be considered before this technology can be fully adopted by industry. First, data ownership. In many cases, digital twins may contain copyrighted material, which means that the intellectual property provisions of contracts need to be updated to reflect the now broader range of uses of digital twin data. In some cases, this can be as simple as including the digital twin in the contractual definition of permitted use, but this varies from contract to contract.

Any license granted in relation to the use of the data should be for a reasonable period of time so that it does not expire before the end of the twin's life. This is likely the entire lifecycle of the asset, process or system, potentially many years.

It must also be legally clear who is the rightful owner of the data contained in the model. It is important that the rights of individual parties making a specific contribution continue to be recognized, especially when the data shared contains copyrighted material. However, complex situations can arise where more than one party has contributed, as the end product of data sharing can result in a shared ownership situation.

Unless regulated by specific contractual provisions, the rights of co-owners may not be clear. If ownership of the individual data contributions resides with the party that shared the data, where does ownership of the digital model as a whole reside? This needs to be set up.

Second, data sharing and confidentiality. By their very nature, digital twins rely on data sharing, and the contracts that govern them must allow for this. This is contrary to current norms, which prohibit non-essential sharing of data. However, this prevailing cultural resistance to data sharing, particularly where the benefits are technical, complex or difficult to understand, must be broken down if the full benefits of digital twins are to be realised. The case must (where possible) be asserted as a legitimate reason for the disclosure of data for the continued benefit of the public.

There is a related issue of confidentiality. Given the number of stakeholders who may have access to the digital twin, some parties may not feel comfortable sharing sensitive information, such as B. trade secrets. This can be further compounded by the fact that with any data sharing platform there is always a risk of security breaches and data loss and any vulnerabilities associated with such systems increase significantly when different digital twins are brought together.

If the data is considered confidential, appropriate non-disclosure clauses may be required in individual contracts, or a project-wide non-disclosure agreement must be signed by all parties. Many users of the twin may require different access permissions so that sensitive data can only be viewed by specific users. Likewise, some parties may request that certain data be redacted. However, this should be proportionate. Even if not all information has to be embedded in the model, a digital twin is only ever as good as the data that flows into it.

Last but not least, liability. Probably the most complex issue is that of liability. Digital twins are interconnected systems in which changes to one piece of data affect other parts of the model, and as the digital twin evolves, more and more parties can use and rely on data, which may contain errors. In situations where there are multiple parties

and sources of data, the digital twin is likely to require a single organization to act as the data gatekeeper to prevent unauthorized changes. However, when there is a fault, it can still be difficult to determine where the liability lies.

Equally, the blame may not lie with one party alone, or it may be hard to prove that the original data provided was not of sufficient quality to begin with. The fact that different parties are relying on the accuracy of data provided by one another may also lead to trust issues.

Easy access models in the cloud

Nowadays it is more convenient to have shared documents in one place that is cloud based. Being cloud-based allows everyone to access the same documents without silos between onsite and offsite work. It's also cost-effective, eliminating the need for paper copying for everyone involved, and it's more sustainable.

All related data on projects can be accessed in a central location where employees or related parties can use their mobile devices to access the files and perform related tasks. Of course, firstly, some of the benefits that could be applied to the construction industry are that they can improve accessibility. The related parties can access cloud applications, files, documents and project files from anywhere as long as you have an internet connection. Everyone on the team can see the status of the projects.

Next, there is no manual update if you are using the cloud base. Everything is updated automatically. Information is also posted to the cloud in real-time, ensuring all connected parties do not miss any information about which projects are being updated and changes made. In addition, adopting a cloud basis will improve the collaboration of each team member. Cloud features like screen sharing and virtual workspaces ensure everyone sees the same documents instantly. This effort can save time and energy as a team.

A cloud-based construction management system also helps create a single source of truth for a project. This measure can ensure a reliable source of data and information that the entire team can trust and improve project consistency and quality throughout the project. Apart from that, using the cloud base provides extra security as the documents and files are kept safe in the cloud storage space until one of the team members needs them. We might lose data when using a phone or laptop, but with the cloud, the document is kept safe.

Robotics

Some of the developing countries like Japan and Germany have already introduced robotics in their construction industry. In Malaysia, especially during the COVID-19 pandemic, the construction industry has started looking for robotic technology. The introduction of robotic technology makes it possible to simplify and fully automate traditional construction activities such as welding, material handling, packaging and many other activities. This action also allows for precision and accuracy throughout the build process and represents a significant time and cost savings.

Different types of robots will perform different types of work and construction phases, e.g. B. Masonry robots, 3D printing robots, robots to support construction site safety,

self-propelled construction vehicles, robots for construction demolition and exoskeletons. Some of the benefits of using robotics in construction include jobsite safety and increased efficiency. In terms of safety, the use of robots can ensure safety measures for the workforce as the robots can be controlled from a safer area, eliminating the need to physically enter the site. Surprisingly, the use of robotics in the construction industry resulted in higher work efficiency due to its program. In addition, robotics can improve on-site accuracy compared to human labor, which can eliminate the likelihood of human error and still provide more accurate results.

Although adopting robotics in construction could be higher in initial cost, robots are faster and more productive compared to manual labor. The task can be solved more quickly and ultimately leads to overall cost savings for construction projects.

3D Printing in construction

3D printing is successfully used in various industries such as aerospace, automotive and healthcare. Significantly, it has gained prominence in the construction sector. This is due to the ease of making prototypes, molds and solid objects and the possibility of last-minute corrections. 3D printing allows for the reduction of labor at the construction site as the process is automated with 3D printers, the ability to manufacture components on site, which can reduce logistics costs and speed up the construction process by printing different materials at the same time. The advantages of introducing 3D printing to the construction site are increasing design flexibility without sacrificing structural stability, using new materials for construction, already integrated components into built structures, such as blueprints.

Sustainable construction

Globally, construction consumes approximately 40% of all global energy production, produces 30-40% of all solid waste and 35-40% of CO₂. By adopting green building methods such as solar technology and increasing focus on a building's thermal performance, the industry can incorporate new technologies and make the final design and structure more sustainable.

In the UK, the construction industry is using sustainable building techniques to meet its target of reducing CO₂ emissions by 50%, with 50% faster delivery and 33% lower cost from the initial cost over the life of a built facility.

Artificial Intelligence (AI) and Big Data

AI can be used at different stages of the construction project lifecycle. Some of the advantages of applying AI in the construction process are avoiding cost overruns, AI is better for building planning through generative design, risk mitigation in terms of safety, quality, time and cost. In addition, AI works better in project planning and makes construction sites more productive. As we know, many local workers are involved in construction work. Adopting AI can address the problem of labor shortage and off-site construction.

Especially in the post-construction phase, facility managers can continue to use AI long after construction is complete. By gathering information about a structure through sensors, drones, and other wireless technologies, advanced analytics and AI-powered

algorithms gain valuable insights into the operation and performance of a building, bridge, roads, and almost anything in the built environment. This means AI can be used to monitor developing issues, determine when preventative maintenance needs to be performed, or even direct human behavior for optimal security and protection.

Based on the research done by Roland Berger, the parties that can be use AI in their construction projects are as Table 3. Implementation of AI involved various parties in every stage in the construction such as architects and planner, construction companies / developer, facility managers, building material distributors / merchants and building material manufacturers.

Each of the parties plays an important role in the construction stage for an example, architects and planner able to develop new creative designs and can reduce effort in planning also integrating the planning into range of services. AI will involve all parties starting from building manufacturers which can improve quality and reduce complaints, reduce downtime etc.

Table 3: Party Involved in AI

Party Involved	Advantages
Architects and Planner	<ul style="list-style-type: none"> • Develop new creative designs • Reduce effort in planning • Integrating the planning into range of services
Construction Companies / Developer	<ul style="list-style-type: none"> • Track progress and quality in real time • Use autonomous machinery • Reduce time for search of tools and materials • Improve safety
Facility managers	<ul style="list-style-type: none"> • Control building technology automatically • Exercise predictive maintenance • Improve decision making
Building material distributors / merchants	<ul style="list-style-type: none"> • Find optimal points in time to procure • Optimize inventory management • Offer optimally tailored prices and services to customers • Optimization and automate (autonomous machinery) delivery of goods
Building material manufacturers	<ul style="list-style-type: none"> • Improve quality and reduce complaints • Optimize formulation and production • Improve utilization of production machinery • Reduce downtimes

The application of AI is supported by BIM, which can be called the backbone of the construction of the future. AI can be applied throughout the construction process, including design, build or execution, building management and operations, and deconstruction.

The activities involved AI in the planning stage are:

- Project concept and idea
- Preliminary of conceptual design
- Detailed design
- Proceeding on the granting permission
- Analysis and simulations
- Detailed planning and documentations
- Competitive tendering procedure

Whereas in the construction stage, the process involving AI are as follows:

- Construction preparation
- Construction, structural work
- Drywall framing
- Building technology work
- Interior work
- Ordering procedure
- Manufacturing
- Logistics and delivery
- Site management
- Handover / acceptance of construction work

Besides that, the AI can also be applied in the FM and Operations stage which involve:

- Facility management, operation and maintenance
- Refurbishment, renovation and reconstruction

In the demolition stage, the AI will be use in the demolition and removal process.

CONSTRUCTION PROJECT LIFE CYCLE

The construction project lifecycle starts with Design & Engineering, Construction, Operations & Maintenance, and Renovation & Reuse. Figure 4 shows in the Operation & Maintenance and Renovation & Reuse phases that the digital technologies used can be varied during the construction process. The industry focuses on finishing and refining buildings and could use this technology:

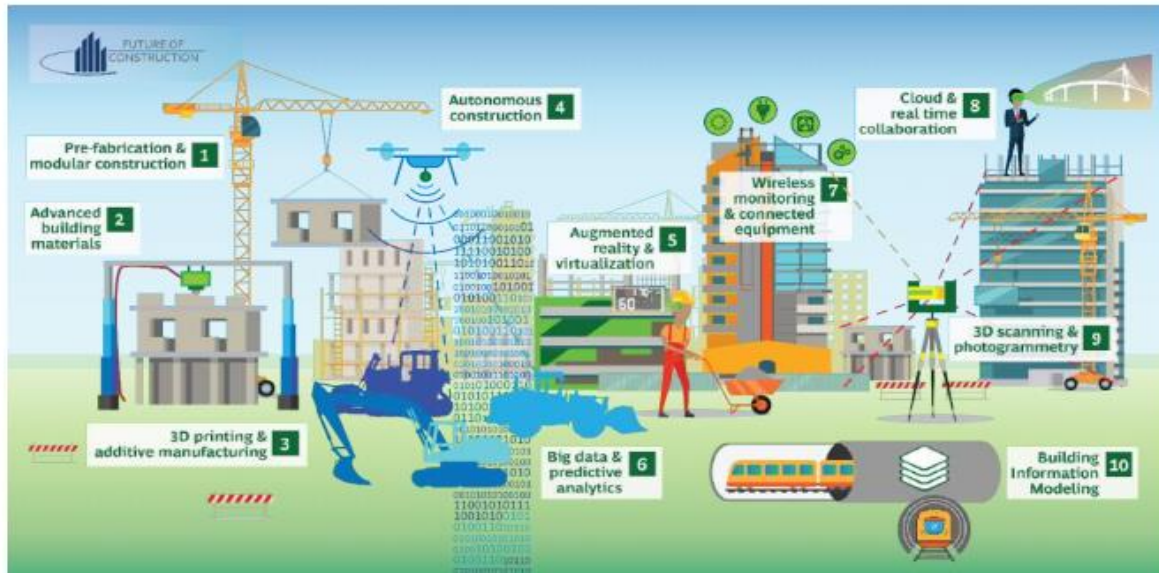
- Autonomous vehicles
- Modular Construction
- Robotics
- Drones
- Digital Reality: Virtual Reality, Augmented Reality, Mixed Reality
- 3D Printing
- 3D Scanning
- Artificial Intelligence (AI) and big data
- Blockchain
- Building Information Modelling (BIM)

Previous researchers have proven that the use of digital technologies in the construction industry leads to cost savings, quality improvements, faster construction processes and the avoidance of waste and emissions. This technology could be used in the various construction phases. For example, an autonomous vehicle could be used in four (4) construction phases (Design & Engineering, Construction, Operations & Maintenance, and Renovation & Reuse). Also, modular design, the technology could be used from the early construction phase to the end of the construction phase.

Stage	Design & Engineering	Construction	Operation & Maintenance	Renovation & Reuse
TECHNOLOGY	Autonomous Vehicle			
	Modular Construction			
		Robotics		
	Generative design	Drones		
	Marketing Tech	Energy Management		
	Digital Reality; Virtual Reality, Augmented Reality; Mixed Reality			
	Inventory and Supply Management		Wireless Charging	
	Blockchain	IoT and Sensoring		
	3D Scanning	Additive manufacturing / 3D Printing		3D Scanning
	Insurtech for construction			
	AI and big data			
	Blockchain			
	Building Information Modelling (BIM)			

Figure 4: Digital Technologies throughout the Construction Lifecycle

In addition, Digital Reality: Virtual Reality, Augmented Reality and Mixed Reality can also be used throughout the construction process. Artificial intelligence (AI) and big data, blockchain and building information modeling (BIM) could also be used along the construction process. Focusing on the later phase of construction, i.e., renovation and reuse or completion and completion of buildings, the technology could be used for 3D scanning, IoT and sensing, AI and big data, blockchain and BIM (Figure 5).



Source: *Future of Construction*, World Economic Forum, Boston Consulting Group

Figure 5: Digitalisation in Construction

The important phases of the construction process can be divided into six (6) categories:

- i. Construction progress monitoring
- ii. Safety management of construction personnel
- iii. Building materials monitoring and waste tracking
- iv. Efficiency optimization of construction equipment
- v. Building performance and quality assessment
- vi. Optimisation of building design and operation

The Boston Consulting Group has outlined the use of digitization along the construction process. Starting from the early stages of construction, where prefabrication and modular construction can be used, to the end of construction with Building Information Modeling (BIM). Ten (10) suggestions for the use of technology in the construction industry are as follows:

- Pre-fabrication and modular construction
- Advanced building materials
- 3D Printing and additive manufacturing
- Autonomous construction
- Augmented reality and visualization
- Big data and predictive analysis
- Wireless monitoring and connected equipment

- Cloud and real-time collaboration
- 3D scanning and photogrammetry
- Building Information Modelling (BIM)

These technologies in the construction industry could set trends for the future use of technologies. The introduction of technology and digitization in the construction life cycle could improve the productivity of the construction sector as well as the country's GDP as a whole. The construction sector has a well-known cross-sectional sector that is closely related to manufacturing, including machinery and equipment used in the construction industry.

A case study conducted by Khalesi et al.,(2020) has categorized 25 buildings as Work Breakdown Structure (WBS) that are expected to take around 348 days to complete the entire construction process. However, the real situation in the implemented time in days delays about 176 days out of the total of 524 days. This number has shown that the productivity in the construction process has the potential delays of the traditional method. The use of digitization could improve construction time, reduce waste and ensure health and safety (Table 4).

Table 4: WBS Level in Construction

No.	WBS Level	Anticipated Time (Days)	Implemented Time (Days)
1	Delivery of Site	1	1
2	Site Preparation	12	19
3	Implementation of Foundation	26	42
4	Implementation of Building's Structure	43	99
5	Initial Flooring	46	107
6	Implementation of Stair's Foundation	5	9
7	Implementation of Roofs and Internal Walls	84	99
8	Implementation of Stories' Foundation	33	38
9	Implementation of External Walls	9	11
10	Moving Frames and Doors to their places	1	2
11	Implementation of Windows	18	23
12	Implementation of Stairs	2	2
13	Flooring the Stories	33	45
14	Moving Electrical Appliances to their places	2	3
15	Installation	16	34
16	Installation of Frames	13	32
17	Implementing Toilets	1	5
18	Initial Joinery of the Floors	19	36
19	Final Flooring	24	36
20	Installation of Cornices	6	12
21	Final Joinery of the Floors	30	44
22	Installation of Floor's Appliances	6	12

No.	WBS Level	Anticipated Time (Days)	Implemented Time (Days)
23	Implementation of Façade	18	43
24	Painting	20	33
25	Delivery of Project	4	7
Total Time		348	524

The use of drones in the construction industry could be applied throughout the construction ecosystem at all stages of a construction life cycle. There are five (5) stages in the construction lifecycle where drones can be deployed:

i. Planning and Design

In this phase, drones make it easier to conduct surveys and prospects. This task could be made easier by recreating 3D maps, aerial photos or ground surveillance.

ii. Construction and logistics

The introduction of drones at this stage could contribute to key operational capabilities in terms of monitoring progress by capturing real-time data, avoiding errors or calculating volume. It also enables site surveillance, structure inspection and access to inaccessible places or areas.

iii. Commercial activities

In this phase, drones help to generate audiovisual content and viewing operations in real time.

iv. Operations and maintenance

Drones can facilitate construction monitoring and regular on-site inspections. Identifying risks and monitoring the useful life of the structure have helped carry out numerous safety campaigns. In addition, the information gained through the use of drones can provide information to insurance companies.

v. Demolition

Drones help capture images and create models to predict the fall. The changes have proven notable in creating a safer work environment.

CONSTRUCTION GO DIGITAL

The first step for the industry going digital is to identify elements of change. Do we have these elements?

Elements in Digitalization

i. **Intelligent design and planning**

At this stage, the base technology could be Building Information Modeling (BIM) and significant data. This could lead to a reduction in design errors and an improvement in the quality of design and construction processes through virtual and digital simulations such as the digital twin.

ii. **Fleet management**

In the task of fleet management, the technologies involved are the Internet of Things (IoT) and Big Data. The application of fleet management enables remote monitoring through the use of sensors and analysis of the status and location of construction machinery such as work vehicles to reduce costs, improve energy efficiency and limit machine idle time.

iii. **Predictive maintenance**

In this predictive maintenance task, the technologies involved are the Internet of Things (IoT), Big Data and AI. This process allows the condition of machines to be monitored through the use of sensors and analytics with the aim of performing preventive maintenance and reducing potential breakdowns.

iv. **Innovative fabrication methods**

The enabling technologies involved in this task are IoT, Big Data, AI, BIM and drones. This process involves rethinking construction processes and operations from an intelligent perspective, using the information gathered through data collection and analysis to speed up processes, reduce costs, improve energy efficiency and operational safety.

v. **Monitoring and Evaluation of Resilience**

The technologies used in this phase are BIM, IoT, Big Data, AI and drones. This technology is a better real-time survey in all phases of the project, such as B. Providing appropriate support to local operators and monitoring infrastructure resilience after project completion.

vi. **Autonomous equipment and self-drive vehicles**

The enabling technologies in this phase include IoT, big data and robotics. In this technology, it introduces driver assistance systems and autonomous driving to improve construction processes and reduce physical workload on the construction site.

Digitalisation Involved by Stages

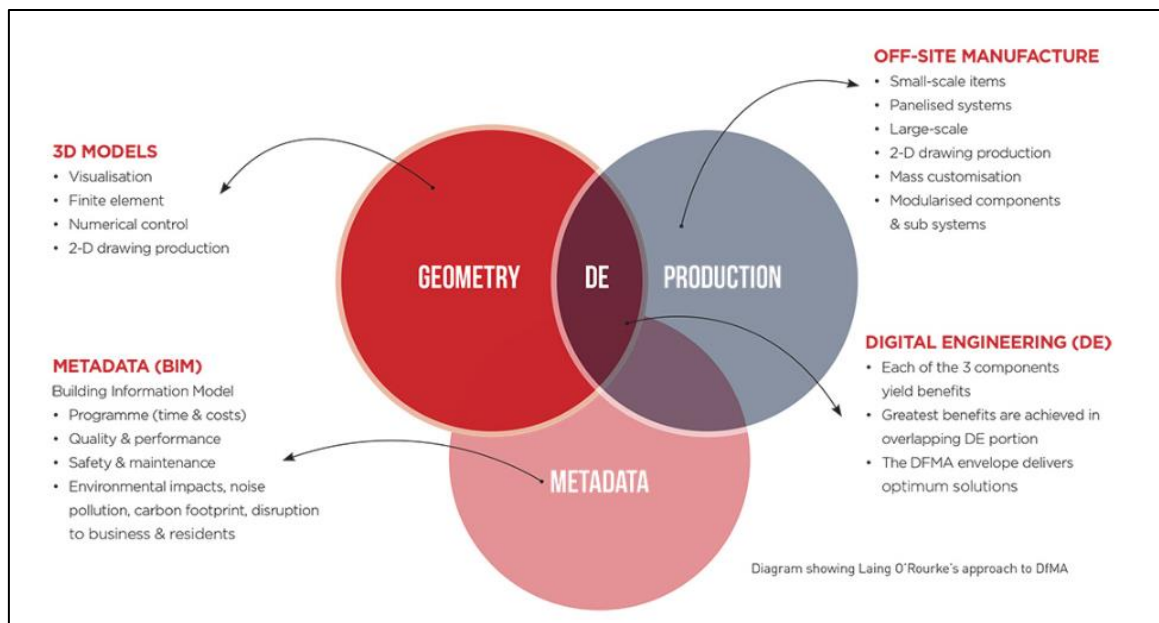
Three stages (3) are determined in the construction industry involved with digitalization as follows:

Pre-Construction Phase

During this phase, the adoption of Design for Manufacturing Assembly (DfMA), Prefabricated Prefinished Volumetric Construction (PPVC), Prefabrication Volumetric Module (PVM), Modular Construction and Building Information Modelling (BIM).

i. Design for Manufacturing and Assembly (DfMA)

Design for Manufacturing and Assembly (DfMA) is a concept or mindset that begins early, before design begins. This concept supported the implementation of prefabricated prefabricated volumetric construction (PPVC), in which the construction workflow is planned from the early stage. From Laing O'Rourke's perspective three (3) key components of DfMA have been outlined: Geometry, Production and Metadata. Figure 1 shows the details of the DfMA envelope (Figure 6).



Source: Mcfarlane et al., (2014)

Figure 6: DfMA Envelope

a) Geometry

The geometric model is the 3D virtual model as represented in a software package such as Building Information Modeling (BIM) and allows the technical and non-technical team members to visually understand and challenge the intent of the design. The main components should include the engineers' finite element models, geometric components and CNC (Computer Numerical Control) models that allow for the automated production of the relevant elements of the project.

The 3D model, with appropriate naming convention, can also be used to create 2D drawings that may be required for non-automated processes such as regulatory

approvals, third party manufacturers of small series, etc. However, this should be minimized by favoring 3D approvals directly from the full model.

b) Production

DfMA production involves off-site fabrication in a factory environment and the modules produced may include small parts such as electrical fittings; large-area objects such as precast concrete ceilings and panel systems made of steel structures, precast concrete parts or wood; and fully enclosed volumetric spaces, such as individual rooms or entire buildings. The entire furnishing process (i.e. structural, electrical, mechanical and decorative work) is ideally carried out in a factory. In particular, factory production generally achieves a higher level of quality control (QC) and improved overall quality assurance (QA).

Notwithstanding, nowadays a significant part of the work can be automated and carried out by robots, where the input to the robots should be provided by computer numerical control software derived from the geometry model.

c) Metadata

The metadata model is a multidimensional database containing all relevant project parameters. This model can be used not only to calculate the impact of time, process, planning and cost, but also to analyze environmental impacts such as carbon footprint, sustainability, noise pollution, air quality and other environmental impacts. Other benefits include waste reduction, error prevention and reduced costs. Therefore, in combination with the 3D geometry model, the metadata model can enable all stakeholders to analyze the impact of different design options.

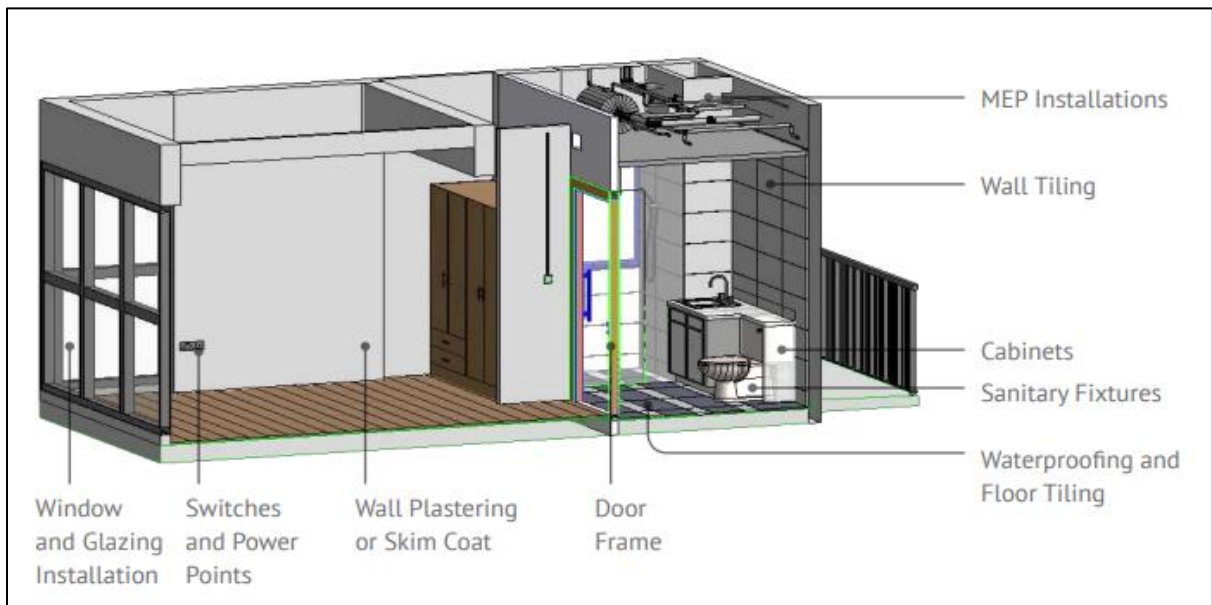
d) Digital Engineering (DE)

Each of the components (geometry, production and metadata) includes Digital Engineering (DE). DE plays an important role in promoting integrated design for manufacturing and installations. DE integrates with 2D, 3D, 4D and 5D for construction design and cost quantification that help build a metadata model, a multidimensional database. This database contains all important project parameters. It enables construction sequencing, scheduling and costing, and supports analysis of environmental impacts such as carbon footprint and sustainability.

i. Prefabricated Prefinished Volumetric Construction (PPVC)

Prefabricated Prefinished Volumetric Construction (PPVC) is a term used in Singapore that objectively supports the DfMA concept to speed up the construction processes. PPVC comprised the volumetric modules completed with finishes for walls, floors and ceilings using two methods, either designed and assembled or fabricated and assembled. Adopting PPVC can result in productivity gains, a better build environment, fewer on-site personnel, and better-quality control. During architectural and mechanical, electrical and plumbing (MEP) work, contractors should consider the work to be carried out in a protected environment and by trained workers. The incorporation of architectural finishing and MEP work into PPVC, which includes:

- MEP installation
- Wall Tiling
- Cabinets
- Sanitary Fixtures
- Waterproofing and Floor Tiling
- Door Frame
- Wall Plastering and Skim Coat
- Plastering, Skim Coat and Painting
- Switches and Power
- Window and Glazing Installation
- False Ceiling
- Railing Installation
- Wardrobe
- Floor Finishes Installation and Skirting
- Lightweight Panel Painting



Source: BCA (2018)

Figure 7: MEP Works in PPVC



Source: BCA (2018)

Figure 8: Finishing Works in PPVC

ii. Modular construction

Modular construction (or offsite manufacturing) is part of the DfMA process. The term modular construction refers to any of several construction methods (applicable to buildings and civil works), all of which ultimately configure the required materials on a site to create a built environment in accordance with a specification. Any method that minimizes on-site labor and maximizes prefabrication is considered modular construction.

iii. Prefabricated Volumetric Module (PVM)

The prefabricated volumetric module can be described as a building process that uses a modular or volumetric method. PVM is a standardized unit of construction designed for ease of manufacture and assembly, with a variety of surface finishes. Execution levels depend on the Client Brief of Recommendation (CBOR).

Prefabricated Volumetric Modular Construction (PVMC), as it is also known, is an effective construction method with a sustainable behaviour that decreases construction time, resource waste, and onsite workload, leading to improved quality, faster, safer, and more environmentally sustainable construction.

The modern urbanisation adaptation of PVMC is a respectable substitute for conventional multi-story building construction. Although it is frequently used in low-rise and low seismic regions, its application under different circumstances might be difficult due to limited awareness and knowledge of the extreme multi-direction forces at play.

Prefabricated volumetric modular buildings' seismic behaviour is dependent on the joint connections made by the modular parts. Therefore, it is crucial to enhance PVMC's joint connection details and implement seismic resisting features.

Researchers from all over the world have carried out experimental and numerical investigations to assess how these buildings respond to lateral loading.

A prefabricated volumetric modular component (PVMC) is made in a factory and transported to the construction site where it is built and linked using specially made connectors. PVMC is an industrialised construction procedure. When compared to conventional structures, PVMC buildings are more efficient and have a lower deadweight because to their assembly method, design system, and detailing requirements. Figure 1 depicts the manufacturing step of the construction of a volumetric building.

Based on the level of prefabrication, there are three categories of prefabricated construction: 1D single element, 2D panelized system, and 3D volumetric system. The most effective type of prefabricated construction is panelized and volumetric construction, often known as modular construction, which enables 70% to 95% of a building to be prefabricated in a factory before being transported for on-site assembly.

On-site, straightforward inter-modular connectors can be used to link prefabricated modules. Even though PVMC has been used extensively for low-rise structures over the past three decades, less than 1% of high-rise buildings have PVMC installed.

Utilizing a volumetric modular construction technique, prefabricated volumetric modular construction decreases construction time, resource waste, and onsite workload. Compared to conventional onsite construction, it offers building solutions that are more affordable, quicker, safer, and environmentally friendly. In addition to its various benefits, PVMC's performance in multidirectional forces is pushing its adoption as a respectable substitute for traditional construction.

Despite having several advantages over cast-in-situ structures, PVMC are not commonly used in the construction sector. This is because there is little information available on the design and force-transfer mechanisms of joint connections. According to earlier PVMC studies, the behaviour of modular buildings can be improved by implementing efficient connecting systems that give the structure enough lateral strength and ductility. Although capable of comprehending connections' responses at the component level, current research is unable to fully anticipate the overall seismic performance of modular buildings.

Existing connection types' structural behaviour is still unclear when applied to actual buildings, hence full-scale prefabricated modular structures with inter-modular connections need to be experimentally examined under lateral loading. Headed bars, an alternative to the traditional development length employing reinforcing bars, have demonstrated greater structural performance and cost-effectiveness for PVMC inter-modular connections.

Currently used design rules for traditional buildings are not appropriate for modular buildings and require unique design for joint connections. The standards for structural design of modular connectors are still unavailable. Future study is therefore required to create guidelines for the structural design of inter-modular connections. The adoption of cutting-edge modular technology for high-rise structures will be made possible by the new design regulations, which make it safer to construct modular

buildings. These initiatives may promote the wide adoption of PVMC in seismically active areas of the world.

iv. Adoption of BIM

When you think of BIM/VDC, you probably think of its use in the design phase. But 3D digital twin technologies are used throughout the real estate life cycle, from pre-construction to maintenance and operations. Having up-to-date 3D visual representations of a physical location or asset, while enabling secure collaboration and continuous data analysis across the organization, adds value to everyone involved in the project: owners, engineers, general contractors and subcontractors, project managers, BIM/VDC experts and property management company. In this context, BIM in the form of an as-built certification could be used as a benchmark for the handover phase.

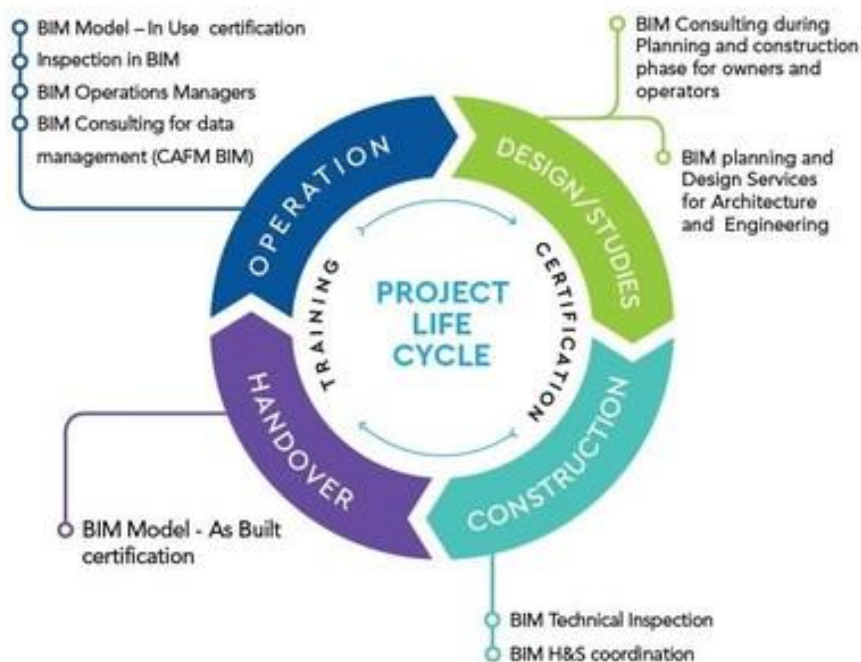






Figure 9: Project Life Cycle in BIM

BIM can be applied in the main phase of construction process. The phase involved BIM can be simplify as Table 5.

Table 5: Application of BIM by Stages

STAGE	APPLICATION
 DESIGN / PLANNING	<ul style="list-style-type: none"> • BIM consulting during planning and construction phase for owners and operators • BIM planning and Design Service for Architecture and Engineering
 CONSTRUCTION	<ul style="list-style-type: none"> • BIM Technical inspection • BIM Health and Safety Coordination
 OPERATION	<ul style="list-style-type: none"> • BIM Model - in use certification • Inspection in BIM • BIM Operations Managers • BIM Consulting for data management (CAFM BIM)
 HANDOVER	<ul style="list-style-type: none"> • BIM model as built certification

Adopting BIM in the construction process is key to the success of Integrated Digital Delivery (IDD), which enables all parties and stakeholders to collaborate using advanced information communication technology (ICT) and smart technologies. The scope of IDD is shown in Figure 3, which includes four (4) phases, namely Digital Design, Digital Fabrication and Manufacturing, Digital Construction, and Digital Asset Delivery and Management.

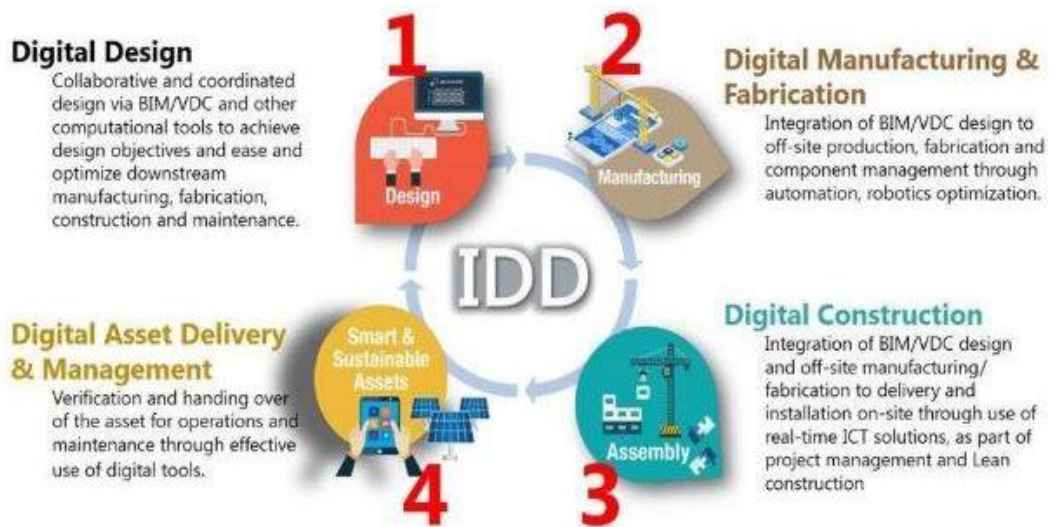


Figure 10: IDD Application in BIM

a) Digital Design

Collaborative and coordinated design via BIM/VDC and other calculation tools to achieve design goals and simplify and streamline downstream fabrication, construction and maintenance.

b) Digital Manufacturing and Fabrication

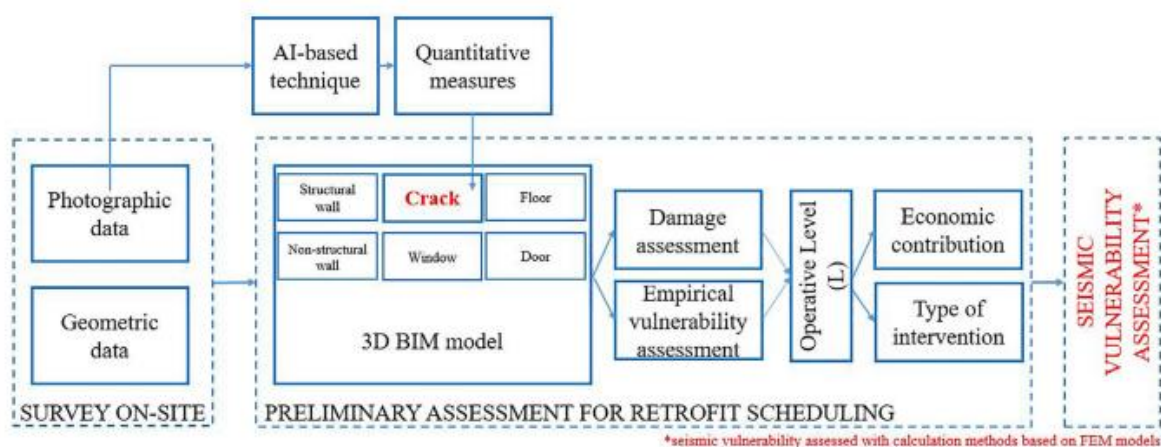
Integrating BIM/VDC design into offsite production, manufacturing and component management through automation, robotics optimization.

c) Digital Construction

Integrate BIM/VDC design and external fabrication/fabrication through to on-site delivery and installation through the use of real-time JCT solutions as part of project management and lean construction..

d) Digital Asset Delivery and Management

Verification and handover of the asset for operation and maintenance through the effective use of digital tools.



Source: Musella et al., (2021)

Figure 11: Workflow of the Damage Assessment Process with Digital Support Tool

One of the key benefits of BIM is the ability to identify conflicts early in the design, resulting in a simpler project flow that saves costs and takes less time. In the traditional design process, specialists worked on separate drawings with tracing paper created during coordination checkpoints to check compatibility. It was not uncommon for collisions to be discovered only on site, with potentially huge costs and delays (Figure 12).

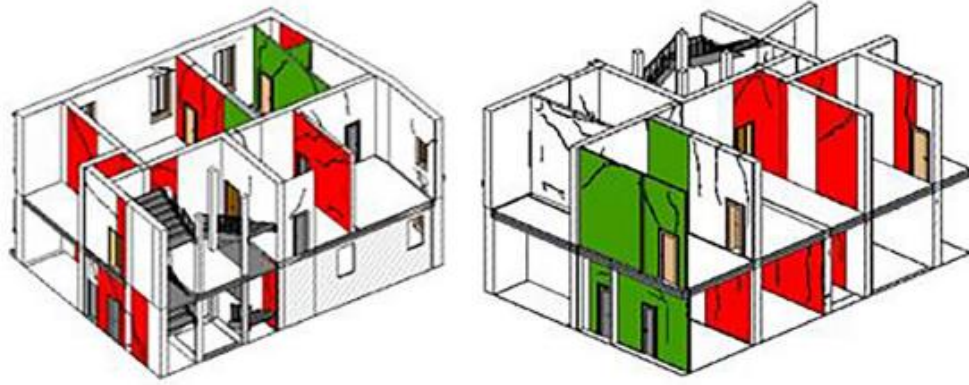


Figure 12: Cracks Identification using BIM

In a Level 2 BIM process creates a set of federated models and uses coordinated data erasures to inform a master model. BIM modeling software and BIM integration tools allow designers to check for clashes in their own models and when combining models.

Clash detection software is becoming more sophisticated, allowing the user to check for collisions within specific subsets (e.g. structural elements against walls) and mark them on the screen (often in bright colors).

Some geometric clashes are always acceptable (think: recessed ceiling lights, pipes embedded in walls) and software rules that rely on embedded object data can prevent these types of clashes from being flagged. As you can imagine, the level of detail in BIM modeling is therefore crucial for collision detection (NBS, 2022).

Globally, BIM has been identified to have four (4) levels which are Level 0, Level 1, Level 2 and Level 3.

a) Level 0 BIM

In its simplest form, Level 0 effectively means no collaboration. Only 2D CAD drawing is used, mainly for production information (RIBA work plan 2013 level 4). The issuance and distribution takes place via paper or electronic printouts or a mixture of both. Most of the industry is already way ahead of that.

b) Level 1 BIM

This typically involves a mix of 3D CAD for concept work and 2D for creating regulatory documentation and production information. CAD standards are managed according to BS 1192:2007 and electronic data exchange is via a Common Data Environment (CDE) often managed by the contractor.

To achieve Level 1 BIM, the Scottish Futures Trust states you should achieve the following:

- i. Roles and responsibilities should be agreed.
- ii. Naming conventions should be adopted.
- iii. Arrangements should be made to create and maintain the project specific codes and spatial coordination of the project.

- iv. A Common Data Environment (CDE) will be adopted to enable the sharing of information between all members of the project team.
- v. An appropriate hierarchy of information should be agreed that supports the concepts of the CDE and the document repository.

c) Level 2 BIM

Level 2 BIM is characterized by collaborative work and requires a project-specific and coordinated information exchange process between different systems and project participants.

Any CAD software that each party uses must be able to export to one of the popular file formats such as IFC (Industry Foundation Class) or COBie (Construction Operations Building Information Exchange). This is the working method set by the UK Government as a minimum target for all public sector work.

d) Level 3 BIM

Level 3 has not yet been fully defined but the vision for it is outlined in the UK Government's Level 3 Strategic Plan. Within this plan, they identified the following “key actions” to be backed up by further funding:

- i. The creation of a new set of international open data standards that would pave the way for easy data sharing across the market.
- ii. The establishment of a new contractual framework for projects procured using BIM to ensure consistency, avoid confusion and encourage open, collaborative working.
- iii. The creation of a cultural environment that is collaborative, aimed at learning and sharing. Trained the public sector client in the use of BIM techniques such as data requirements, operational methods and contracting processes.
- iv. Promoting national and international growth and jobs in technology and construction.

Building Information Modeling is an incredible new engineering technique. Many builders, engineers, architects and contractors use it as it has benefited construction projects throughout the building life cycle.

Project stakeholders and teams benefit from BIM as it allows them to visualize the model and get a clear overview. It helps in identifying potential disputes and resolving them early in the design phase, resulting in a more accurate and precise project design. It also improves collaboration between multidisciplinary project teams and models. The architectural, structural and mechanical, electrical and plumbing teams work on the same platform, visualizing every change at every step of the design phase. It helps reduce material waste, installation problems, and element conflicts.

A study conducted by Oliver Wayman and Autodesk has mentioned that BIM will improve work processes throughout the lifecycle of a construction project, which includes:

i. Design

In this phase, BIM enables an optimized offer design (customer requirements vs. cost ratio) through informed, visual and multiple simulations. It can also reduce the cost of sale through improved product visualization through to possible co-conception and reduce rework through collision detection. BIM as a way to industrialize processes and parts.

ii. Construction

In the construction phase, BIM can improve field productivity through coordinated planning (logistics and maintenance). It can also reduce procurement costs through optimized specifications, quantities and easier negotiations. Additionally, it can reduce workplace injury safety incidents through behavior monitoring and facilitated risk awareness. Overall, at this stage, BIM allows for easy tracking of construction progress through field solutions.

iii. Operations

At this stage, BIM can improve handover management through a documented BIM model. In addition, BIM can optimize maintenance planning (inspections, repairs) through full project transparency. It can also facilitate building energy management (and others like light and air quality) through BIM-powered dashboards. With regard to warranty costs, BIM can reduce these through fewer field failures and optimized decommissioning management through transparent material and quantity documentation.

3D Laser Scanning / High-Definition Surveying (HDS) or reality capture

3D laser scanning services, also known as high definition surveying or reality capture, is a technique that uses laser beams to collect incredibly fine and accurate data of a construction site. A laser beam measures various dimensions of the structure such as the length, width and height of the components and how they are connected to one another. The scanning process uses a special technology for scanning the objects of a construction project. The technology is known as LiDAR (Light Detection and Ranging).

Using laser rays, 3D laser scanning is a technique for gathering incredibly precise and accurate data on a construction site. The length, width, and height of the various construction components as well as how they are connected to one another are all measured by a laser beam.

The 3D laser scanner's point cloud image accurately replicates the scanned objects. Depending on the brand and model of the 3D scanner, it could be used up to many metres away. Building information modelling (BIM) and computer-aided drawing (CAD) technologies can then be used to create 2D CAD drawings or 3D Revit BIM models using the information gathered.

The industry of building can greatly benefit from 3D laser scanning. Using 3D laser scanning, we can swiftly gather data. Most often, point clouds are scanned by drones and converted to BIM. This unmanned aerial system usually uses slam scanners.

Simple to deploy pedestal for aerial mapping and surveying with drones. On the other side, numerous nations have banned drones due to security concerns. Contrarily, the drone gives us crucial 3D laser scans for the BIM process.

Two of the most common types of 3D scanning methods are LIDAR and photogrammetry:

A LIDAR scanner, which is frequently used in architecture and construction, consists of a powerful laser moving horizontally and a mirror spinning on a vertical axis. In this way, the laser scans a vast area at hundreds of dots per second. A strong computer that can store and analyse massive amounts of data is also necessary for laser scanning.

A method for producing 3D models from several images of an object of interest is called photogrammetry. It is periodically essential to create large-scale models of constructions, such as buildings, for a variety of purposes, including restoration, documentation, and archaeological investigation. One of two methods, such as measuring each dimension or 3D scanning the complete structure, could be used to obtain a model of the building. For most circumstances, scanning a structure is more simple than measuring every window, door, and wall.

With the right tools, such building scanning approaches have no boundaries. In a single pass, certain lasers can scan an area with a radius of up to 350 metres (approximately 1150 ft). Even a drone equipped with one of these laser scanners can be used to examine tall buildings and other structures.

On the other hand, photogrammetry mostly depends on the quantity and calibre of images taken. However, it's best to avoid sunny days when using photogrammetry because reflections can easily lead the software astray. Drones can help in this case by taking pictures of remote areas.



Application of 3D Laser Scanning can be used in different stages in construction as follows:

a) Design

Laser scanning technology can be used for site design at the design stage. Some architects use the scan to BIM method to get detailed information to start the construction process and to manage the process. Next, the point cloud data is converted into a 3D model. At this stage, the contractor can opt for complex MEP models or opt for a finely detailed model.

Builders can evaluate the design execution process using 3D laser scanners. To ensure quality, they perform a quick scan to create a 3D picture of the scenario and compare it to specified models and drawings.

b) Retrofits, Renovations, and Operations

With regard to retrofits, renovations and operational phases in construction, laser scanning captures every detail that is considered an as-built record. This data can be used for demolition, additions, renovations and construction operations.

c) Clash Detection

Laser scanning can be used to reduce clashes in a project, including equipment that is not the right size or incorrect placement of pipes. These scans enable the detection of possible problems. Prior to installation or production, components or objects are inspected for potential clashes (interferences, collisions). This process is known as clash detection. It is a method that is applied in a wide range of industries to guarantee that parts are installed without difficulty and with the least amount of downtime or rework possible.

Any recognised disagreement can be economically resolved at the design phase as opposed to being discovered on site and resulting in expensive delays and material costs.

d) Construction Coordination

Laser scanning is used in construction coordination, particularly to avoid conflicts between different systems such as plumbing, electrical, HVAC, and more. The data is then shared between the parties to help with remote coordination.

Scanning can be done at any point in the construction timeline to document milestones and reduce the need for job changes. This scanning can help document where mistakes are made and find a quick fix. 3D laser scanning can also be used for other applications such as during construction and building information modeling (BIM).

Laser scanners promote improved coordination and collaboration, allowing decision-makers in the construction industry to move more quickly. Transparency and communication are improved on a construction site when there is better cooperation.

In many aspects, 3D laser scanning is better to conventional building methods. It makes project execution quicker, more effective, and more seamless. From the initial

design stage to the final delivery stage, builders can execute projects flawlessly by using laser scanners to create precise virtual models of a building.

To obtain precise information and insights into their construction projects, stakeholders in the industry should use 3D scanning services providers. To advance your profession as a builder, engineer, or architect, take advantage of 3D scanning services.

During Construction Phase

Interior finishing is an important process in a building after it has been constructed. The interior finishing includes:

- Painting
- Plastering
- Tiling
- Wiring
- Plumbing
- Heating, Ventilation, and Air Conditioning (HVAC)

This process requires a lot of effort and time for a precise result. The shortage of skilled workers in the finishing process will lead to a repetitive and tiring process, especially for high-rise buildings.

Therefore, there is a significant need for derivative technologies. mobile robots to the criteria of simplicity, low weight, low cost and efficiency. Mobile robots suitable for the construction industry should be able to carry bulky and heavy equipment. A reliable robotic system for interior construction should meet several requirements suitable for construction industry as follows:



Mobile Robotic system to cover a large environment and reach high elevations up to three floors (9-10 meters)



Higher load capacity, stability, and safety, needed to support heavy weights and equipment and reach high elevations



Adaptable to various deployed positions and the shapes of different architectural surfaces and corners



Adapt to environmental conditions and light variation in construction sites such as high temperature, humidity and dust

The interior finishing robots that can be used on the construction site including painting robots, fireproofing robots, and wallboard robots.

a) Painting Robots

Painting robots are widely used in developed and developing countries. The advantage of using painting robots, which can relieve workers from tedious tasks as they no longer have to work near dangerous spray particles and at height. It also minimizes pain dust, paint waste, and human exposure to harmful paint chemicals.

Indoor painting robots are equipped with cameras and scanners. You can scan the surfaces to be painted and then work without human intervention. However, there still needs to be someone overseeing the process. The worker fills up the paint supply and positions the robot before launching it. One person can take care of many robots, which increases the increase in productivity.

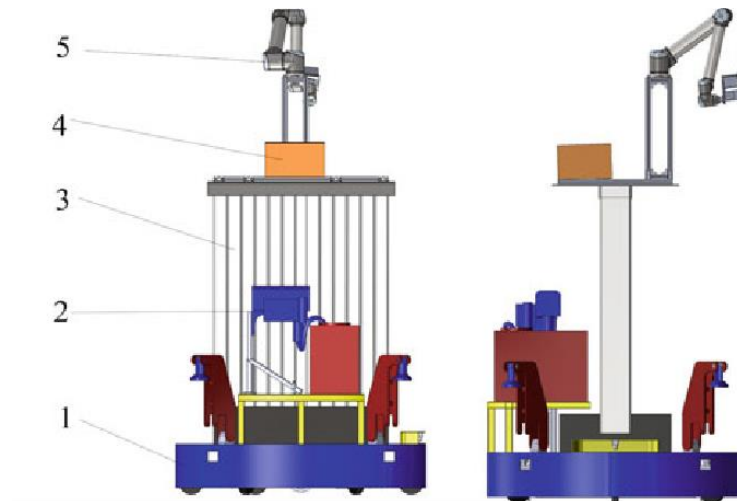


Figure 13: High-Rise spray-painting robot

Both industrialised and emerging nations have a strong demand for painters. Painting ceilings by hand is risky, physically taxing, tiresome, and time-consuming. The RoboPainter is one of the many painting robots that fall under this category in the modern world.

Along with beautiful wall drawings, RoboPainter is able to paint entire walls and ceilings. It has a 6 Degree of Freedom (DOF) spray painting arm installed on a 2 DOF differentially powered mobile base, giving it a total of 8 DOF. The painting arm has a spray painting gun at its tip, and it is also possible to attach other painting guns that are readily accessible in stores. The Maxon DC-gearred motors, position encoders, and ESCON servo controllers used by RoboPainter to control torque actuate the joints.

Another example of an intelligent mobile robot that automatically scans, plans, and paints a building's interior is Transforma's Pictobot. It can work effectively and safely alongside human coworkers as they do the tiresome and tedious chore of painting. It relieves employees of the strenuous job and eliminates the need for them to work at heights or close to dangerous spray particles.

Another model made by Transforma is called QUICABOT, and it is used to check and evaluate the interior finishes of buildings. It gathers information and scans the interior finishing using several sensors and artificial intelligence (AI) to produce an autonomous assessment of various types of faults, including cracks, unevenness, alignment, lippage, and more.

PictoBot is a well-known painting robot that can safely work alongside human coworkers while carrying out repeated interior painting tasks at great heights. PictoBot offers a method for fusing the advantages of building automation with those of human

dexterity and inventiveness. As a result, workers may watch the robot and paint walls from a low height without having to engage in the strenuous activity of climbing, bending, kneeling, and reaching.

A 3-DOF mobile robot, a 1-DOF long-reach jack-up mechanism, a 6-DOF industrial robot arm, an airless paint pump, a painting head system, and a computer-controlled system are the six main subsystems of this robot. The mobile robot's mounting of all spraying subsystems permits the robot to freely move around the construction site and has enough agility to paint corners and surfaces. Through in-situ scanning and spray-gun motion planning, PictoBot is equipped with a sensor-driven painting system that can adjust to the uncertainties of the construction site and robot deployment from various places. Due to its exact control over paint distribution, the robot provides the benefits of collaboration by leveraging worker safety and finishing quality.

b) Fireproofing Robots

Applying the fireproof material to the structural component is said to be one of the most painful procedures involved in construction.

The fireproofing robot SSR1 was first created by the Japanese company Shimizu Corporation to perform this disagreeable duty without endangering human lives. The robot was created to fireproof structural steel members with a mixture of rock wool and cement.

An oil hydraulic unit, spray gun, travel unit, and manipulator's arm were all included with the first generation SSR1. A supply plant and a control panel for travel and spraying were also present. It was battery-operated and moved around the ground with the aid of cables. Because it was pre-programmed, operations could be repeated without interruption all the way across the building.

The operator was 3 metres away from the spray nozzle, reducing exposure to the toxic solutions. Despite all of these advantages, there were some disadvantages, such as the time required to move the unit from one place to another. Each activity required maintenance, careful planning, and training of the workers for the unit's operation.

These problems were taken into account when the SSR-2 was developed. It featured an ultrasonic sensor that enabled the device to automatically adjust its position, a pressurised delivery system that allowed for uniform application of the fireproofing mixture, and an extended arm length for thorough coverage of the area. The guiding cable, which was present in the SSR-1 for automated travel, was eliminated in the SSR robot's second generation. In addition to these updated characteristics, SSR-2 included a unique algorithm that allowed the robot to modify its spray pattern in relation to the architecture of the building.

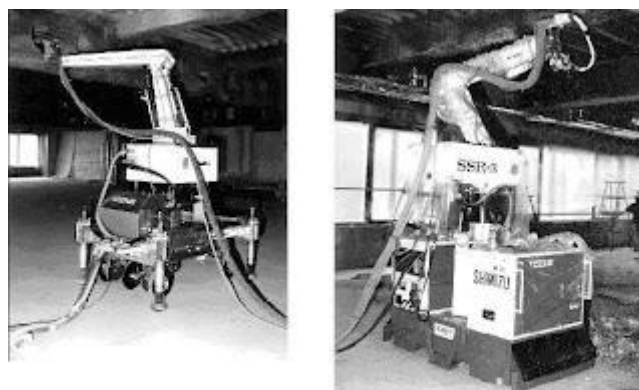
Although the second generation was an improvement over the first, some issues remained. It took time to move the unit from one place to another, and the operator needed training to use and maintain the unit.

SSR-2 underwent more development to create SSR-3. New control panels were added in place of the hydraulic unit, which made the unit smaller and lighter. A remote panel that runs on the offline training system can control the new robot. This made it

possible to cut the "teaching" time by 5 minutes. The arm was changed to enable it to trace the shapes of the structural elements. It enabled it to continue moving while spraying the solution.

The new design also did away with the need for assembly and disassembly. It arrived pre-assembled and needs to be dropped at the desired position using a moving object. Despite all these advantages, the fundamental problem continued to be the operating staff's adequate training. In the field of robotics, this is a prime illustration of the incremental development methodology.

The application of the refractory material to the component is perceived as unpleasant compared to other construction work. Shimizu Corporation Japan was the first organization to develop the fire protection robot SSR1, which was designed to spray the mixture of rock wool and cement onto structural steel parts for fire protection. The new SSR3 design eliminates the need for assembly and disassembly.



“SSR-1” Fireproofing Spray Robots

Figure 14: Fireproofing Spray Robots

c) Wall Board Robots

As reported by Mark Fairchild (2021), drywall workers have a high rate of work-related injuries, the most common being straining and falls. Drywall robots can finish more than 5 levels of drywall. The robot is guided by the worker and can achieve the highest level of smoothness and appearance. Using Artificial Intelligence (AI) and assisted computer vision, the robot can mask and apply the mud, sand the wall and capture 99.9% of the dust.

Wallboard robots are used as suitable robots for mounting the board on walls, partitions and ceilings. The Taisei Wall Board Robot, also known as the BM.02 Robot, is designed for installing large and heavy panels on walls and partitions. It uses vacuum suction cups to hold the board. The cart allowed for the additional storage and movement of 5 to 8 wall panels along with the unit.

The installation of boards on the wall, divider, and ceiling is the primary interior-work task. Wallboard robots are employed for this. For instance, the BM.02 robot, also known as the Taisei Wall Board Robot, was created to put huge, heavy boards on walls and dividers. While the worker adjusts the board's supporting frame, this

manually controlled robot holds the board in place. To hold the board, vacuum suction pads are used. Five to eight wallboards could be moved along with the device and stored in additional space on the cart.

The CFR-1, also known as the Shimizu Ceiling Panel Robot, was created to install lighter boards on ceilings. Just below where the first panel is attached, the machine is positioned. The technology automatically modifies the position of the adjacent panel after the first panel has been lifted and set in place. Scaffolding is not needed with CFR-1, which also lowers labour costs and labour hours.



Figure 15: Wall Board Robots

Post-Construction Phase

In Malaysia, assessment of build quality is done through the Quality Assessment System in Construction or known as QLASSIC. QLASSIC was adopted by the Construction Quality Assessment System (CONQUAS). The Construction Quality Assessment System (CONQUAS), introduced in Singapore since 1989, serves as a national standard for assessing the quality of building projects.

The criteria for the many facets of construction work are established by CONQUAS, which awards points for work that complies with the requirements. The CONQUAS Score for the construction project is then calculated by adding all these points.

The majority of general building architectural works are covered by CONQUAS, and evaluations must be finished before applying for TOP or CSC inspection, whichever occurs first.

The assessment consists of four components:

- (1) Internal Finishes,
- (2) Installation Methods Verification and Functional Tests,
- (3) External Finishes, and
- (4) Bonus Points

(a) Internal Finishes: Internal finishes are primarily concerned with the components and finishes. The level of craftsmanship and quality are most apparent at this point.

The evaluation includes: I architectural components, such as floors, interior walls, ceilings, doors, and windows. Permanent internal fixtures, such as wardrobes, kitchen cabinets, countertops, mirrors, bathtubs, water closets, shower screens, and basins, as well as permanent external fixtures, are examples of components (such signage, railings, unit number plates, lift fittings, letter box, lightings, metal gate, etc.). (ii) the fundamental M&E fixtures, such as faucets and mixers, toilets, floor traps, electrical switches, trunkings, fan coil units, air conditioning diffusers, light fixtures, CCTV cameras, shower heads, etc. Lift display and call button panels are examined as M&E fundamental fittings in the elevator lobby.

(b) Verification of Installation Methods and Functional Tests: During the first phase of the project's construction, installation procedures verification for the following 4 trades will be done: Bathroom and toilet waterproofing, stone and tile installation, installing wood floors, and window installation are just a few examples. BCA will check each step of the above-mentioned trades against the submitted approved method statements and compare it to BCA's good industry practise manuals. The verification of the aforementioned installation techniques will be done in the factory for projects that use prefabricated prefinished volumetric construction (PPVC).

If the PPVC manufacturer or factory has Manufacturer Accreditation Scheme (MAS) accreditation, requirements a, b, c, and d will be waived; if the waterproofing specialist has SCI accreditation, requirement a will also be waived. (ii) Functional tests will be performed to assess the watertightness of windows, wet areas, and the adhesion of internal wall tiles. A maximum of 30% of the total window water-tightness test samples and 20% of the total wet area water-tightness test samples will be completed in the factory for projects that use PPVC.

(c) External Finishes (i) The evaluation will include the building's roofing, exterior walls, and exterior construction.

(d) Bonus Points (i) Qualified personnel from QM/CONQUAS Projects with certified QM/CONQUAS staff receive bonus CONQUAS points. This will promote quality attainment and the on-site deployment of qualified, competent staff. (ii) Material and Design Decisions Projects with superior buildable designs that enable greater quality attainment receive bonus points. Projects with the Quality Mark (QM) According to the quality rating obtained using the QM tiered grading system, bonus points are awarded to the project.

Components to be Assessed	Category of Development		
	Weightage (%)		
	Private Residential	Public Residential	Non-Residential
1. Internal Finishes	60	55	50
2. Installation Methods Verification and Functional Tests	20	25	30
3. External Finishes	20	20	20
Sub Total CONQUAS Score	100	100	100
4. Bonus Points	8	7	7
Total CONQUAS Score	108	107	107

Note : (i) For private mixed development with residential component, the project will follow the weightage under the private residential category.





The total CONQUAS score of a building is the sum of points awarded to the four components in each category of building.

The Quality Assessment System in Construction (QLASSIC) is a system or method for measuring and evaluating the quality of execution of construction work based on the Construction Industry Standard (CIS 7:2006). QLASSIC enables the objective comparison of the execution quality between construction projects using a scoring system. The QLASSIC assessment essentially follows the concept of:

- Pre-determined sampling – Samples are selected from drawing and plans of construction projects
- Assessment – A one-time assessment will be done through site inspection based on the samples identifies from the drawing and plans.

QLASSIC is a percentage rating and is used to assess the construction quality of the building. There are 4 building types for the QLASSIC standard (Table 6). Four categories assessed in QLASSIC are landed housing, stratified housing, public / commercial / industrial buildings without centralized cooling system and public / commercial / industrial buildings with centralized cooling system.

Table 6: Category of QLASSIC Assessment

CATEGORY	TYPES OF PROPERTY
 CATEGORY A	Landed housing
 CATEGORY B	Stratified housing
 CATEGORY C	Public/ commercial/ industrial buildings without centralised cooling system
 CATEGORY D	Public/ commercial/ industrial buildings with centralised cooling system

There are 4 main components for QLASSIC assessment:



Figure 16 (a): Components of QLASSIC

The figure shows the components assessed in QLASSIC which are External Works, Architectural Works, Structural Works and Mechanical and Electrical Works.

Component	Category A Landed Housing	Category B Stratified Housing	Category C Public Building	Category D Special Public Building
Structural work (%)	25	30	30	30
Architectural work (%)	60	50	45	35
M&E work (%)	5	10	15	25
External work (%)	10	10	10	10
Total score (%)	100	100	100	100

Figure 16 (b): Components of QLASSIC

Research done by Construction Research Institute of Malaysia (CREAM) suggested three (3) Smart Technology can be utilized in the Building Completion and Finishing assessment. The feasibility to assess building projects using SMART technology seems to be one of the best methods to utilize digitalization at par with the developed

countries. Smart technology used in QLASSIC assessment is divided by Internal and external finishes. For the external finishes, the smart technology adopted to assess the quality of finishing is Drone. The scope in the external finishes including roof, external wall, apron and perimeter drain and car park / car porch (Table 7).

Table 7: Smart Technology used in External Finishes

Smart Technology	Scope	Defect Category
DRONE	Roof	Finishing
		Rough / Uneven / Falls
		Cracks and Damages
		Joint / Sealant / Alignment
		Chockage / Ponding
		Construction
	External Wall	Finishing
		Alignment and Evenness
		Cracks and Damages
		Jointing
		Finishing
	Apron and Perimeter Drain	Alignment and Evenness
		Cracks and Damages
		Fall / Gradient
		Joints and Gaps
		Finishing
	Car Park / Car Porch	Alignment and Evenness
		Materials and Damages
		Functionality
		Joints and Gaps

Source: CREAM (2021)

Whereas in the internal finishes, the defect area is divided into three (3) categories which are Floor, Wall and Ceiling. In the defect are Floor, Camera or Visual is the smart technology use to assess defect in Finishing, Crack and Damages and Jointing, while Laser Leveller is using for Alignment and Evenness and Tapping rod used to detect hollowness or delamination.

For defect area wall, camera or visual is also use in the defect category finishing, crack and damages and jointing, while laser leveller used in the defect category alignment and evenness. Likewise, floor defect area, tapping rod is using to detect hollowness or delamination. In the ceiling defect area, two (2) types of smart technology were used which are camera and laser leveller. Camera or visual is using in the defect category finishing, crack and damages, jointing and roughness or patchiness while laser leveller using for alignment and evenness.

Table 8: Smart Technology used in Internal Finishes

Defect Area	Defect Category	Smart Technology
Floor	Finishing	Camera = Visual
	Cracks & Damages	

	Jointing	
	Alignment & Evenness	Laser Leveller
	Hollowness / Delamination	Tapping Rod = Frequency
Wall	Finishing	Camera = Visual
	Cracks & Damages	
	Jointing	
	Alignment & Evenness	Laser Leveller
	Hollowness / Delamination	Tapping Rod = Frequency
Ceiling	Finishing	Camera = Visual
	Cracks & Damages	
	Jointing	
	Roughness / Patchiness	
	Alignment & Evenness	Laser Leveller

Source: CREAM (2021)

This section pictures the digital roadmap by phases. Table 9 shows the Digital Roadmap for Building Completion and Finishing involving Pre-Construction, Construction and Post-Construction. The solution for each stages is divided into three sections which are Basic, Intermediate, and Advanced.

Table 9: Digital Roadmap by Phase

No.	Process	Solution	Basic	Intermediate	Advanced
1.	Pre - Construction	Adopting Concept of Offsite Construction	Concept of Design for Manufacturing Assembly (DfMA)	Adoption of Prefabricated Prefinished Volumetric Construction (PPVC)	3D Laser Scanning/ High-Definition Surveying (HDS) or reality capture
			Adoption of Building Information Modelling (BIM)	Adoption of Modular Construction	
2.	Construction	Smart Technology	Adoption of Building Information Modelling (BIM)	Drones	Robotics
3.	Post - Construction	Detailed Assessment	Internal Finishes	Digital Handover user manual	Artificial Intelligence (AI)
			External Finishes		
			Defect Group Categorisation		

DIGITAL SKILLS NEEDED

Industry Skills in Digitalisation

Currently, the use of smart technology or digitization is trending and is especially needed in the construction industry, which can reduce the number of workers on the construction site. The digital transformation in the construction industry will change the skills needed in the industry. Future workers in the construction industry should equip themselves with the skills to use tablets and other smart devices that will greatly simplify the monitoring of processes and operations on the construction site. Some of the digital skills required in this industry are as follows:

Mobile technology

Mobile technology is no longer a foreign word these days. The use of mobile technology in the construction industry can help streamline workflows that keep projects on schedule, eliminate errors and replace manual labor, improve communication and collaboration, and increase productivity during the construction process.

For example, in the reconstruction phase, the quality assessment of the building is required to check for defects in the building. Previously, all accessors used paper to tick the score. This action can lead to human error, typographical errors and the potential risk of paper loss during transmission. However, if the current technology, namely a tablet, can be used during the assessment, it can simplify the workflow during the assessment and reduce the risk of errors.

Building Information Modelling (BIM)

“A shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition” – U.S National BIM Standard

BIM can be applied into various stages in construction.

- Initial idea modelling
- Identifying the ability to build the idea
- Modelling of the structure
- Modelling the electrical and mechanical installation
- Identifying architectural and structural clashes
- Identifying the change of results
- Identifying the construction schedule

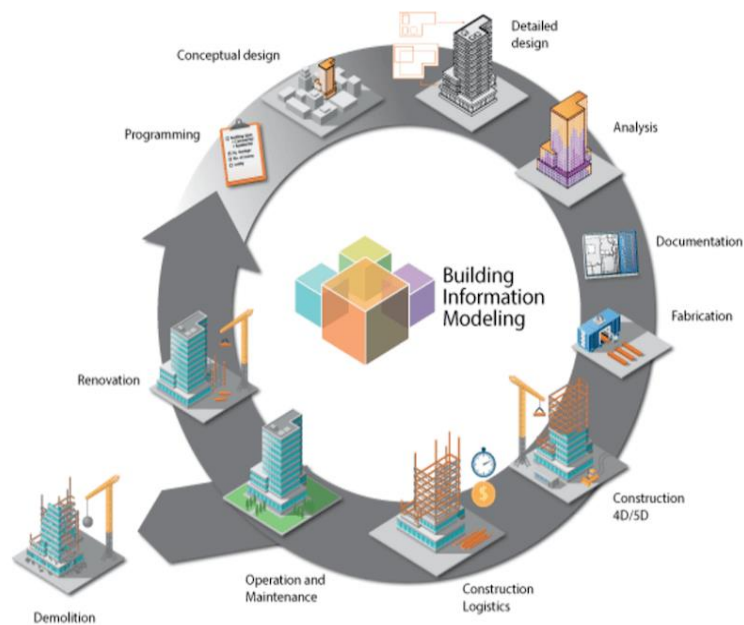


Figure 16: BIM in Project Lifecycle

BIM should be used in the early construction phase. This technology could shorten the construction time, reduce the overall cost and rework cost. Future construction workers should have knowledge of how to implement BIM in their construction projects. BIM can be included throughout the construction process, such as B. Detailed planning, analysis, documentation, manufacturing, construction 4D / 5D, construction logistics, operation and maintenance, demolition, renovation, programming and conception.

BIM enables the contractor to plan and design better. BIM should allow a completed building and all associated M&E services and systems to be visualized on screen before the groundbreaking ceremony. This information enables the architect to better plan and design, making more effective use of the available space and resources.

Many training centers such as Akademi Binaan Malaysia (ABM), CIDB Holdings, IKBN have already introduced BIM training. The students practice how to use BIM in a project and in their organization.

Virtual Reality

Virtual reality is used in a variety of industries, including the construction industry. It can be used as an effective tool for safety and training, and to prevent costly overruns. Virtual reality can help keep employees safe, provide a quick overview of what can be changed to improve productivity, and give management a clear view of designs and construction sites before construction begins.



i) Benefits of Using VR in Construction Training

In the context of cast-in-situ concrete works, research has demonstrated that VR construction training is much more successful than traditional training.

ii) Increasing staff safety

As many personnel must deal with heights and complicated hardware risks, the working environment in the construction industry can be highly hazardous. Therefore, even small mistakes might have serious consequences. Fortunately, safety training in the building sector reduces the possibility of injury because mistakes committed in a VR application will not have serious repercussions. Additionally, learning in a relaxed, safe setting aids in better assimilation of the subject and heightens employee attentiveness.

iii) Boosting professional skills

Virtual reality training programmes can comprise as many scripts as your personnel requires to advance their qualifications. Typically, there isn't spare time to conduct in-person training sessions and occupy workers away from their tasks. Thanks to VR headsets, each professional can train alone at the right time and learn the abilities they need to develop. Your team will be making improvements continuously as a result.

iv) Reducing human error

Simple errors that a machine would never make can be caused by carelessness, distraction, a lack of information, or a lack of abilities. Because of this, acquiring knowledge and practicing frequently are important techniques for lowering human error.

As a result, VR training may offer employees specialized learning resources as well as a variety of script situations to overcome and train. Each professional can respond more quickly and take the necessary action to avert disaster as a result.

v) Improving work performance

Training in a secure, engaging setting gets people ready for specific types of work. Specialists will perform better in the real world as long as VR training can give them a clear idea of what to do in actual, occasionally risky environments by studying it in a safe environment. It's because they'll be knowledgeable enough to avoid spending time on errors, inquiries, and misunderstandings of their responsibilities.

vi) Cutting extra costs

A lot of money and effort are required to plan and carry out in-person training. Having too many employees distracted at once while using a trainer result in additional costs.

Additionally, if we approach this problem from a different angle, it becomes evident that workplace injuries brought on by subpar job training might result in significant financial outlays for the injured personnel. As a result, training in virtual reality can significantly reduce costs as it doesn't necessitate group instruction or human instructors.

vii) Types of Construction VR Training

Virtual reality training for the construction industry is different from completing a video course; it's typically used for many different training types. A single VR solution can therefore handle numerous operations and activities.

viii) VR training employees in construction

Training for the construction industry include developing the abilities of various employees. Employees can practise with virtual avatars, for instance, to become more cooperative with one another. As a result, those who participate in VR training can execute cooperative duties like watching out for coworkers, hauling large goods, or supervising cranes.

This lessens misconceptions and improves group effectiveness generally. Employees can also apply their theoretical knowledge and consider the effects of different choices while at work.

ix) Construction safety training

The risks associated with working in the construction business, such as carrying big objects at heights and using heavy machinery, place workers at a significant risk of injury. Additionally, learning new things and practising in a risky situation have a detrimental impact on how well the learning materials are retained.

Fortunately, virtual reality safety training for the construction industry enables risk-free work experiences. Employees receive training in an interactive setting using scripts that closely resemble actual working situations. Workers can receive training as many times as necessary to achieve the end result, which is a high degree of problem-solving and correct performance of their jobs.

x) Emergency training

Emergencies can happen in the building industry occasionally as a result of human mistake or defective equipment. In these circumstances, stress can cause poor judgments that have serious repercussions for both people and the company. Therefore, it is better if staff members receive interactive virtual environment training on how to handle frequent situations. In this approach, the staff accurately practises the necessary conduct and receives training on how to behave under pressure.

xi) Onboarding training

Because they are thrust into a brand-new work environment and are required to learn how to engage with it, often under difficult circumstances, new workers face the greatest difficulties. Companies that value their employees frequently provide onboarding initiatives with unique VR applications. For instance, you can practice interacting with tools, equipment, and other personnel by taking a virtual tour of a company and a building site.

xii) Hardware training

The construction sector demands a high level of equipment expertise and familiarity. Thankfully, you can learn how to operate large machinery like cranes and excavators in the immersive VR training environment. Professionals can learn how to recognise and use building components including hangers, angles and straps, base and cap hardware.

xiii) VR Training Approaches in the Construction Industry

VR exercises are created using a variety of applications. In essence, these programmes are developed to meet the specific requirements of each business in order to handle a variety of activities. Despite this, the majority of training software employs crucial techniques suitable for the construction sector. Four VR training strategies used in the construction sector are listed as below.

Intriguing work environment construction education Developers of VR applications build an immersive setting that replicates a real-world construction site. Using hand controllers that imitate the user's actions, employees can interact with things and the surrounding area at the training facility. Additionally, sound effects contribute to the vivid experience.

Scripts For Interactive Training. Scriptwriters develop changeable scenarios, situations that workers frequently face in real life, in collaboration with construction specialists. Employees get the ability to react appropriately to various situations during training. Additionally, when taking illegal activities or making illegal judgments, the user is aware of any potential repercussions but does not risk their health.

Support For a Virtual Educator. During training, employees are not fully on their own because a virtual instructor helps them. An example of such a feature might be a 3D character or visual, textual, and audible instructions. As a result, the

employee can learn all the knowledge they need without the assistance of a live person, correct their mistakes, and go over the training material as many times as necessary.

Competency Evaluation. VR training is required not only to educate new hires but also to enhance or assess the credentials of seasoned staff. A training programme built on specialized algorithms can evaluate performance objectively and point out areas that need improvement. As a result, the staff's output will continuously improve.

Artificial Intelligence

AI is about using machines or software that can copy human functions and process enormous amounts of data. In construction, this can be robots or machines that take over the manual labor aspects of a project to save time and money, or programs that take data and turn it into 3D models of projects so they can be analyzed for safety and cost-effectiveness before they are physically built.

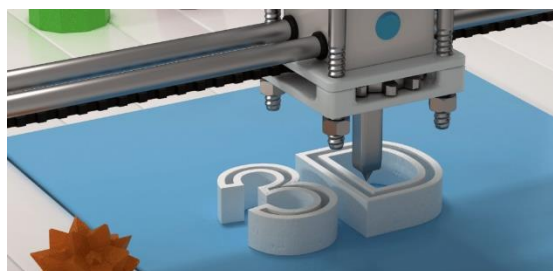
i) Artificial Intelligence in the Future of Construction

The use of artificial intelligence can greatly increase construction productivity. Artificial intelligence fills in the gaps as the construction sector struggles with a personnel crisis and diminishing productivity. Artificial intelligence, however, is not a precise science or model of inherent human intelligence. In this way, artificial intelligence complements human intelligence rather than replacing it, especially in the field of construction where each project is distinct and subject to a variety of outside forces and moving parts (weather, other trades, etc).

Cost will also be a barrier to the widespread use of artificial intelligence. Robotics and autonomous cars may be able to improve the production that a single worker can produce, albeit at a significant cost. Companies will need to make a significant initial investment to cover the cost of the technology as well as the increased management skills required. Something that may not be feasible for many businesses in a sector where technology spending is only 1% of total sales.

Construction is increasingly using artificial intelligence. Similar to earlier technological developments, those that are prepared to adopt it will have an advantage over their rivals.

3D Printing



3D printing helps create scaled-down complex or bespoke design structures, reducing material and labor costs and producing less waste. It could also allow construction work to be completed in environments unsuitable for people to work or used to reduce accidents.

Overall, 3D printing has too much potential to be ignored. Even while the industry might never get to the point where it's employed entirely, it's just a matter of time before the technology is greatly enhanced. Overall, 3D printing is positioned to be a practical option that offers significant advantages in terms of cost savings and environmental friendliness for the future of our building.

Cloud File Storage and Data Sharing

Cloud-based mobile technology enables construction teams to store important data such as blueprints, contracts and other documents in one place where others can access them quickly and conveniently, no matter where they are. This improves communication and collaboration by making it easier to share notes, ask questions, and discuss revisions in real time easily and securely. Cloud-based file storage and sharing makes construction teams more efficient and fewer costly mistakes because they can access everything they need right from their mobile devices.

Drones

Today, anyone with drone knowledge has additional industry recognition. Not only the construction industry, other industries such as services, healthcare and tourism have also started using drones as one of the smart technologies in their industries. Many studies have shown that drones can reduce overrun costs in the long term. It can also reduce labor and reduce the risk of human error.

STEM Skills

Much of the current technological advancement has been driven by people in Science, Technology, Engineering and Mathematics (STEM) fields. As the nature of work becomes increasingly digital, the demand for more innovation and technological advances will only increase. More and more companies are relying on automation to get various tasks done.

This technological advancement and innovation is being led by workers with advanced STEM skills, so you can expect demand for these skills to remain high in the future.

SMAC Skills

The convergence of social, mobile, analytics and cloud (SMAC) technologies is driving business innovation and revolutionizing the world. As work becomes increasingly digital, these technologies will play a key role in improving business operations and helping companies effectively reach their customers at minimal cost.

The majority of people access online services through mobile devices. Statistics already show that more users are accessing the internet on mobile devices than on desktops. The use of mobile devices, social media, smart devices and wearable technology creates a stream of data that creates new business models.

Many companies are also turning to cloud computing to make operations more efficient and develop new business models. In the future, SMAC technologies will become a core aspect of every company and will increase the demand for employees with advanced SMAC skills.

Careers in Digital Construction

The digital skills can offer lot of roles in the world of digital construction such as:



i. BIM Technician

A building information modeling engineer uses computer software and technology to gather all of the information about a project and put it in one place. The model will appear in multiple dimensions, with all the important components for each person working on it.

The following are the responsibilities of a BIM technician:

- Gathering data from various plans and combining it into a single computer model that can be used to construct and maintain a structure;
- Communicating with design teams, clients, architects, surveyors, engineers, and project managers;
- Assisting engineers and senior managers with drawings and blueprints; • Producing structural models, drawings, and schedules using computer programmes and BIM;
- Presenting the results of the work to engineers and senior managers;

ii. BIM Manager

A Building Information Modeling Manager works with designers, clients and architects to ensure all production materials and designs are created and managed throughout the project. BIM coordinators are in charge of the digital procedures connected to a project's design and construction phases. They supply project information models to clients and make sure that 3D models, drawings, and structural data are hosted in a single, easily accessible location.

iii. CAD Technician

A Computer Aided Design Operator uses computer software to create 2D and 3D drawings for design and manufacturing projects. As a CAD operator, you may be designing buildings, machines, or component parts. They take complex

information and use it to create technical building diagrams for architects, engineers, and other construction workers.

The following are the duties of a CAD technician: • Meeting with engineers, draughtsmen, and designers to evaluate plans and design drawings.

- Entering design requirements into the CAD programme.
- Producing surface and solid CAD models in accordance with customer requirements.
- Participating in both team-based and lone CAD projects.
- Going over CAD models with the customer and making a few tweaks.
- Carrying out the last model rendering and delivering the finished item.
- Finishing work reports.

iv. Architectural Technologist

An architectural technologist specializes in presenting building designs using technology. They provide customers with technical advice and work with design teams to bring new structures to life. As an Architectural Technologist, you will work with architects to develop building models before construction takes place. The role of Architectural Technologist are as follows:

- Assessing what surveys (such as land surveys) are necessary before construction can begin and making sure that such surveys are done and their results integrated into the project;
- Contributing to planning applications and other regulatory application procedures;
- Early meetings with clients and other professionals to establish the project brief;
- Comprehending how a construction project's design elements affect and relate to performance and functional difficulties so that initial practical concerns can be resolved;
- consulting with the necessary authorities (such as planning inquiries and building inspectors) when preparing documentation for statutory approval;
- assessing and advising on environmental, legal, and regulatory issues.
- When a construction project is finished, reporting on the performance of the contractors and obtaining feedback from clients and building users are important steps to take. Other steps include assessing the performance of buildings that are already in use and producing maintenance management information, as well as evaluating and offering advice on renovation, re-use, recycling, and deconstruction.

- doing risk assessments at the design stage; managing contracts and project certifications; creating project briefs and working on them as the project moves forward;
- managing the work of trainee technologists and contributing to the smooth operation of the business;
- creating and presenting design proposals using computer-aided design (CAD) and traditional drawing methods;
- leading the detailed design process and coordinating design information;
- advising clients on selecting the best and most appropriate contracts for the work they are undertaking.

v. Technical coordinator

A technical coordinator takes care of the technical aspects of a project. Depending on the construction sector in which they work, they may process inquiries, assist in the creation and interpretation of engineering diagrams, plans and documentation, create delivery schedules and engage in project management. Technical coordinators are in charge of managing the operations of a technical firm or the technology division of a bigger company. They must be in charge of maintaining and troubleshooting the highly developed technological equipment used by their organisation or department.

To start digitalisation in an organization, firstly the organisation needs to identify which type of technology consideration in the organisation. The technology choose must be suitable and adaptable to use in the organisation. Currently, most of the organization has started to adopt Artificial Intelligence (AI), Cloud based, Internet of Thing (IoT) and other technologies. So, an organisation may choose which technology is suitable and can be fully use for operation in an organisation.

Secondly, measure the readiness. Readiness in the organisation can be divided into three (3) categories which are early adopter, fast follower or just a common follower. For a big organisation, if they have adopted basic technology, they can be categorised as adopter. However, for a SME organisation, they can start from follower and move to fast follower and next to an adopter with certain period of time.

Next, an organisation can do the trial on the digitalisation adoption. It can start with slowly start to use digitalisation and set a time (one year to 3 years) to check the results.

Then, an organisation can measure the results on the trial adoption of digitalisation whether it is success or not. This stage will identify the hurdles and challenges in adopting digitalisation and how we resolve the issue.

If the organisation feels that they are suitable with the technology chosen, they may fully adopt digitalisation in the company and continue for learning and improvement.

However, if an organisation fails to adopt digitalisation and technology, they may seek help from related agencies such as MPC, CIDB, etc and repeat trial of technology adoption.

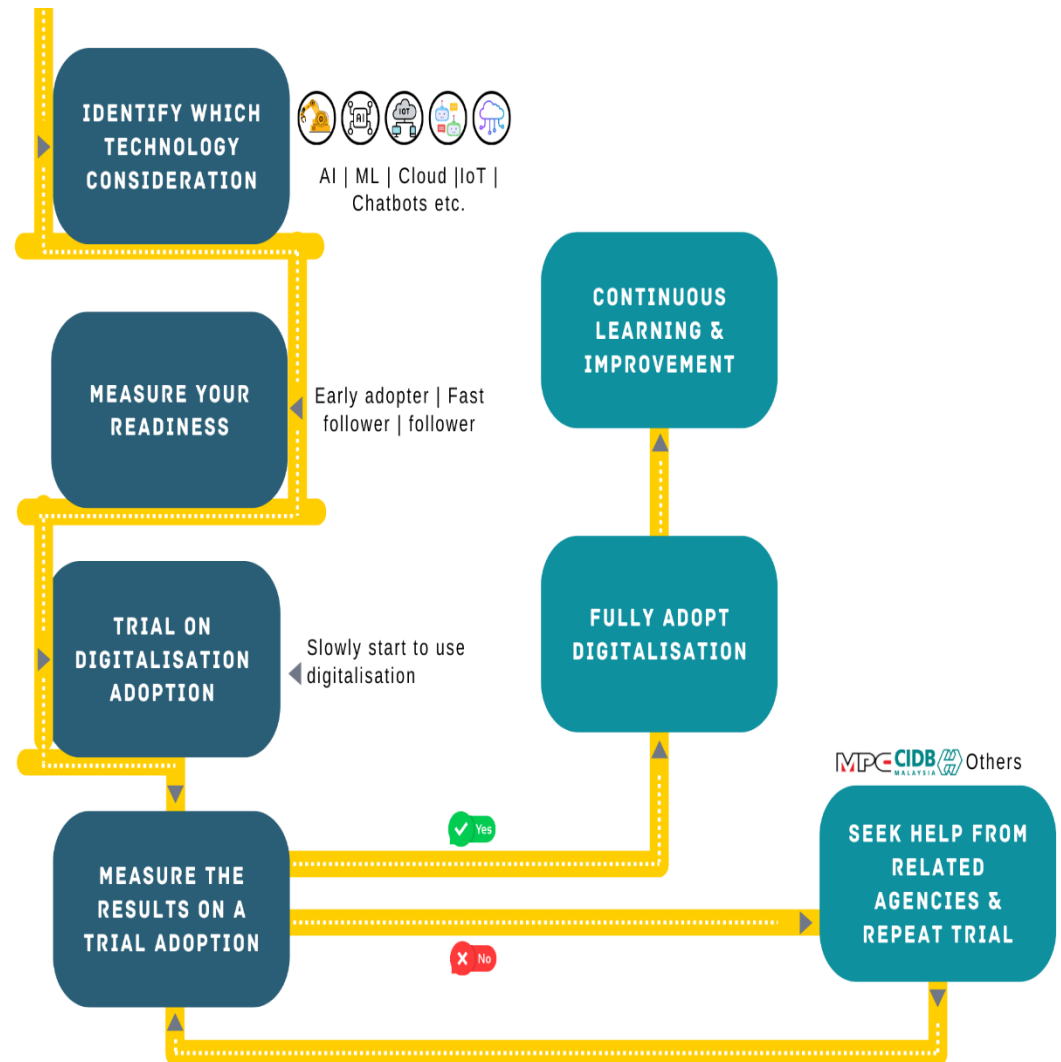


Figure 17: Flow Chart to Start Digitalisation

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