IEM Position Paper On Revolutionizing Construction 4.0 For The Construction Industry in Malaysia

Date: 22 November 2022

Status of document: Version 3.0

Remarks by Chairman of IEM Position Paper on Revolutionizing Construction 4.0

It has been a very tumultuous period since the Covid-19 pandemic crisis struck our country in early March 2020, and we have been affected by it since then. And our construction industry has been badly hit by the series of national-wide and state-wide lockdowns, which has disallowed or restricted the construction work activities in most if not all site areas, including infrastructure works in Light-Rail-Transit (LRT) and Mass-Rapid-Transit (MRT) in the Klang Valley region.

In light of the discussion in one of the Special Covid meetings at IEM, there was a proposal to form a Position Paper Committee to publish an IEM's stand on Construction 4.0 which is in line with the nation's aspiration to shift the technological development to Industrial Revolution 4.0. The intention is to identify areas of the local construction industry to modernize and upgrade itself, in overcoming the outdated mode of the construction process which is labor-intensive as well as not in line with technological change. This is to enable the construction industry to combat the aftereffects of the Covid-19 pandemic which has slowed down the construction industry nationwide.

The Immediate Past President of IEM, Ir. Ong Ching Loon has appointed me to chair this Position Paper Committee, which has its first meeting on 2nd December 2020, after having invited experts and representatives from the industry to contribute to this effort to draft this Position Paper. The Committee has managed to source relevant references from Malaysia's Construction Industry Development Board (CIDB) 2020-2025 Five-Year Strategic Plan Towards Construction 4.0, as well as view the progress of Singapore's Building Construction Authority in implementing their initial stages of Construction 4.0.

The Position Paper Committee has agreed to form various Working Groups to investigate and to make a review study of key areas deemed to be critical for implementing the policies of Construction 4.0 by the Government. These key areas are: Smart Construction and Materials, Big Data and Connectivity, Mobile Communication and Robotic Automation, and finally Human Capital Development. The Working Group members and the Position Paper Committee members are all volunteers, either representing interest groups from IEM, or are invited representatives of industry stakeholders – both from the private as well as public sectors. Without their dedication and selfless hard work put into the work of developing ideas, proposals, and drafting work, the final form of this Position Paper would not have taken this finalized form. To properly thank and acknowledge the effort and invaluable contribution of these invited members, their names and represented groups or organisations shall be listed separately following these remarks.

To that, I would like to give my heartfelt thanks and deep appreciation to all members of the Position Paper Committee and the various Working Groups involved. My special thanks to Ir. Dr. Wang Hong Kok for proposing I take the lead as the Chair of this IEM Position Paper Committee, while he took on the role as Lead Person for the WG on Smart Construction. My appreciation also goes to IEM Immediate Past President Ir. Ong Ching Loon for believing in me and my selected team members to deliver this final IEM Position Paper after months of hard work by all the members.

My last thanks go to IEM Secretariat, in particular, Mr. Gabriel Lim for his hard work and dedication in producing records of meeting minutes, obtaining literature and references, setting up online meetings and organizing various webinars for the committee members.

By.
Chairman of IEM Position Paper on Revolutionizing Construction 4.0
Ir. Prof. Dr. Jeffrey Chiang Choong Luin
Date: 22 November 2022

Remarks by IEM Immediate Past President

It gives me great pleasure to congratulate the team on IEM Position Paper Committee who has completed their given assignment by producing and publishing the IEM Position Paper on Revolutionizing Construction 4.0 for The Construction Industry in Malaysia. This is a very timely document with proposed recommendations to be forwarded to relevant stakeholders to digitalize and modernize our construction industry by leveraging the current technological knowledge in line with Industrial Revolution 4.0.

IEM has always been in the forefront of the professional learned society in the country by taking the lead or initiative to critically review present practices in the industry, and proposing ideas and action plans to improve or to upgrade the skills level of engineers and the engineering workforce, as well as to upgrade on the usage of smart engineering methods, materials, remote and self-mobile equipment, and so forth.

We sincerely hope that this Position Paper will provide a good insight into the current issues faced in the construction industry in the present Covid-19 pandemic crisis. We also hope that the presented recommendations to appropriate institutions and agencies in the public sector, especially Government ministries and departments, will be seriously looked into, and follow-up actions will be put in place and implemented as soon as possible.

I would also like to express my thanks to the stakeholders and representatives from external organisations invited to be part of the Position Paper Committee, and they have indeed contributed tremendously to the work in producing the final Position Paper in its present form. My special appreciation goes to Ir. Prof. Dr. Jeffrey Chiang Choong Luin for his remarkable leadership and unwavering conviction to the deliverables of this Position Paper.

Last but not the least, my thanks and appreciation to our IEM Secretariat staff members for working hard with dedication to provide secretarial support to the Position Paper Committee in their tasks over the last ten months since it commenced its work in December 2020.

We sincerely hope that this IEM Position Paper will be well-received and shall be widely read, studied in depth, and be taken seriously by the relevant stakeholders in the construction industry.

Majulah perindustrian pembinaan di Malaysia.

By.
IEM Immediate Past President
Ir. Ong Ching Loon
Date: 22 November 2022

Names (and Organizations represented) of all IEM Position Paper Committee Members:

The Institution of Engineers Malaysia (IEM)	Ir. Prof. Dr. Jeffrey Chiang Choong Luin – Chairman
IEM Urban Engineering Development Special Interest Group	Ir. Dr. Wang Hong Kok
IEM Mechanical Engineering Technical Division	Ir. Dr. Alvin Yap Chee Wei
IEM Project Management Technical Division	Ir. Dr. Harris bin Abd Rahman Sabri
IEM Urban Engineering Development Special Interest Group	Ir. Phillip Wong
Jabatan Kerja Raya, Kuala Lumpur HQ (JKR)	Ir. Dr. Ahmad Firdauz bin Abdul Mutalib
Association of Consulting Engineers Malaysia (ACEM)	Ir. Liew Shaw Shong
Tunku Abdul Rahman Universiti College (TARUC), Kuala Lumpur	Assoc. Prof. Ts. Dr. Lee Wah Pheng
China Construction Development (S) PLC	Mr. Wei Ke Wu
IJM Corporation Bhd	Mr. S. Ramesh a/l V. Subramaniam
Bina Initiatives Sdn Bhd	Mr. Bruce Kong
Universiti Kebangsaan Malaysia (UKM)	Ir. Dr. Maggie Chel Gee Ooi
GMCM Sdn Bhd	Dr. Lim Yee Mei
Construction Industry Development Board Malaysia (CIDB)	Ts. Dr. Gerald Sundaraj

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Chapter 1: Introduction to Position Paper on Construction 4.0 in Malaysia

1.1 Background

The issue of the lagging construction industry in Malaysia has been there even before the Covid-19 pandemic crisis took place from late 2019 to early 2020. In comparison with many developed countries, which also include our closest neighbor Singapore – Malaysia's construction industry is not as technologically advanced nor as less reliant on unskilled and semi-skilled workforce on sites.

The Malaysian Government has been pro-actively advocating the use of updated tools and means to improve the efficiency and to streamline the construction industry for many years since early 2000 such as Industrialized Building System (IBS) now better known as Modular Design and Construction, as well as Building Information Modeling (or BIM). But the other key stakeholders in the industry displayed lukewarm reception to such initiatives, citing high cost of investment, low rate of investment returns, the country has plenty of cheap foreign labour force, and many other reasons.

In a commendable effort, the Economic Planning Unit (EPU) under the Government's Prime Minister's Department has come up with the Blueprint for the National Fourth Industrial Revolution (4IR) Policy – the front page cover is shown in Figure 1-1 [1]. The 4IR Policy Plan was launched on 19 February 2021 with the blessings of the Prime Minister, in support of two ministries, the Ministry in the Prime Minister's Department (Economy) and the Ministry of Science and Technology and Innovation.

As stated in the Policy Plan, 4IR refers to the disruptive transformation of industries through the application of emerging technology. In other words, the policy is intended to promote the use of the latest or updated technology available which can assist to push through new and creative ideas and innovations that will "disrupt" or push through "drastic changes" in the current level of knowledge and application of soon-to-be outdated mode of design, planning, and operation – especially so in the lagging and slow-to-pick-up construction industry in this country.

The next question to ask is – what is this 4IR Policy by the Government? It is supposed to support the 12th Malaysia Plan (RMK-12) and complement the Malaysia Digital Economy in driving the growth of the digital economy. By that, it means, that the construction industry will be part and parcel of the digital economy eventually, with full participation by stakeholders from both the public and private sectors. It was also stated that the 4IR Policy is needed to provide:

1. Key guiding principles and strategic direction to ministries and agencies to formulate respective policies and action plans to implement such emerging technologies in a timely fashion.
2. Guidelines to address risks from 4IR technologies whilst preserving values and culture.

From the above, we can conclude that proposals and suggestions from all affected stakeholders to the Government would be most welcomed – and this is where the IEM Position Paper will be very useful if the recommendations herein are viewed positively and constructive enough to complement the 4IR policies and propel the actions plans into the implementation stage.

Figure 1.1: Front cover of the National Fourth Industrial Revolution (4IR) Policy

Before the 4IR Policy launching, the Construction Industry Development Board (CIDB), which is the key Government Agency overseeing the practices in the construction industry in this country launched its own Construction 4.0 Strategic Plan (2021-2025) [2] – the front cover of this is shown in Figure 1-2.

The key driver of this Construction 4.0 Strategic Plan (2021-2025) is CIDB with the support of the Ministry of Works. Unfortunately, The Institution of Engineers (IEM) was not officially invited to participate in the development of this Strategic Plan. Nevertheless, IEM recognized that this is a good initiative that will benefit the whole construction industry in the long run, especially with the advent of emerging technology which will enhance the efficiency in the processes involved from feasibility studies, to project design and planning, right down to construction stage, maintenance and maybe even to demolition stage of obsolete projects.

In his Foreword to the document, the Senior Minister of Works has linked this Construction 4.0 Strategic Plan by CIDB to the National Policy of IR4.0 (or Industry 4WRD), and the Government very much looks forward to seeing the successful implementation of CIDB's Strategic Plan for Construction 4.0 as a pathway to fulfill the national goal for 4IR policy.

To that end, this IEM Position Paper shall be seen as the working plan and instrument for CIDB and EPU to review and to re-look at their respective policy and strategic plan for revolutionizing Construction 4.0 for the industry.

Figure 1.2: Front cover of the Construction 4.0 Strategic Plan (2021-2025)

The issue of Construction 4.0 at the initial stage is very much linked with Building Information Modeling (BIM) – and what is BIM, by definition?

BIM is a process or work sequencing, which is supported by various tools, technologies, and contracts involving the generation and management of digital representations of physical and functional characteristics of recorded information placed into a series of linked computer files, for knowledge dissemination, sharing, and decision-making. BIM is made easier by software applications used by individuals, businesses, and government agencies who plan, design, construct, operate and maintain buildings and diverse physical infrastructures, such as water, refuse, electricity, gas, communication utilities, roads, railways, bridges, ports, and tunnels.[3].

In Malaysia, the concept of BIM and its encouraged application in the Architectural, Engineering, and Construction (AEC) industry was mooted by Aryani Ahmad Latiffi et al (2013) [4]. In the joint paper, the authors concluded that the implementation of BIM in construction projects can lead to successful completion, as BIM has significant added value to the development plans by the Government. Hence, as the major client in many public construction projects, the Government needs to be an early adopter of BIM technology.

The use of BIM has also been advocated in Singapore through the publication of the "Singapore VDC Guide, version 1.0" by the Building Construction Authority (BCA) Singapore in October 2017. Virtual Design and Construction (or VDC) is a subset of an emerging technology within the construction industry, and hence it is part and parcel of Construction 4.0 as we know it. Refer to Figure 1-3 which shows the front cover of the Singapore VDC Guide [5].

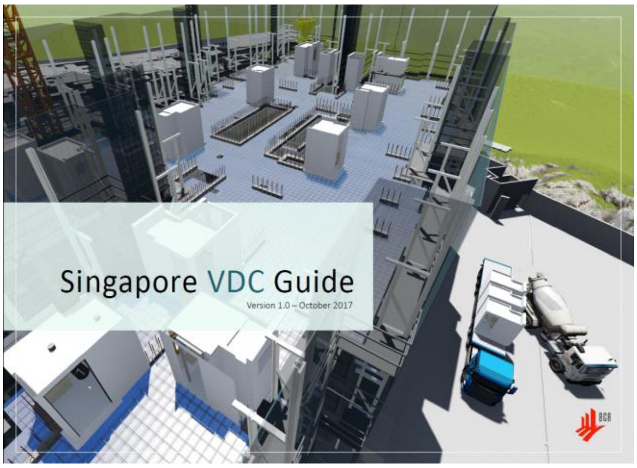

Figure 1.3: Singapore VDC Guide (BCA, Singapore 2017)

In this IEM Position Paper, the use of Building Information Modeling (BIM) as part of the implementation of Construction 4.0 in Malaysia is heavily emphasized, as it is the start and the beginning of the digitalization of technology and innovation systems for the construction industry. Besides Singapore, many developed countries including the United Kingdom are investing in BIM as the way forward to push their construction industry into the forefront of IR4.0. The UK's Institute of Structural Engineers has recently published a booklet to introduce BIM as a technological tool to lift the construction industry to the next level of development. See Figure 1-4 below [6].

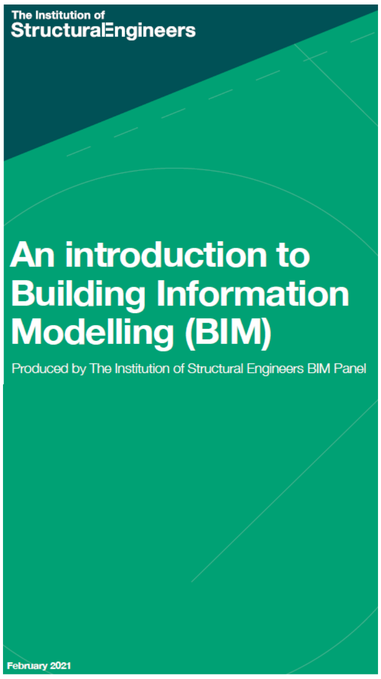

Figure 1.4: An Introduction to BIM by IStructE, UK (February 2021)

On 14 November 2018, through a media release [7], the Singapore Building Construction Authority took the next step forward by launching the Integrated Digital Delivery (IDD) implementation plan to encourage more built environment sector firms to go digital. And what is IDD, one may ask.

IDD is a delivery system via digital means which involves built environment sector firms and professionals using ICT technologies, solutions, and platforms across the entire building process from design, and fabrication, to assembly on-site, as well as operations and maintenance of buildings. IDD builds on Building Information Modelling (BIM) and Virtual Design and Construction (VDC).

Therefore, as part of the recommendation of this IEM Position Paper, the forward steps undertaken by our neighbouring ASEAN partner would be an indication of the direction for us to move towards, so that we can set similar mindsets and timeframes for our various Governmental ministries and agencies to push our Strategic Plan for Construction 4.0 in our country.

1.2 Significance of area of study

It has been highlighted many times that certain key industries such as the manufacturing, automobile, and banking sector have already tapped into the future by adopting a fully digital approach to their everyday business; thereby, contributing to their productivity, accuracy, efficiency, and improved customer satisfaction. However, the construction industry, which contributes a significant portion to the country's GDP (see Figure 1-5) [8], is still dominated by a paper form of communication for passing information.

Malaysia GDP From Construction

Summary Forecast Stats Download

Malaysia	Last	Unit	Reference	Previous	Highest	Lowest
GDP Growth Rate	-2.00	percent	Jun/21	2.70	17.30	-16.10
GDP Annual Growth Rate	16.10	percent	Jun/21	-0.50	16.10	-17.20
GDP	336.66	USD Billion	Dec/20	364.68	364.68	1.90
GDP Constant Prices	336345.00	MYR Million	Jun/21	343067.00	370128.00	130630.00
Gross National Product	331.40	MYR Billion	Jun/21	340.90	359.54	127.10
Gross Fixed Capital Formation	71450.00	MYR Million	Jun/21	73454.00	86871.00	27407.00
GDP From Services	189890.00	MYR Million	Jun/21	196701.00	216950.00	99821.00
GDP From Mining	23992.00	MYR Million	Jun/21	24110.00	27542.00	20435.00
GDP From Manufacturing	81699.00	MYR Million	Jun/21	81779.00	84229.00	45868.00
GDP From Construction	12589.00	MYR Million	Jun/21	13797.00	17204.00	6464.00
GDP From Agriculture	24130.00	MYR Million	Jun/21	22684.00	28030.00	19362.00

17204/370128 x 100 = 4.6%

Source: Department of Statistics, Malaysia

Figure 1.5: Malaysia's GDP by selected industries (June 2021)

There are plausible reasons for the slowness in the construction industry to catch up with their more illustrious counterparts. The segmented nature and site-based activity of the construction industry, coupled with the resistance to change among the construction professionals have made the evolution of the industry into a fully digital process a much more difficult process, as most of the contracts are still documented in paper form.

Likewise, the performance level of a construction professional is related to the quality of information available to the professional. In a bid to increase the performance of the construction professional, the use of BIM has been introduced into the construction industry in Malaysia (see the background information above) for easy means of passing information, especially at the design stage.

There has been expectation that BIM will eliminate the requirement of passing construction designs in paper format through different construction professionals that are predisposed to making errors. And the use of BIM as a form of Information and Communication Technology (ICT) for construction work is coming of age by smoothening the interoperability and disjointed method of application.

The many shortcomings in construction industry give rise to the idea of adoption of industry 4.0 concepts as the future direction for the construction industry, by leveraging on IR4.0 in the broad sense. The concepts of industry 4.0 has its origin in Germany manufacturing sector and was used as a synonym for the scheduled 4th industrial revolution which represents the increase in the digitization of the manufacturing sector towards enabling communication between the products, business, and customers.

Hence, applying industry 4.0 concepts to the construction industry is a new concept using the Internet of Things (IoT) for the integration of information among different platforms and adopting new gadgets like laser scanning, drones, and 3D printing with the expectation of enhancing the ability to monitor construction projects at the design, construction and in use stages towards delivering sustainable and smart buildings. Similarly, the idea of advocating Construction 4.0 would involve the digitalization of the industry towards producing a smart and intelligent way of assembling data by using sophisticated and new gadgets; thereby, facilitating easy analysis of data towards making prompt decisions that enable the establishment of a smarter, efficient and responsive built industry.

Against this background, this IEM Position Paper will examine the awareness and readiness of construction professionals towards adopting construction industry 4.0 in Malaysia to create a roadmap for the implementation of construction industry 4.0 concepts in the nation's construction industry environment. And from there, some constructive recommendations will be presented for consideration by relevant stakeholders especially in the Government sectors to implement.

1.3 Scope of work

At the beginning of the formation of the IEM Position Paper Committee, there was a need to define the scope of work involved by the Committee – as the topics in Construction 4.0 are very wide-ranging. At the first meeting of the IEM Position Paper Committee on 2nd December 2020, the following topics were considered for the standy to pursue to achieve the objectives in stating IEM's stand and position as well as to recommend future course of actions to implement Construction 4.0 for the country.

THE ORIGINAL PROPOSED FOCUS AREAS OF THIS POSITION PAPER COMMITTEE
1. Mobile communication technology – immediate real-time problem solving 2. Smart construction – intelligent work sequencing / scheduling / information modelling 3. Data-centric – Big data, data mining, multi-usage of data 4. Smart materials – cost control, quality assurance, sustainable development 5. Smart development of brownfield projects 6. Robotic automation, digital control, drone monitoring / inspection 7. Others – upscaling from 3D to 4D (time) to 5D (cost)

It was later decided that topics 5 and 7 shall not be pursued further given the lack of expertise and experience in those areas. And given the importance of developing the right human resource and capabilities in the new era of Construction 4.0, a new topic on Human Capital and Capacity Building was proposed and accepted.

From thereon, six working groups (WGs) were formed to tackle the six selected areas, which are:

THE SELECTED AREAS OF THIS POSITION PAPER COMMITTEE
1. Mobile communication technology – immediate real-time problem solving 2. Smart construction – intelligent work sequencing / scheduling / information modelling 3. Data-centric – Big data, data mining, multi-usage of data 4. Smart materials – cost control, quality assurance, sustainable development 5. Robotic automation, digital control, drone monitoring / inspection 6. Human Capital and Capacity Building – training and educating the existing workforce and new influx of skilled and semi-skilled human resources

Lead Persons from the Position Paper Committee were appointed to take the lead in each of the six Working Groups formed, and numerous meetings of WGs and the Position Paper Committees itself have held a meeting every month from December 2020 to the conclusion of the final draft of the IEM Position Paper produced.

1.4 Sources of information (such as surveys carried out, interviews conducted, and webinars attended)

From the Introduction pages of this Position Paper alone, the following documents were cited as references:

1. National Fourth Industrial Revolution (4IR) Policy – Economic Planning Unit (EPU), launched on 19 February 2021.
2. Construction 4.0 Strategic Plan (2021-2025) – Construction Industry Development Board (CIDB), published in 2020 by CIDB Malaysia.
3. What is Building Information Modeling (BIM)? source: *https://en.wikipedia.org/wiki/Building_information_modeling*
4. Aryani Ahmad Latiffi, Suzila Mohd, Narimah Kasim, and Mohamad Syazli Fathi, "Building Information Modeling (BIM) Application in Malaysian Construction Industry", International Journal of Construction Engineering and Management 2013, 2(4A): 1-6 DOI: 10.5923/s.ijcem.201309.01.
5. Singapore VDC Guide, version 1.0, published by Building Construction Authority (BCA) Singapore in October 2017.
6. An Introduction to Building Information Modeling (BIM), published by IStructE, UK, February 2021.
7. BCA Continues Its Digitalisation Push With Industry Partners, Media Release by Building Construction Authority, Singapore, in launching the Integrated Digital Delivery (IDD) implementation plan, 14 November 2018.
8. Malaysia's GDP From Construction, Department of Statistics Malaysia, June 2021.

Besides the above references, many more references cited by the working groups in producing this IEM Position Paper are compiled at the end of this paper for further referencing by readers.

In addition to the above, four webinars were organized by IEM and conducted by invited speakers, all of whom are members of the IEM Position Paper, as indicated below:

1. Webinar – Smart Construction, by Mr. Wei Kewu on 3 February 2021.
2. Webinar – 4D, 5D in BIM, by the Bina Initiative team on 4 March 2021.
3. Webinar – Road Map to C4.0, by Mr. Wei Kewu on 15 April 2021.
4. Webinar – Reality Capture, by Mr. Bruce Kong on 17 July 2021.

The Working Group on Human Capital and Capacity Building developed a set of questionnaire survey among IEM members to gauge their responses to the following topic “Human Capital required for future labour force in Construction 4.0”. Numerous responses were received, and the full details of these are reported in the following section of this position paper.

Chapter 2: Smart construction and materials

2.1 Introduction to smart construction and smart materials

Smart construction is an operational model that incorporates the data and predictive analytics of construction into the integrated data system. With the design, operation, construction, and management stage executed through the smart construction framework, it would be able to improve the operational efficiency, productivity and hence saving the cost on projects. This is done through the building information modelling (BIM), intelligent work sequencing and usage of the right materials (refer to smart materials here onwards) to effectively:

- tackle design clashes and improve design flexibility
- enhance the project efficiency and sustainability
- reduce time and resources waste due to design and other environmental challenges.
- boost information communication through collaborative partnership
- improve the occupational safety and health for on-site execution
- prevent accidents and disaster

2.1.1 Building Information Modelling/Management (BIM)

According to Building and Construction Authority (BCA) Singapore, BIM is referred to as “an advanced computer technology that allows building preference to be simulated digitally so that design conflicts can be collectively resolved upfront to avoid costly abortive work at the construction” [1]. It represents the physical and functionality of building digitally on the architecture, engineering and construction aspects to effectively plan, design, construct and manage the building. Explicitly, it is a technological platform that involve the best construction practises and modelling software. Latter component can be the scale of 3D covering the spatial building plan, 4D covering time factor, 5D covering cost and even 6D covering project management.

2.1.1.1 Why is BIM an important tool?

There are great benefits from the adoption of the BIM. It includes the improve accuracy and productivity among the built environment professionals through shared information through the BIM platform. Construction involves large of team of people across multidisciplinary firms of designer, engineers, contractor and owner. BIM provide a clear line of communication across the team to reduce misinformation and update change over all the dependent aspects. It makes it easier to identify potential clashes in design so that the problems could be rectified in time. With the greater efficiency due to the early stage in planning and design, it would help to save the unnecessary operational cost and achieve zero error in the design phase. As BIM requires the commitment of every key player in the project in the design stage, the engagement would promote communication at an early stage to prevent pitfall during execution. The BIM model can continue to be used by engineers and contractors for continuous monitoring and cross-checking.

2.1.1.2 Connecting technologies

Multiple technologies could be integrated with the BIM in the construction industry. These technologies have leveraged the ability of BIM to assist with the followings:

(a) Prefabrication & Modular Construction (PMC)

Prefabrication and modular construction is the construction technique that fabricates the construction components off-site and then transported them to the construction site to be assembled on-site. This practice can control the construction quality and cost with the higher precision of the factory's manufacturing and allocation of time, human and material resources. PMC greatly reduces the uncertainties due to the on-site environment and improves workers' safety as well as the environmental impacts during the construction. The modular construction information could be integrated into BIM during the design, production, and execution of prefabricated panels. BIM could then assist and enhance the coordination and communication of different construction components, including Mechanical, Electrical, and Plumbing (MEP) within the modular construction framework.

(b) Augmented and Virtual Reality

Augmented and virtual reality, commonly known as AR and VR are the technologies involved to create an enhanced version or complete virtual version of the real world. When incorporated into BIM, it can enhance the users' experience to visualize the actual environment within the BIM design. It provides a platform for the users to actually see the design and even roam within the planned premises. It also serves as a good tool to monitor building's progress during the construction stage.

(c) Virtual Delivery Construction (VDC)

VDC is building on the foundation of BIM in order to create a virtual model with the involvement of team organization and workflow process, before embarking on the actual construction. Hence, VDC is usually considered a framework, where BIM is one of the components. At present, the construction industry is known for inefficiency as inconsistency of drawings of various consultants is a fact of life. BIM intends to improve the situation by demanding that the drawings are carried beyond the submission stage while VDC introduce a collaboration period to coordinate and synchronize all designs, construction, and operation to support business objectives.

(d) Integrated digital delivery (IDD)

Building upon the usage of BIM and VDC, IDD pushes the boundaries of productivity by integrating the work processes and linking the project stakeholders with digital technologies throughout the construction cycle, according to BCA. The digital areas included digital design, digital fabrication, digital construction, and digital asset delivery and management. As an example, the introduction of PMC technology will greatly reduce time and cost in construction, and greatly improve the quality due to the controlled environment of fabrication works and finishes works.

2.1.2 Advanced Building Materials

Smart or intelligent materials are described as materials that can achieve a controlled, predictable, variation in one or more of their properties as a direct response to an external stimulus and/or a change in their environment. The external factor that causes the change in smart material properties may be in the form of mechanical stress or strain, electrical or magnetic field, and changes in the environment such as temperature, moisture, pH, and light. Hence, smart materials are greatly diverse to serve their purpose. Some can change their properties due to more than one of the external stimuli, while some materials offer greater adaptability due to certain external changes than others. A common feature of smart materials is their response to changes is reversible, which makes these kinds of materials particularly versatile.

Their unique properties make them a crucial material in many fields of engineering and science. They are used in civil engineering projects and these materials can be used to create efficiencies in the construction process, increase the lifetime of buildings or structures and enhance their performance over time.

2.1.2.1 Why is smart material an important development?

Construction materials made up a big part of the solid waste generated whether during the construction process or the demolition process of a building or structure. On top of that, the building itself generates a large carbon footprint when considering the amount of energy spent to operate it. This is where smart materials play a role to improve the energy efficiency and sustainability of the buildings. From which, natural and man-made materials used during the conventional construction process (concrete, wood, glass, etc) can be improved, and made versatile to external changes so that they can contribute a less carbon footprint produced. There are huge benefits in refining efficiencies, improving performances, saving resources and long-term maintenance when smart materials are used.

2.1.2.2 The technologies behind the materials

There are several technologies behind new smart construction materials as shown in Appendix 2.1, Figures 2.1 and 2.2. Innovation, research, and development in materials engineering have introduced new materials that are changing the different components within buildings and other engineering infrastructures. As follows are some materials impacting the industry [2, 3, 4]:

(a) Shape memory alloys

These materials possess the ability to regain some previously defined shape or size when subjected to permitted thermal changes. Shape memory alloys find their applications in new applications in civil engineering specifically in seismic protection of buildings and due to their great durability and reliability in the long run. The applications of shape memory alloy in civil engineering when there is to absorb strain energy without permanent deformation, undergo wide a range of cyclic behavior, and resist fatigue resistance under large strain cycles.

(b) Magnetostrictive materials

These materials undergo mechanical deformation (change in strain) is proportional to the electric or magnetic field. It also means that these materials changes in size in response to an electric or magnetic field, and conversely, produce a voltage when stretched. These materials have been reliably applied in pumps and valves, applications as actuators and sensors as well as an aerospace wind tunnel.

(c) Piezoelectric materials

These materials possess the capability to produce voltage when surface strain is introduced, where they can generate electrical energy across their surfaces in response to mechanical stress. The process is reversible, meaning that it can generate stress or a mechanical response when an electric charge is applied through it. This reversible ability enhance their applicability in sensors, energy harvesting material, and actuators within various building systems.

(d) Electrorheological fluids

They are colloidal suspensions that change in viscosity when subjected to an electric field. Such fluids are highly sensitive and respond instantaneously to any change in the applied electric field. Often, they could be found in shock absorbers.

(e) Electrochromic materials

They can alter color and transparency when an electric voltage is applied to it through a process called electrochromism. As well as being reversible, the changes can be instantaneous, making them a core component of smart glass in windows and building envelopes. These materials alter their light transmission properties when voltage is applied.

2.2 Current practices in the industry / Government policies or directives in place

Malaysia is set to embrace the digitization economy in a big way when former Prime Minister Muhyiddin Md. Yasin announced the Malaysian Digital Economy Blueprint (MyDigital) on 19 February 2021. Digital economy according to the official definition is "economic and social activities that involve the production and use of digital technology by individuals, businesses, and the government." [6] As the world is becoming aware, to embrace digitization is to improve the quality of life, and standard of living, especially during the upheaval of the COVID-19 pandemic. With the action plan and efforts lined out up to 2030 in the blueprint, 500,000 new job opportunities are expected to contribution to 22.6% of Malaysia's gross domestic product (GDP). The benefits of the digital economy to the people, businesses, and government are:

- People: Through digital literacy, better-paying jobs are expected, improving social well-being and environmental sustainability.
- Businesses: More cost-efficient. Businesses can expand regionally or even internationally.
- Government: Provide improved services to people, more efficiently, and more transparently.

In the said digital economy blueprint, construction sectors are named as one out of the 4 sectorial initiatives recommended. In line with the key thrust and strategies specified in the national initiatives, the themes delineated the need for digital adoption, information sharing, and enhancing digital skill sets to embrace the change to transform from traditional to digital practices. The sectorial initiatives expected outcomes, and targets have been clearly outlined in the blueprint. The answer to fulfilling the aspirations of MyDigital lies in the Construction 4.0 Strategic Plan, 2021-2025, launched by the Government in 2020. The strategic plan hopes to bring the Government, industry, and academia with the construction industry to respond to the rapid changes towards Industry 4.0 (IR 4.0) [7]. A long-held notion about construction is the complaint about 3Ds, i.e dirty, dangerous, and demeaning [8]. In an attempt to reshape the image, productivity, and safety of the construction industry, digital adoption is expected to roll out in phases through Construction 4.0. The strategic plan envisages the construction industry is to boost the economy and produce RM3.4 trillion of GDP by 2030 by improving the skills of the existing workforce, increasing income diversity and creating new career opportunities. A total of 12 technologies are targeted for quick adoption in the CIDB Construction 4.0 roadmap for 2021-2025 [7]. Of these, at least five are directly relevant to smart construction and smart materials:

- Cloud and real-time collaboration (short term - less than 1 year)
- Building information management (BIM)* (short term - less than 1 year)
- Augmented reality and virtualization* (short term - less than 1 year)
- Prefabrication and modular construction* (short term - less than 1 year)
- Advanced building materials (long term – less than 5 years)

2.2.1 Smart construction

CIBD surveyed in 2016 on the readiness of diffusion of BIM in the construction industry [8]. Up to 2016, there are only 17% of BIM adopters although up to 84% of respondents have expressed their willingness to adopt the implementation of BIM.

- 41% of organization lack clear policies that support implementation of BIM
- 72% of organization lack allocations for any financial incentive for using BIM
- 64% of organization failed to invest in BIM training
- 67% organization failed to invest in BIM hardware and software

As shown in the plans for technologies adoption listed above, the duration and planned targets of the adoption of the relevant technologies are within one year, i.e. the end of the year 2021. Based on the 2016 survey, only 39.3% (37.5%/18.6%) of organizations will adopt BIM in 5 (3/1) years period [9]. The adoption rate remains low but it is not clear whether this is the desired rate targeted. Hence, it would be more useful to include the realistic adoption percentage of the organization together with the period of achievement. Also, it is necessary to reiterate the feasibility of these strategic plans, especially during the time of the pandemic.

While looking back at the adoption stage of the uptake of BIM technologies, it is more welcomed and adopted in the private sector [10]. Based on profession, the distribution of adoption rate is uneven, with the architect (42%) leading the statistics followed by civil structure engineering (21%), contractor (13%), quantity surveyor (12%), and others (2% each) including developer and contractor, management consultant, mechanical and electrical engineering, project management, building surveyor and technologies [9]. The higher uptake rate of the architects lies in the familiarization of technology-wise software that is their main design tool. Nevertheless, the imbalance between the adoptions down the production line might cause the missing information on structure, materials, engineering, and project management to be included at the first designing stage.

2.2.2 Smart materials

Despite numerous of research conducted and smart materials available, the smart material applications are only within the pilot projects on small-scale applications. However, it requires a significant mass application in order to gain more confidence in terms of usage, building track records as well as implying overall cheaper cost. The latter could be achieved when there is higher demand for the smart material, which translated into lower manufacturing costs. Smart materials need to be applied more on real-life projects, especially for prestigious projects to expedite industry interest in using this.

Some of the applications of smart materials in construction include the following [11]:

2.2.2.1 Smart concrete: self-sensing and self-healing

After water, concrete is the most widely used product in construction. Whilst its use has brought about great benefits to structures and buildings worldwide, its production accounts for almost 8% of CO_2 emissions. Therefore, anything that can help slow down its usage and increase its time in-situ can only be good for the environment.

Cracks and changes in stress within the set concrete can and do occur, and over the long term can allow water, chemicals, or other external substances to get inside or bring about other impairments. Undetected or unrectified, this can damage the concrete and the structure itself, making it weaker and increasing the need for maintenance or replacement – increasing the cost and reducing the lifespan as a consequence. Smart concrete is an overarching term covering concrete products that have a specific ability; among the most common are self-sensing and self-healing. They can be used to monitor the health of a structure, make changes to the concrete's composition, and take action to rectify the issue.

Self-sensing concrete, as the name suggests, can monitor its condition and the stress levels within the structure of which it is part. It is made by adding microscopic carbon fibers and silica fume admixtures to a standard concrete mix to produce concrete that can conduct electricity, changing resistance values (of the electric charge) when damaged. It can be used to monitor vibrations on a structure, replacing vibration sensors that are often used in high-rise buildings, bridges, runways, dams, and other structures. The concrete itself becomes the sensor and can detect cracks and other damage caused by high winds, humidity, temperature changes, and other environmental conditions [12].

Self-healing concrete simply can repair cracks on the concrete face autonomously. It is made by adding a healing agent (like bacteria and calcium lactate) to a standard concrete mix. The agents are dormant for the most part and only become activated when water is introduced through the cracks themselves. This then enables the mixing of the bacteria and the calcium lactate to produce limestone which seals the crack. Another method is to use micro-capsules containing a sodium silicate healing agent within the concrete mix. When cracks appear, the capsules break up, releasing the chemicals which, when reacted with the calcium hydroxide in the concrete, form a gel that repairs the cracks [12].

Both the self-sensing and self-healing concretes have proven themselves in the labs and are being developed for mass, real-life construction usage. These smart materials will play an important role in ensuring structures have increased lifespan and durability, which in turn will reduce costs and improve maintainability.

2.2.2.2 Smart windows: switchable, unbreakable, and warming

Glass is another material that has undergone some major improvements recently which will highly impact its usage and reliability in the long run. For centuries, glass has been used to make windows that allow light and heat into buildings, reduce sound entering or exiting, and provide an overall aesthetically pleasing look. Whilst the shape and architecture of the window itself may have changed over the centuries; the glass component has largely been unchanged until recent technological advances.

One such technology is electrochromic which enables windows to change the amount of light that passes through glass by adjusting the voltage running over it. The ability to switch from transparent to opaque can help optimize energy usage during the day. Under indoor environment in which lighting condition is important such as schools, hospitals, and offices, this material could potentially reduce lighting, heating, and cooling costs of running these buildings.

Structural glass is another component of a home or office that has changed how the building is occupied, what energy usage it has, and how aesthetically pleasing it is. While traditionally, glass panes were incorporated within (load-bearing) steel or timber window frames, their use in modern construction could involve a large piece of glass that is frameless and forms part of the load-bearing element of the structure; a wall, floor, or column or roof. The structural glass itself is much thicker and stronger compared to normal framed window glass and is made using toughened or laminated glass. Without the need for framing, the flexibility that structural glass provides engineers designing residential and commercial offices offers an opportunity to innovate with the structure itself, and its use.

Combining structural glass with thermal heating glass and energy-saving low-e glass coating also means that, although sunlight can pour into the building from all angles, it doesn’t become a greenhouse. Modern innovations in glass technology mean that it has become more than an element of a framed window. It can provide changes to the structural makeup of a building and the energy levels used within – making glass a much more versatile smart material.

2.3 Issues and challenges faced by the industry

2.3.1 Smart Construction

In essence, BIM involves converting the traditional 2D drawings to sophisticated 3D or even higher level models that could be understood by every key player of the project. Resistance to adoption of BIM is expected. It is natural as the existing staff will need to move away from their comfort zone to learn new things.

According to the CIBD BIM survey conducted in 2016, technology, the findings from the survey showed that the request for budget allocation was the main challenging factor for the implementation of BIM [9]. BIM is perceived as a costly technology, in terms of the software, hardware to run it as well as the accompanying training cost. It is inherently difficult and a steep curve to learn, not to mention whether company has appointed the right person to learn. The second emerging factors causing the people factor. First of all, the lack of knowledge and awareness on BIM on its ability as well as cost and benefits can stray the decision away from the implementation. There is also a great shortage of BIM training and manpower that would provide technical support to the new learners and subsequently enough manpower to trigger the competency among each other. However, the resistance of change and lack of skilled and trained personnel are definitely the greatest impediment to the adoption [13]. Thirdly, it is the predicament in the process of implementation. As it is rather new technology to some companies, longer time is required for the experiment and implement but in realistic the owner would not tolerate with longer project delivery time. The implementation has become more difficult with the lack of pilot project to serve as reference. Last but not the least, there is no proper requirement or mandate that present to lead the direction and provide financial assistance to invest on the implementation. Although some initiatives from the government exist, it is still not strong enough to transform the entire industry. The challenges discussed are listed as below, with asterisk (*) sign showing the top challenges in the industry:

(a) Technology

- Technology and software cost*
- Training cost*

(b) People

- Lack of knowledge and awareness on ability and benefit of BIM*
- Shortage of ready BIM training and manpower*

(c) Process

- Lack of time to experiment and implement BIM in projects
- Lack of reference to assist in BIM implementation
- No BIM requirement/mandate exist

2.3.2 Smart Materials

When it comes to smart material, main issues that inhibit its use are:

- the maturity of technology
- overall cost compared to conventional way of doing things
- change management in terms of applying new techniques
- lack of actual implementation.

A study on housing development in Brazil [14] identified that the main barriers for adoption of smart material in building construction are as follow:

a) Economic constraint

- Cost of the smart material is high
- No market demand

b) Available policy

- Regulatory policy have not mandated the use of such new materials
- Statutory bodies had enacted law/policy to use certain limited materials hence new materials could not be used

c) Social perception

- Lack of knowledge and awareness, hence lack of acceptance
- Stigma on whether such material will be beneficial

d) Technical

- Lack of technical expertise for installation and testing

- Not sufficient support service

2.4 Proposed solutions and recommendations for relevant Authority / Agency

The nation-wide adoption of new policy and techniques often require commitment and intervention the government agencies for the enforcement. The implementation of smart construction and adoption of smart materials require the knowledge, skills and communication across different parties across the whole construction work processes. Similarly, it applies to the agencies involved. With CIDB as the sole driver for the smart construction, it would be difficult to steer the implementation of smart construction forward timely. The Kementerian Perumahan dan Kerajaan Tempatan (KPKT) which tasked with design and involve the local authorities need kick start the implementation of BIM. From which the subsequent parties such as Kementerian Kerja Raya Malaysia (KKR) can continue with the specification of construction methodology and monitoring, especially with government project to take the lead. The formulation of standard and guidelines on building and infrastructure could then be continuously evaluated, improved and released by the Jabatan Standard Malaysia (Standards Malaysia). Owing to the new technologies that still have relatively low uptake rate, human resources training will need to be geared up to run workshop on targeted groups such as industry players, graduates, university student to nurture skills required for the proper implementation of the plan. Below has discussed the proposed solution and recommendation more specifically for smart construction and smart materials.

2.4.1 Smart Construction

To achieve a paradigm shift and transformation in the construction industry, government mandate is necessary to collaborate with the industry to adopt the revolutionary practices [15]. The survery shows a promising 95% of respondents who willing to implement BIM within their organization, while 91% believes the government mandate would help the adoption of BIM in the industry [9].

It can simply start with adoption through pilot projects co-administered by the government and industries to understand the possible pitfall and difficulty, with grace period allowance. This is among the first few baby steps taken by the Building and Construction Authority (BCA) Singapore at the early stage. The smart construction technologies could be extended in-phase from the early BIM, VDC to IDD at each stage, for example from design, construction and procurement. Having these pilot project as examples, it would be much easier for the authorities to develop the guidelines and standard of the deployment of the technologies with progressive in-phase adoption from BIM, VDC and IDD technologies.

With achieving this, the human capacity and skills could be developed. First and foremost, the courses should be offered to train the teachers, trainers and coaches to disseminate the skills to the trainees. Short courses target the existing employees and fresh graduates to equip them with basic and advanced digital skills. The engagement with engage with higher education institutions to integrate these skills into university and college courses are also essential to prepare the graduates with competing skills. The recommendations are tabulated in Table 2.1.

Table 2.1: Recommendations to be addressed by respective agencies

No	Recommendation	Agency to address	Timeframe
1	Monitor and provide subsidy for implementation of BIM	CIDB	By 2025
2	Implementation of BIM on local district level	Kementerian Perumahan dan Kerajaan Tempatan (KPKT)	By 2025
3	Specification of construction methodology and monitoring on government project	Kementerian Kerja Raya (KKR)	By 2025
4	Implementation of BIM on government pilot project	Kementerian Kerja Raya (KKR)	By 2025
5	Formulation of standard and guidelines on building and infrastructure	Standards Malaysia	By 2025
6	Build up teams of trainers with BIM skills	Kementerian Sumber Manusia	By 2025

7	Inclusion of smart construction courses in university class and for fresh university graduates	Kementerian Pengajian Tinggi (KPT), Institut Pengajian Tinggi (IPT)	By 2025

In our quest to adopt Construction 4.0 as envisaged by Construction Industry Development Board Malaysia (CIDB), Government assistance in terms of grants is expected. Failing which, the momentum is not built to kick start digital technologies for Construction 4.0. Drawing from the experience learned in Singapore, the following table identifies what amount of grants are required, how many firms will stand to benefit from it, and over which year. The purpose of quantifying in numbers is simple. Because numbers are easily read, learned, and understood. It is an accurate form of measuring the success or failure of any task. The criteria to determine which firm is deemed suitable as target as recipient, and the manner in which grant is to be released are beyond the scope of this article. See Table 2.2.

Table 2.2: Suggested adoption target on smart Construction in line with the Construction 4.0 Roadmap 2021-2025

No	Number of related companies undertaking in YEAR/state subsidy in RM	2021	2022	2023	2024	2025
1	BIM	No: 0 SS: 0	No: 5 SS: 1M	No: 10 SS: 2M	No: 30 SS: 6M	No: 50 SS: 10M
2	VDC	No: 0 SS: 0	No: 5 SS:0.5 M	No: 10 SS: 1M	No: 30 SS: 3M	No: 50 SS: 5M
3	IDD	No: 0 SS: 0	No: 5 SS: 0.5M	No: 10 SS: 1M	No: 30 SS: 3M	No: 50 SS: 5M

2.4.2 Smart Materials

Based on the identified challenged of usage of smart materials, corresponding solutions are proposed. High costs of smart building technologies, the degree of technological maturity within this field, and the low diffusion of production technologies in the market can be mitigated by tax cuts (especially imports) to stimulate the adoption of technologies related to smart buildings that prove to be more efficient environmentally. Lack of financial and financing incentives can be mitigated by developing incentives for smart building concepts and technologies adoption in construction development.

The usage of smart materials can also be encouraged through the change in regulation environment with inclusion of the material and materials standards/code. The regulatory shall be able to provide predictability to stakeholders who want to invest and to permit the sharing of infrastructure costs for adopting smart building concepts and technologies.

Problems such as quality and availability of specialised workforce can be solved by increasing investments in smart building technology courses. It can be done through developing courses by official associations and universities for technical development in smart building technologies. Professional certifications by associations can also assist in identifying and increasing the qualification of available labour.

Lack for an appropriate communications infrastructure for big volumes of data, which operates in an integrated manner, can be stimulated by the adoption of technological standards and communication solutions that prove effective. Last but not the least, consumer engagement should be promoted to create awareness on how to adopt these smart building technologies and its benefits. The discussed points are summarized as below:

a) Economic constraint

- Tax system that allow tax break in use of smart materials
- Provide incentives for adoption of smart building concepts and technologies

b) Regulatory change

- To provide predictability to stakeholders who want to invest and to permit the sharing of infrastructure costs for adopting smart building concepts and technologies.
- To include usage of new smart materials and relevant standards or cods in the regulation in construction material use

c) Social perception

- Consumer engagement to create awareness the benefit and method to adopt the new smart building technologies

d) Technical

- Increase investments in smart building technology courses
- Develop courses by official associations and universities for technical development
- Provide professional certifications by associations to qualified personnel
- Availability of communication infrastructure for big volumes of data

The adoption of smart materials in new or existing projects can be achieved via grant or tax waiver from the government, as part of the effort in promoting smart material usage in Malaysia construction industry, as well as pioneering the application among the region. Since smart material is considered new in the market, the raw materials and processing cost would be on the higher side. Added with low usage and demand from the market, promotions and efforts are needed to increase the usage of the smart materials. With increasing demand in Malaysia construction scene, it is foreseen that the overall smart material cost will become cheaper in long term.

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Appendix 2.1 Smart Construction and Materials

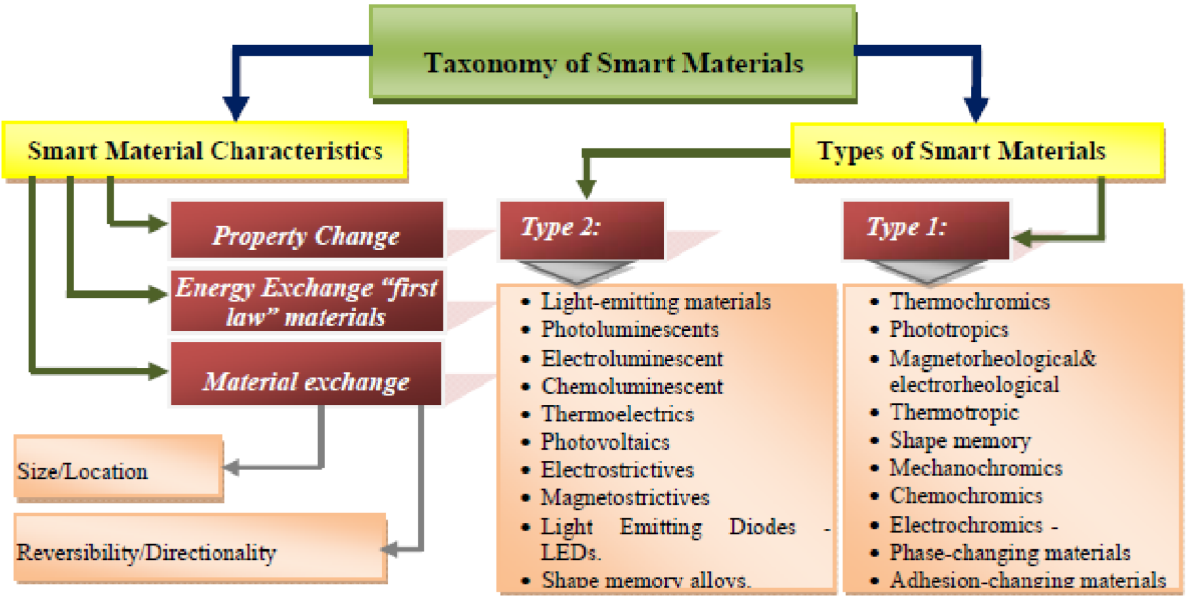


Figure 2.1: Taxonomy of smart material (extracted from [5])

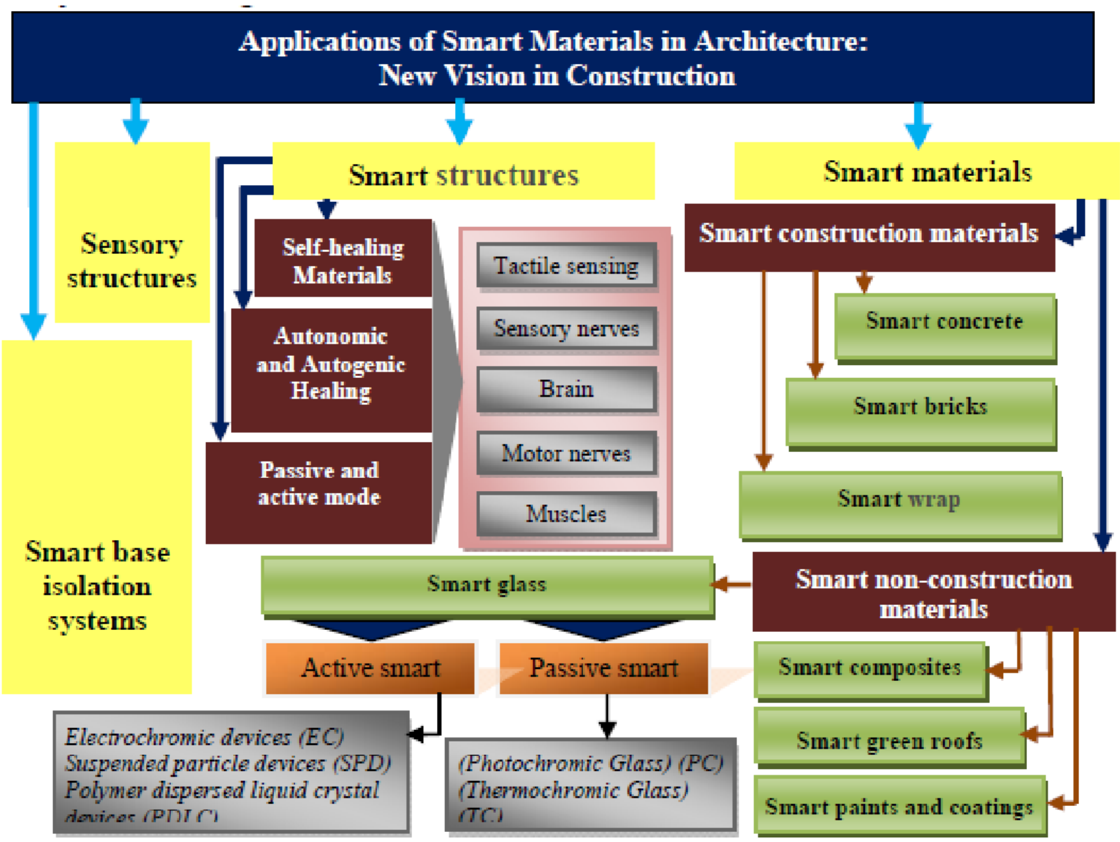


Figure 2.2: Application of smart materials in architecture/building (extracted from [5])

Chapter 3: Big data management and connectivity

3.1. Introduction to Big Data in construction

Today, the tasks of developing methods for estimating parameters of big data, defining approaches to their structuring, accumulation, testing and storage, as well as determining the relationship between formats and their streaming become very important. The competitive advantage is the ability to transform the results of big data analysis to identify, understand and respond to hidden trends in order to make management decisions.

Basically, Big Data has six defining attributes (refer to Figure 3.1), namely:

(i) volume (terabytes, petabytes of data and beyond);
(ii) variety (heterogeneous formats like text, sensors, audio, video, graphs and more);
(iii) velocity (continuous streams of the data);
(iv) veracity (reliability, data quality);
(v) value (profitability of information); and
(vi) variability (structured, unstructured data).

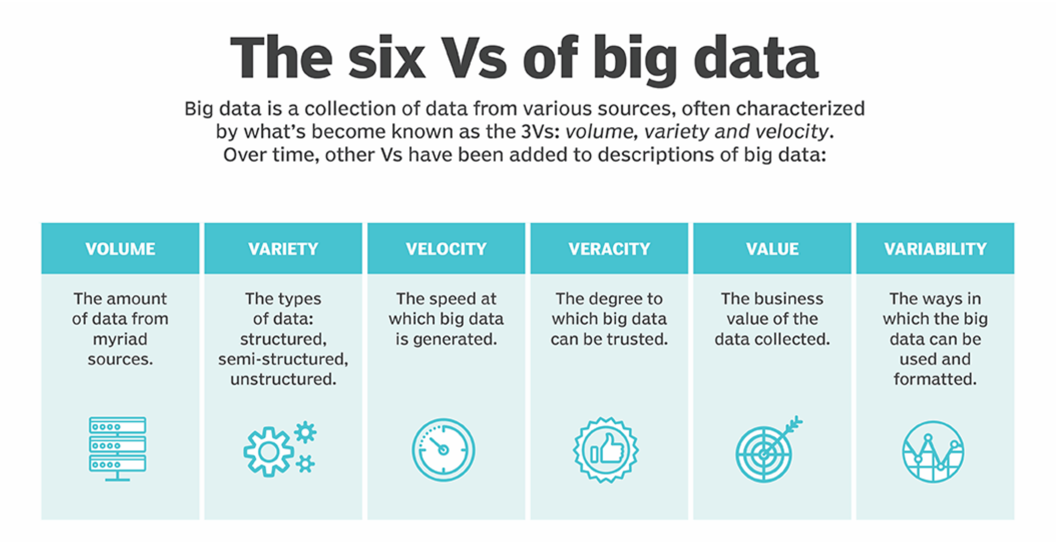


Figure 3.1: The six Vs of big data

source: https://searchdatamanagement.techtarget.com/definition/big-data

The 6V's of Big Data are clearly evident in construction data. Construction data is typically large, heterogeneous and dynamic. Construction data is voluminous due to large volumes of design data, schedules, Enterprise Resource Planning (ERP) systems, financial data, etc. Therefore, the construction industry faces different obstacles than the manufacturing sector to increase productivity. For example, high numbers of interrelated processes, sub-processes and participating actors at different stages and in different building locations make the construction industry complex. This complexity leads to high levels of uncertainty in the industry. Construction projects usually are unique, time-limited, require high degrees of customization and in part are undertaken on-site, a location that is highly influenced by weather conditions. Moreover, due to the temporary nature of construction projects, complete and standardized specifications for processes, materials, work and teams are missing. To overcome these challenges, four keys to the digital transformation are seen as decisive: digital data, automation, connectivity, and digital access.

In addition, research efforts lag behind the attention Industry 4.0 receives in other manufacturing fields. Today, Building Information Modeling (BIM) is considered to be the central technology for digitization of the construction manufacturing environment. Other associated technologies and concepts such as Radio-Frequency Identification (RFID), the Internet of Things, Cloud Computing, Augmented Reality, Virtual Reality and the Human-Computer-Interaction also are seen as major components of Industry 4.0 that enable digitized construction environments.

Figure 3.2 shows the trend of big data in terms of consumption and revenue up to 2025. This data shows the importance of preparing short–term and long–term strategic planning in Malaysia, especially in the construction industry.

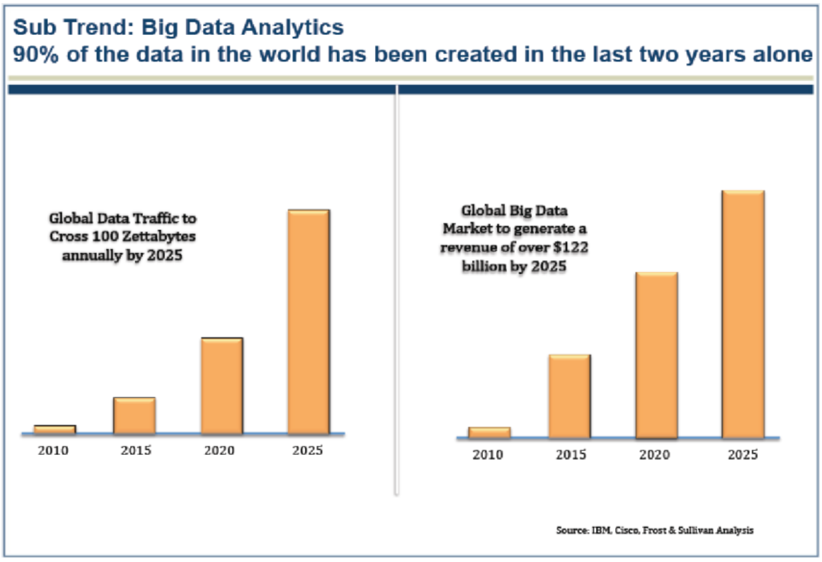


Figure 3.2: Big Data Analytics related statistics showing increasing of usage and revenue until 2025.
source: IBM, Cisco, Frost & Sullivan Analysis

3.2 Current practices in the industry / Government policies or directives in place (Big Data)

3.2.1 Big Data Maturity model and Basic Roadmap

In the Industry 4.0 maturity models, there are several ways to look at the mentioned staged approaches. One such maturity approach looks at the information and actual operations and manufacturing systems perspective with autonomous machines and systems as true Industry 4.0. It should be a staged approach with potential value opportunities to be tapped at each step. Typically, the Industry 4.0 models can be divided into four (4) stages (refer Figure 3.3), which will be described below:

Stage 1 – See and ask what is happening

Under the preliminary stage; this is where connectivity is required to connect all relevant sensors to collect real time data. This involves sensors and monitoring tools, which can also include hardware as well as software. At this stage; the amount of data collection might be huge and falls under big data, therefore it is necessary to identify the right data that is required to focus with. Once the data is available, it has to be converted to the information via various analyses to explain what is happening.

Stage 2 – Understand and ask what has happened (Descriptive)

Under this stage, it starts to inject the elements of intelligence as well as technical understanding based on the data that has been collected from previous stage. The intention is to convert from information to knowledge, where it should be able to explain why the event is happening based on the data. Data patterns can be studied and generate more analytics based on recognized events. Various artificial intelligence and machine learning method can be utilized in order to analyze the data.

Stage 3 – Prepare and ask why did it happen (Diagnostic)

At stage 3; it provides the capability to predict why did it happen based on the data given. It transfers the data from knowledge to wisdom, and turns it the ability to forecast what would be the expected outcome if no intervention is taken within stipulated time. It allows people ample time to make necessary preparation and calculated risk prior to the event.

Stage 4 – Adapt autonomous and ask what is going to happen (Prescriptive)

Under autonomous; the system should be able to prescribe the proposed action based on the data patterns with minimum human intervention. The system should be able to automatically self-optimize the expected outcome. Data will be elevated from wisdom to reaction and from forecast to proactive action. Under autonomous, it provides the element of agility, allowing higher tolerance of flexibility as well as uplifting the true innovation of industrial revolution 4.0.

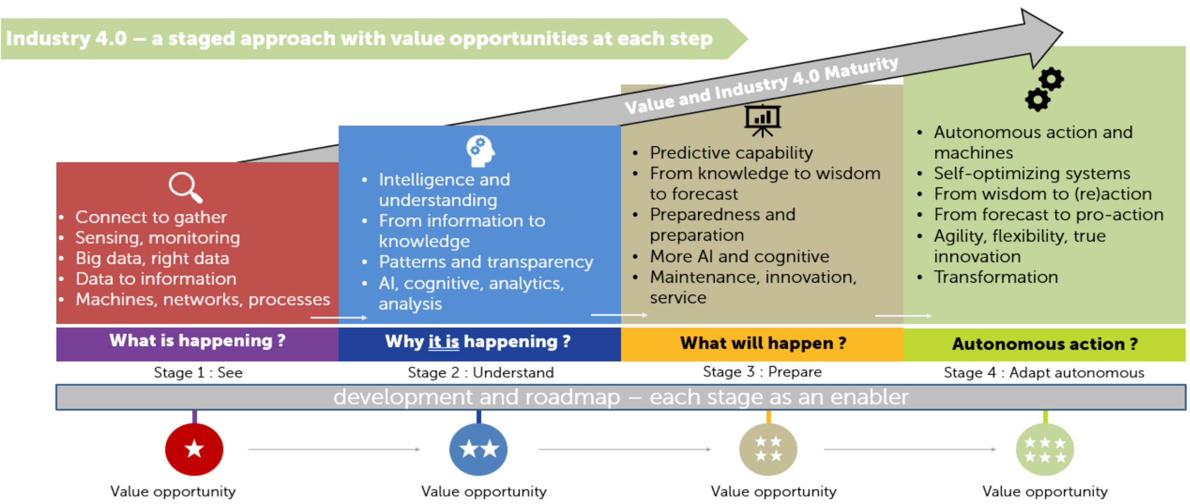


Figure 3.3: Value and Industry 4.0 Maturity

The industry 4.0 maturity marks the emergence of a physical cyber system that will change the future in construction process. The emphasis on the utilisation of technology plus a need to enhance skills and knowledge is a vital basis in facing these changes. Significant to the situation, the Ministry of Works aka *Kementerian Kerja Raya (KKR)* through CIDB, and in collaboration with parties with interests in the construction industry successfully developed a Construction Strategy Plan 4.0 (2021 – 2050) to help the construction industry through the changes.

Construction Strategy Plan 4.0 is a 5 year, CIDB short-term plan, which will be the basis for a draft plan framework that will boost the construction industry capabilities in the 4.0 Industry revolutions. The strategic plan is being developed in line with the Shared Prosperity Vision 2030 or *Wawasan Kemakmuran Bersama (WKB) 2030* and the National 4.0 Industry Policy (Industry4WRD)/ *Dasar Industri 4.0 Nasional (Industry4WRD).* It also supports and complements other national policies, amongst which are, National IoT Strategic Roadmap/ *Pelan Hala Tuju Strategik Internet of Things (IoT) Kebangsaan*, Malaysia Smartcity Framework/ *Rangka Kerja Bandar Pintar Malaysia* and, Digital Economic Policy/ *Dasar Ekonomi Digital*.

Furthermore, there are several ongoing implementations by relevant Government Agencies such as:

i) Big Data with BIM with other domains such as resource and waste optimization, generative designs, clash detection on designs, performance prediction and visual analytic. For example, PWD has embarked on the utilisation of BIM that enable the technical department to manage and oversee the asset life cycle processes starting from the planning stage, acquisition of the asset, design, registry of asset for buildings and subsequently, the facility management activities.

ii) Big Data with cloud computing related to the data storage in order to support the integration of tasks in BIM-based applications. The Government through the Malaysian Administrative Modernisation and Management Planning Unit (MAMPU) has implemented the Public Sector Data Centre (PDSA) project in 2011. To date, PDSA has installed more than 1000 servers for 120 agencies through PDSA centralised services. PDSA has created data centre services and the Disaster Relief Centre for centralised ICT service operationalisation for Government agencies. With the implementation of the PDSA project, the Government has been able to reduce 20% of its ICT operational cost and intensifies the focus on the core business for its agencies' technical personnel. The Government also succeeds in protecting its ICT assets and minimises the impact of threats on those assets.

iii) Big Data with Internet of Things (IOT) such as RFID usage for construction monitoring and quality control. In 2019, PWD signed a Memorandum of Understanding (MOU) with Telekom Malaysia (TM) to undertake an IoT and Big Data Analytics initiative on Smart Traffic Light. This system provides intelligence and maintenance prediction capabilities that will ultimately provide traffic management efficiency. So far, the system has been installed more than 30 smart traffic lights at various spots. Recently, PWD is embarking on a new initiative, a potential collaboration with a leading global provider of ICT infrastructure and smart devices utilising Artificial Intelligence and Machine Learning in construction project called The New Generation i-Supervision. The feed from a set of high-definition video monitoring smart cameras installed at various spots at the construction site will be analysed to provide construction resources management and progress analysis and prediction. Integrating the system with Building Information Modelling (BIM) allows for more accurate and comprehensive project monitoring and control.

iv) Big Data for smart buildings that promise comfort, safety and energy such as sensors related to motion, temperature, airflow, lighting and sensor based fire-fighting systems. The initiative of using sensors has been widely used in the Facility Management contract. For example, in government buildings, sensors are used to monitor the energy consumption. Also some of private buildings used the Building Automation System (BAS) consists of a system installed in buildings that controls and monitors building services responsible for heating, cooling, ventilation, air conditioning, lighting, shading, life safety, alarm security systems, and many more. With these initiatives, the building owners can optimized the energy usage and save cost in the operations of the building.

v) Big Data with Augmented Reality (AR) such as virtual site visits, proactive schedule dispute identification and resolution, and as-panned vs. as-built comparison. This requires new interactive platforms and methodologies to visualise construction related datasets.

3.3 Issues and challenges faced by the industry (Big Data)

3.3.1 Data security, privacy and protection

Public sector and private sector must work together in formulating the solution related to the issue of data security, data ownership, and management issues.

3.3.2 Data quality of construction industry datasets

The construction industry is well-known for fragmented data management practices. Despite the aggressive promotion of BIM, companies using BIM are still rare. Null values, misleading values, outliers, non-standardised values, among others, are some of the essential traits of industry data. And producing high-valued analytics is challenging due to poor data management practices. High quality data is preliminary for successful Big Data projects. It is observed that analytics projects usually require approximately 80% of time cleaning noisy datasets before embarking on analytics. So, Big Data projects in construction industry shall also be specially taken care of, for data quality related issues. Otherwise, the resulting insights are likely to mislead, which in turn will result in unpleasant and pessimistic feeling in the industry. Consequently, the industry will be reluctant towards adopting such fascinating trends like Big Data.

3.3.2 Cost implications for Big Data in construction industry

Every technology incurs cost so introducing Big Data in construction is not for free of charge. Companies are required to set up data centres and purchase software licenses, which can be an attractive investment. Also, skilled IT personnel to keep the entire ecosystem running are another overhead. So Big Data has inevitably substantial cost implication. The construction business is considered amongst the low-profit-margin businessess, and introducing such costly add-ons to projects is more likely to be opposed and difficult to be defended. However, Big Data has the potential to enhance the overall project delivery by optimising processes and reducing risks that companies usually bear due to myriad inefficiencies such as delays, litigations, etc. It is highly optimistic that construction industry can gain huge revenue from this investment as experienced by other industries, provided the right methodology is used to employ Big Data. The exact cost implication of Big Data is, however, difficult to quantify. More studies on cost benefit analysis of using Big Data technologies in construction projects are required.

3.3.3 Internet connectivity for Big Data applications

In order to monitor project site activities at real-time, instant data transmission between project sites (dams, highways, etc.) and centralised Big Data repository should be supported. However, project sites usually have low bandwidth; due to unavailability of sophisticated networking infrastructure in rural, underdeveloped areas. Advanced wireless sensor networks need to be extended to tackle internet connectivity issues in these types of Big Data applications; otherwise, the decisions on stale offline data will not be useful for effective monitoring. Next chapter will touch on this topic regarding the connectivity in construction industry.

3.4 Proposed solutions and recommendations for relevant Authority / Agency (Big Data)

Below are some of the recommendations that can be extended from existing Government initiatives:

3.4.1 Identify the needs of upgrading existing infrastructure in the Government relevant agencies towards implementation of Construction 4.0 and expend the needs from the Private Sector (in term of budget allocation, creating a data centre or hyper scale hybrid data centres, cloud computing services and special unit/organisation as the caretaker of the digital infrastructure). This special unit/organisation will responsible in monitoring, the data governance, data security, data usage, data analysis and reporting. This will also involve the existing regulations related to protecting the privacy; administering public/private sector's data resources so that they can be jointly utilised by public and private organisations; and facilitating the evolution of labour market in potentially disruptive industries through automation and digital technology. Refer to Table 3.1 below:

Table 3.1: Recommendation for action by leading agency to address needs of the Construction Industry

No	Leading Agency	Stakeholders	Timeframe	Cost
1	Ministry of Works (Kementerian Kerja Raya – KKR)	i- MAMPU ii-Ministry of Finance (MOF) iii-Jabatan Peguam Negara iv-Economic Planning Unit (EPU) v-ICU - Unit Penyelarasan Pelaksanaan JPM vi-Jabatan Kerja Raya (JKR) vii-CIDB viii-BEM ix-IEM x-GLCs (e.g. TM)	By 2025	The development efforts will be undertaken via a series of public-private partnerships, with the private sector contributing funds and expertise.

Note for Table 3.1: The above recommendations may have time and cost implications. Further study will have to be carried out should the recommended agency is agreeable to take the lead to initiate the course of action as required.

3.4.2 Leverage and enhance the integration of existing data platform for construction data sharing between the Government relevant agencies and the private sectors (To formulate the suitable integration approach between the data from the Government relevant agencies and the private sectors). Refer to Table 3.2 for an over view of this issue.

Table 3.2: Recommendation for action by leading agency to co-ordinate integration and data sharing

No	Leading Agency	Stakeholders	Timeframe	Cost
1	Malaysian Administrative Modernisation and Management Planning Unit (MAMPU)	i) Ministry of Works ii) Economic Planning Unit (EPU) iii) ICU - Unit Penyelarasan Pelaksanaan JPM iv) Jabatan Kerja Raya (JKR) v) CIDB vi) BEM vii) IEM viii) GLCs (expert in ICT)	By 2025	Depend on the mutual agreement (percentage ratio) between the Government and the private sectors.

Note for Table 3.2: The above recommendations may have time and cost implications. Further study will have to be carried out should the recommended agency is agreeable to take the lead to initiate the course of action as required.

3.4.3 Encourage the usage of real-time data for monitoring update and utilise big data analytics for decision making process and insights in the construction industry. Refer to Table 3.3 for over view of leading agency and relevant stakeholders involved.

Table 3.3: Recommendation for action by leading agency to monitor real-time data usage

No	Leading Agency	Stakeholders	Timeframe	Cost
1	Economic Planning Unit (EPU)	i) ICU - Unit Penyelarasan Pelaksanaan JPM i) Ministry of Works ii) Jabatan Kerja Raya (JKR) iii) CIDB iv) BEM v) IEM	By 2030	To be further studied

Note for Table 3.3: The above recommendations may have time and cost implications. Further study will have to be carried out should the recommended agency is agreeable to take the lead to initiate the course of action as required.

3.5. Introduction to Connectivity in construction

The construction industry is one of the least-digitized industry in Malaysia. Many leading local enterprises in construction industry are still operated in the traditional manner due to many challenges such as resistance of culture change, new business model, talents shortage and unaffordable digital solutions. But times are changing in the Fourth Industrial Revolution (IR 4.0) era, applying IR 4.0 technologies in construction i.e. Construction 4.0 is inevitable as the trend in construction industry in order for them to stay competitive in their business. Within the eleven technology pillars for IR 4.0, connectivity through the connectivity platforms is particularly crucial to achieve digitally connected enterprises. It will be able to increase the visibility in business processes, gaining greater efficiencies and productivity.

3.5.1 Definition of connectivity

Connectivity is used to describe how well the hardware and software devices can communicate to perform information exchange. It is synonymous with the multi-layer concept comprised of different type of networks with interconnected end nodes such as a computer, controller, smart device, smart phone from the local to the regional and globally. The value of connectivity and therefore its significance lies in the role of end nodes and connectivity platform connected them into the networks. Hence, when the cost of connectivity platform is low, then it will likely to achieve complete connectivity whereas when the cost is high, the connectivity is low, hence limited the interaction between the end nodes.

3.5.2 Value of digital data sharing

Data is an essential resource for economic growth, competitiveness and innovation in generation. Awareness on the value of digital data in order for an enterprise to use it to create value [1] for their product or services, it is necessary to understand the evolution of data from IR 2.0 to IR 4.0 as shown in Figure 3.4. In the early industrial revolution, data is used for process control and improvement of activities in the manufacturing and services. Due to the advancement of Cyber-Physical System (CPS) technologies in IR 4.0 such as Internet of Things (IoT), cloud computing, data analytics and artificial intelligence (AI), the large amount of collected real time data will be useful for providing the product business insights not only within the enterprise but also benefited to others stakeholders in the supply-demand chain. Hence, data can create value, it is an asset to create competitive advantages and increase enterprise’s competitiveness in business.

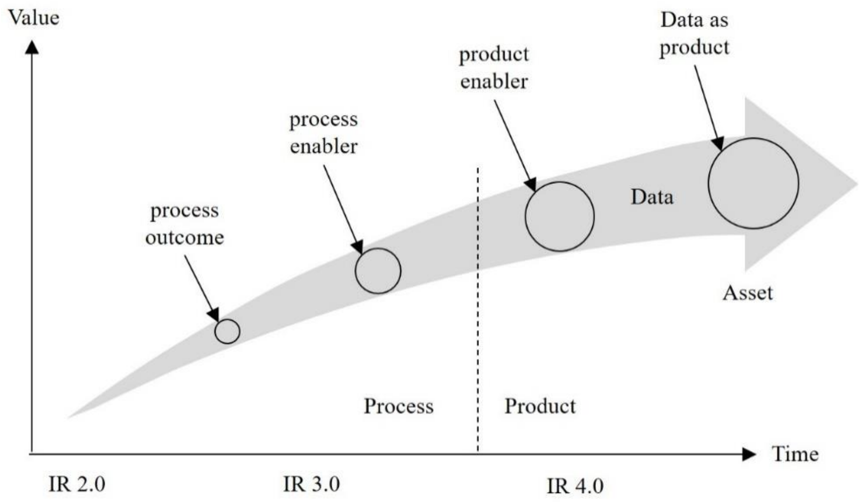


Figure 3.4: Value of data in the industrial revolution

Data can be collected and process it to a useful information from the activities in the value chain [2] as shown in Figure 3.5. The value chain in an enterprise has the primary activities include logistics, operations, services, marketing and sales. These primary activities need to connect to ensure the data integrity and timeliness through upgrading of digital infrastructure and adoption of system integration technology. Connectivity as a digital channel for the data to be shared among activities in the enterprise, it will help to increase business efficiencies, maximise the human resource utilization and managing procurement to increase productivity.

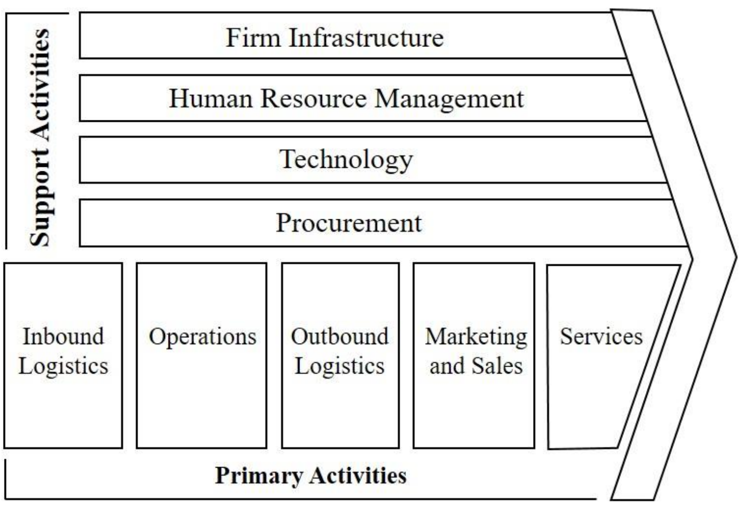


Figure 3.5: Value chain of a stakeholder

Beside beneficial to the enterprise, connectivity allows to exchange real time digital information among the stakeholders through an integrated value chains as shown in Figure 3.6. The activities from project-based nature of construction projects require the stakeholders in the value chains to work together. These activities in the value chain utilises many different skills, knowledge and disciplines, from architecture and design, convert raw materials to product, distribution to the purchasers to use in the construction projects.

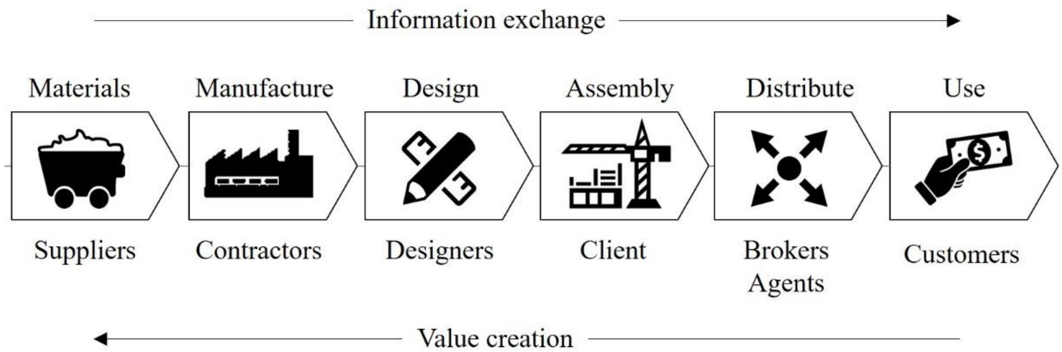


Figure 3.6: The flow of information for value creation in the integrated value chains

Multiple stakeholders influence the data from the construction projects and information flow in the supply-demand chain systems [3] as shown in Figure 3.7**.** The information can flow from the supply chain system such as the used of green materials information flow from the material suppliers, subcontractors and to the project developers can be used to set the sales and marketing strategy in the demand chain system to promote environment friendly housing projects, setting the government tax incentives, investment bank policy, investment by the investors etc. Hence, each of these activities have to create, access, share and interpret different sets of information other than materials, it can extend to the project specifications, visualisations, architectural plans and models, structural calculations, plans of work, bills of quantities, quality assessments and so on.

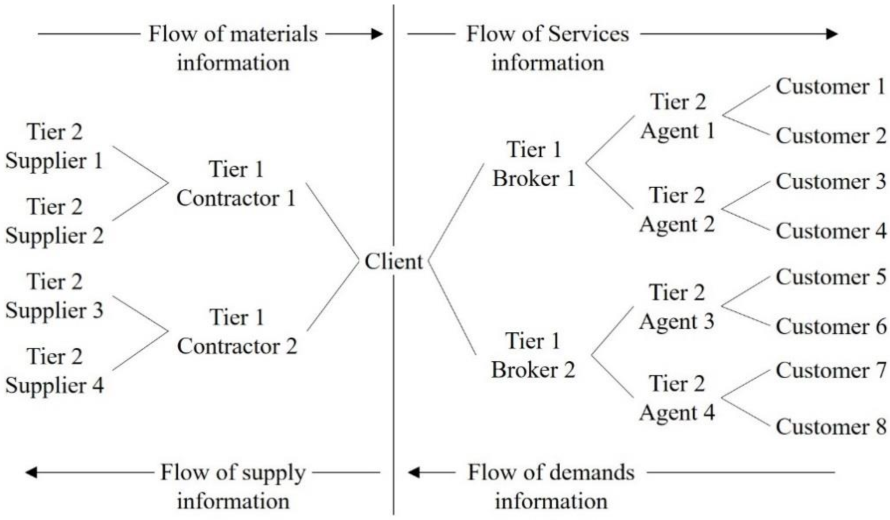


Figure 3.7: The flow of information in the supply-demand chain systems in construction

3.5.3 Pain points without connectivity

Construction projects are information-intensive fields of activity due to its scale and complexity of supply-demand chain. Problems of minimal information sharing between the stakeholders working on the same project remain. Incomplete or inconsistent information results in errors, expensive re-work, misunderstandings and conflict. There are numerous factors which contribute to these problems. The disciplinary basis of construction work produces a silo mentality and unwillingness to exchange information, where the interactions between different design disciplines, or design and construction, are limited. As a results, there are pain points of no connectivity within and between stakeholders as listed below:

- Obtain accurate information on the market demand and supply of construction materials to manage the cost and inventory resulting in the price per unit increase.
- Unable to predict the supply chain disruption which is important for pro-active actions planning and provide business insights for sales and marketing strategy planning
- Fail in managing the construction materials delivery, storage and logistics which will increase in cost due to time and materials wastages.

3.6 Connectivity challenges

Due to the scale and complexity of the supply-demand chain in construction industry, there are a few challenges to connect the value chain of stakeholders in order to exchange information to overcome the pain points. The challenges including the vertical and horizontal integration, connectivity platform integration and interoperability, cyber security and data sovereignty.

3.6.1 Vertical and Horizontal Integration

The vertical and horizontal integration [4] in construction industry is shown in Figure 3.8. The operations in the shop floor to top floor is vertically integrated so that the real time digital data can be utilized for business decision and planning. Conversion of digital data into useful information should be make available for the stakeholders in the horizontally integrated value chains. The stakeholders will be able to exchange information to improve their product or services in order to create values for their customers in the supply-demand chain. For example, manufacturer of construction material may require material design from the design stakeholder, and the design stakeholder may need the digital data from the assembly stakeholders to perform analytics for the material design improvement. However, in order to integrate vertically and horizontally within and between stakeholders, it requires affordable and sustainable digital solutions and ability to identify the digital assets which can be shared among the stakeholders to create value in the business activities.

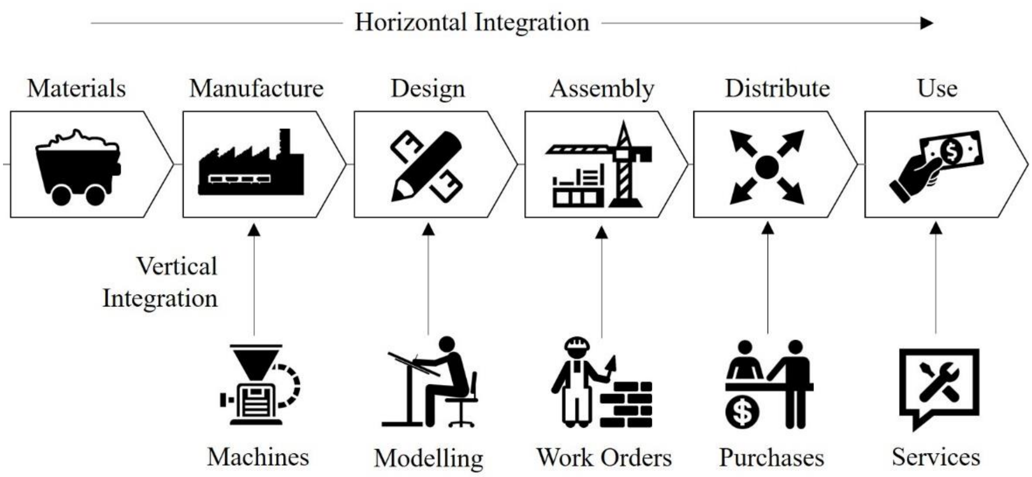


Figure 3.8: Vertical and horizontal integration in construction industry

3.6.2 Integration and Interoperability

There are many connectivity platforms across the entire construction supply chain [5,6,7] for different applications as shown in Figure 3.9. The Building Information Modelling (BIM) is focused on the construction design and planning, whereas the Manufacturing Chain Management (MCM) is for the manufacturing processes digitalization and management in the integrated value chains. Another common connectivity platform is the Internet of Things (IOT) platform for the smart devices to be connected and share sensor data within different stakeholders. Each of the connectivity platform has its own strength. Hence, the platform integration and interoperability come up to be important between connectivity platforms. One connectivity platform needs to have the ability to communicate to each other to channel the information from one platform to the others, which will provide a way to exchange information from the different processes or services in order to help drive decisions and improve efficiency. However, not all connectivity platforms provide method for integration. Some of them also do not follow the international Standards in order to achieve interoperability.

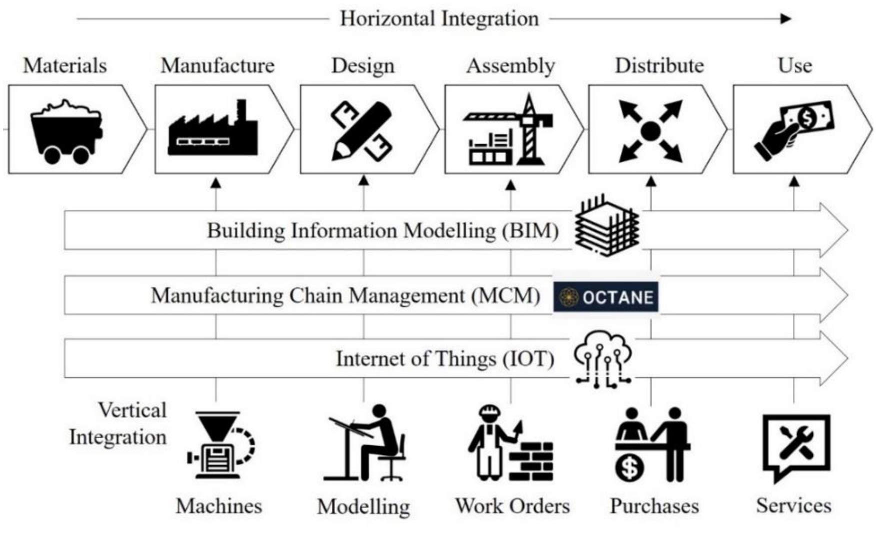


Figure 3.9: Different connectivity platforms in the horizontal integration

3.6.3 Cyber security and data sovereignty

In any industry, digital data is an asset for the enterprises. The data autonomy is important for the enterprise to complete control over the data. The data owner can decide what and when data can be shared within the enterprise and with which stakeholders through access control to maintain the data sovereignty and confidentiality. Other than that, the enterprise needs to face challenges on the storage of digital data either on-premise or in the cloud, they also concern about cyber security issue which may cause the collapse, losing of data and cost incur to do the disaster recovery. Hence, the data management architecture is important to ensure above mentioned challenges can be reduced to the minimum.

The widely adopted data exchange architecture [8] is shown in Figure 3.10. The data broker will act as a mediator to hold the data description but not the actual data itself. It connects and only share the data description with the stakeholders which are connected to the broker. In this case, the materials supplier who is the data provider will give access permission to the manufacturer as data consumer through the broker. After granted the permission, point to point connection is established and the digital data will deliver to the data consumer until the permission is lapsed. Hence, the digital data still contain within the enterprise to maintain the data sovereignty. However, this digital data management ecosystem with infrastructure to host the data description and manage it to benefit everyone of the stakeholders in the construction industry is yet to establish in Malaysia.

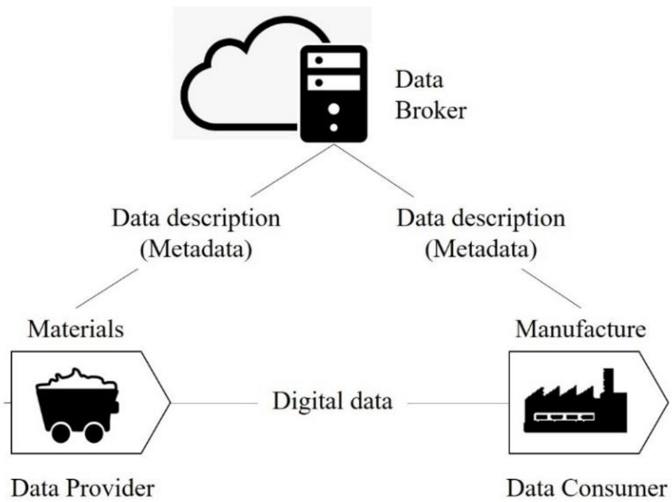


Figure 3.10: Data exchange architecture

3.7 Connectivity initiatives

Connectivity has become a defining feature of the modern economy and one of the significant trends in the Fourth Industrial Revolution (IR4.0) era. This is reflected in the increasing demand for resources to be invested in linking communities, economies and countries. There are many digital data-driven initiatives to meet the growing demand for connectivity with objectives of promoting growth and productivity, enhancing access markets and opportunities and building network resilience in various business sectors.

3.7.1 China: Digital Silk Road, 2015

Announced in a 2015 Chinese government white paper [9], the Digital Silk Road has both foreign and domestic policy objectives that include creating China-centric digital infrastructure, exporting industrial overcapacity, facilitating the expansion of Chinese technology corporations, accessing large pools of data and potential to enhance digital connectivity in developing economies to improve the efficiency of purchase and delivery of construction raw materials, tooling and equipment such as steels, machines, parts manufactured by the factory in China to deliver to the developing economies to build the seaport, highway and railway for the Belt and Road Initiative (BRI). The Digital Silk Road is comprised of four interrelated, technologically-focused components. First, China is investing in digital infrastructure abroad, including next-generation cellular networks, fibre optic cables, and data centres. Second, the initiative contains a domestic focus on developing advanced technologies that will be essential to global economic, including satellite-navigation systems, artificial intelligence, and quantum computing. Third, promotes e-commerce through digital free trade zones, which increase international e-commerce by reducing cross-border trade barriers and establishing regional logistics centres. Fourth, China is working to establish its ideal international digital environment through digital diplomacy and multilateral governance. This has included using multilateral institutions to establish technological standards related to telecommunications infrastructure and promoting the principle of cyber sovereignty.

3.7.2 Singapore: Integrated digital delivery, 2017

Integrated Digital Delivery (IDD) [10] is the use of digital technologies to integrate work processes and connect stakeholders working on the same project throughout the construction and building life-cycle. It covers the four areas as shown in Figure 3.11. IDD builds on the use of Building Information Modelling (BIM) and Virtual Design and Construction (VDC), which have been implemented in many projects over the past few years. VDC is the management of integrated multi-disciplinary performance models of design-construction projects, including the product, work processes and organization of the design - construction - operation team in order to support explicit and public business objectives.

Figure 3.11: Integrated Digital Delivery (IDD)

source: Singapore Building and Construction Authority, Integrated Digital Delivery

3.7.3 European Commission: Common European Data Spaces, 2018

The Common European Data Spaces [11,12] are composed of both the secure technological infrastructure for connectivity and the governance mechanisms ranging from health to the green deal as shown in Figure 3.12. It will allow digital data from across the EU, both from the connected public sector and businesses, to be exchanged in a trustworthy manner and at a lower cost, thereby boosting the development of new data-driven products and services. It will also ensure that more data becomes available for use in the economy and society, while keeping the companies and individuals who generate the data in control.

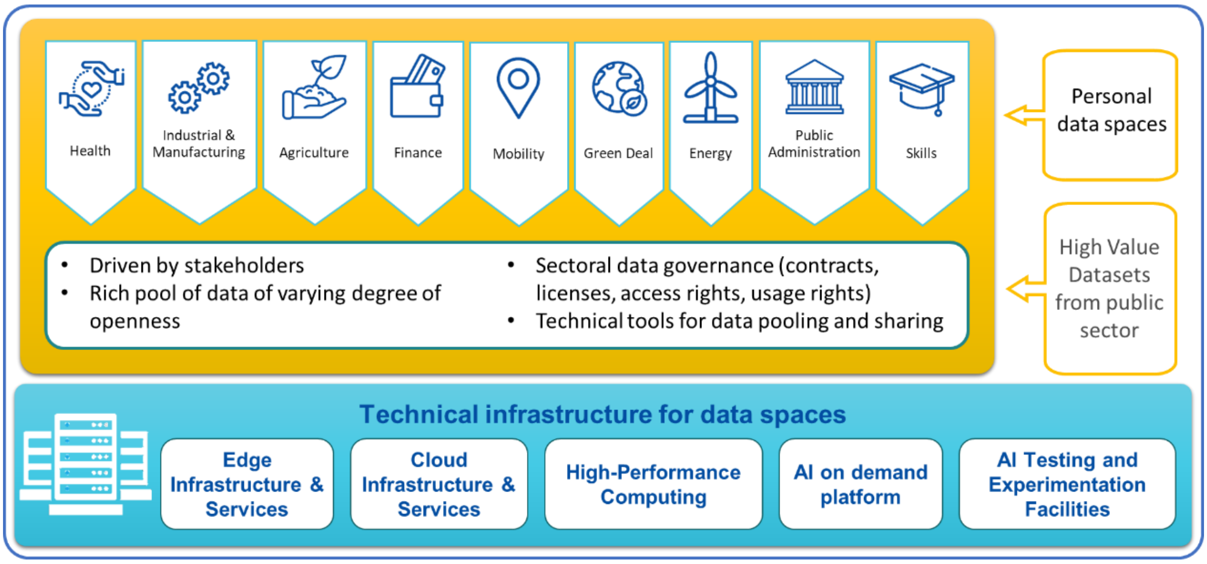


Figure 3.12: Common European Data Spaces

source: European Commission, "Building a data economy", 21, January 2021

3.7.4 Malaysia: National Fiberisation and Connectivity Plan, 2019-2023

The National Fiberisation and Connectivity Plan (NFCP) [13] is shown in Figure 3.13. The time frame for implementation of NFCP is 5 years from 2019 to 2023 was formulated in response to the desire to improve broadband quality and coverage, reduce broadband prices and provide Internet access across all spectrums of society in Malaysia. NFCP provides the strategic direction for the implementation of policies and initiatives whilst creating an ecosystem to facilitate adoption of future technologies. It addresses issues that hinder the availability of high-quality and affordable digital connectivity. Supports the needs of the country moving forward while harnessing opportunities offered by these new services/technologies and provides clarity in terms of strategic directions for initiatives to support the digital economy and the adoption of future technology.

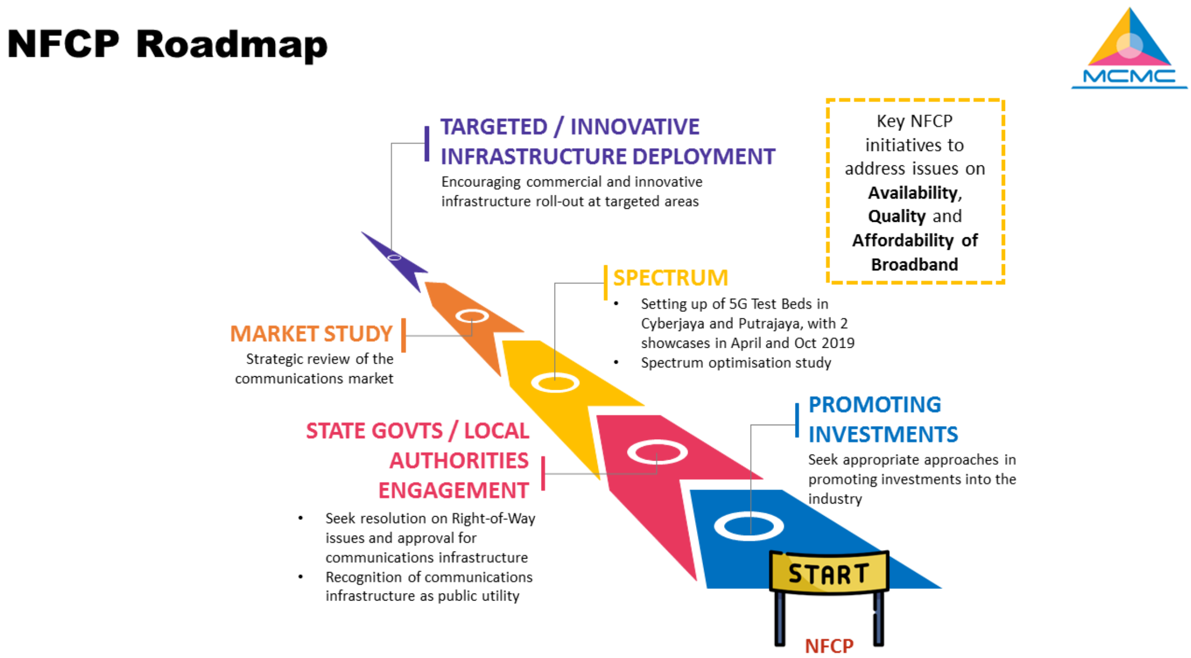


Figure 3.13: National Fiberisation and Connectivity Plan (NFCP)
source: MCMC, https://www.nfcp.my/?lang=ms-my

3.7.5 Malaysia: National 5G Plan, 2021

Digital Nasional Berhad (DNB) announced its partnership with Ericsson (Malaysia) on July 2021 [14] to accelerate the deployment of Malaysia's nationwide fifth generation (5G) network. The 5G network is one of the four pillars identified under Malaysia's digital transformation plan MyDIGITAL. It will serve as the nation's connectivity backbone and will be the springboard towards achieving the vision of a connected future and regional leader in the digital economy. In addition, it is expected to be a catalyst for significantly greater investment in related products and services to support the new jobs that will be created by the network and technology roll-out.

3.7.6 Impact of connectivity initiatives to construction industry in Malaysia

The connectivity initiatives in various countries will inevitably accelerate the move towards more collaborative construction contracts. It will also prompt new roles in the construction industry, roles that help facilitate collaboration and help to avoid and/or decide on disputes faster so that the materials and projects can be delivered on time.

The connectivity initiative will change the way that construction professionals interact, with office spaces changing to accommodate online conferencing and virtual reality workshops. This change will require a new breed of professionals with facilitation and coaching skills to help foster better communication between the project team members.

The connectivity initiative will also change the way of how the construction project from the initial planning to the implementation stage and deliver to the customers. It helps to increase productivity and improve quality through the data analytics and intelligence collected by the IoT device in the construction site with wire and wireless connectivity.

The construction industry in a country must setup and establish its connectivity to ensure the construction industry is stay competitive. It must set aside outdated silo processes and isolated management methods to make this a reality. Build a digital data-driven construction ecosystem. The industry will then be able to benefit from the opportunities that the latest advances in technology innovation for business operations present and connected.

3.8 Connectivity proposals

Connectivity is important in the digital data-driven construction ecosystem. Connectivity enables organizations to connect to different data sources in real-time and use them for visualization, data analytics, business and process intelligence vertically and horizontally in the integrated value chains.

In order to achieve the above objectives, there are two immediate actions for Construction industry to move forward in the Fourth Industrial Revolution (IR4.0) era. First action is to know the digital data origin through a unique identifier belong to the data provider. Second action is the scalable and sustainable connectivity platform for structure and unstructured data management in an affordable manner especially small and medium enterprises.

3.8.1 Digital Asset Identify Standardization

An International Registration Asset Identifier (IRAI) is proposed to the Department of Standards Malaysia (DSM) to have a connectivity Standard for a unique digital data identifier for digital information exchange in the construction industry as shown in Figure 3.14. IRAI is a unique asset identification number created by the enterprise based on the IRAI setting standard. The asset with its unique identifier can be shared with other stakeholders within the integrated value chains which will improve product and services, reduce waste and increase productivity.

An asset is an object that contains metadata and data elements that that creates value to meet the needs of enterprises. IRAI defines a structure for uniquely identifying organizations and their asset elements, enabling traceability and digital data interchange in a value chain especially perform business intelligence for the industry development and help to improve the business activities between different stakeholders.

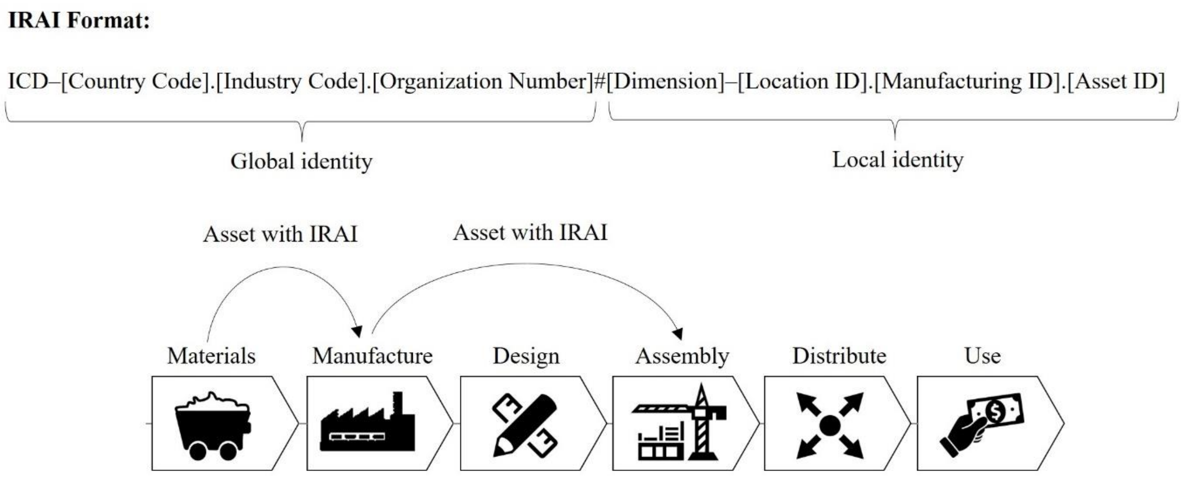


Figure 3.14: IRAI format and flow of data with IRAI in the integrated supply chains

The proposed IRAI setting standard is in line with the proposed National Smart Manufacturing Standard System Framework Guideline and the National Policy on Industry 4.0 (Industry4WRD) and it is also aligned to the government policies such as New Industrial Master Plan (2021 – 2030), Malaysia Productivity Blueprint (MPB), 12th Malaysia Plan and PENJANA.

IRAI setting standard should be designed to further support the implementation of National Smart Manufacturing Standard System Framework. The manufacturing industry can trace the asset and exchange of asset data based on the collaborative business model to between business entities to strengthen product quality, research and development and increase productivity.

3.8.2 Malaysia Construction Assets Space Strategy

A common connectivity platform is necessary for the construction stakeholders in the integrated value chains to exchange information in the form of asset that they agreed to share with others for the economic growth, competitiveness, innovation and job creation in the construction industry. This connectivity platform is called Malaysia Construction Assets Space (MaCAS). It has to be led by MOSTI to set it up and manage by an independent organization to support the construction industry in Malaysia. The objective of the strategy is to make Malaysia a role model using digital data to create value in the construction industry. The MaCAS strategy should focus on the following four key area of activities:

1. A governance and sharing framework for asset identify, access and use
2. Support the construction industry by government through grant or incentive to setup the infrastructure to connect into MaCAS
3. Empowering enterprises, investing in skills and technology related to big data analytics, business and process intelligence
4. Enhance IoT network coverage and applications development

The proposed architecture of Malaysia Construction Assets Space (MaCAS) architecture is shown in Figure 3.15. The MaCAS architecture is a connectivity between any of the stakeholders in the integrated value chains. The enterprise need to setup a Connector to connect their value chain, selected assets that can create value for the business and share their metadata in MaCAS. Any of the stakeholders can go through MaCAS platform to request for asset data permission from the asset provider. After the asset provider approved the request of asset consumer, the asset data will channel from the point of asset provider to point of asset consumer directly without going through any intermediary platform to maintain the data sovereignty.

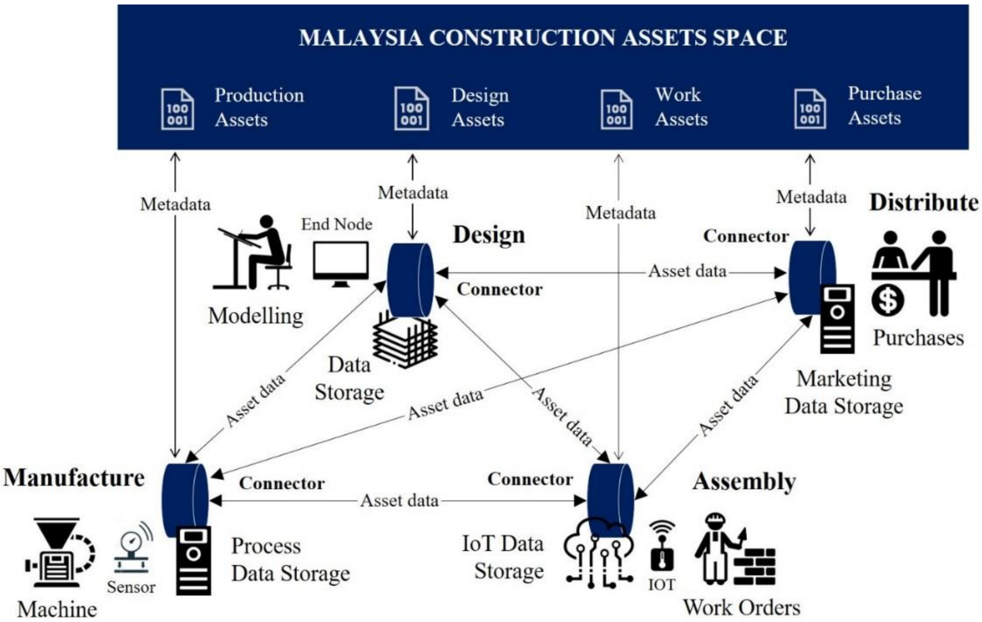


Figure 3.15: Malaysia Construction Assets Space (MaCAS) Architecture

The Malaysia Construction Assets Space can be used as the business level connectivity platform for the application of IOT devices in the construction industry is shown in Figure 3.16. Connectivity at the application and business level to share of IoT data with other stakeholder has always been a challenge in construction industry due to lack of access area to provide quality network on site, and the lack of backbone network coverage. IoT networks such as Sigfox and NB-IOT have recently been made available in Malaysia but the adoption to the network remains low. This is due to the high setup cost, lack of network coverage especially in the area of lower density population and availability of connectivity platform. Also, this couples with the lack of network access in the local construction area.

Hence, the challenge of the construction industry is to utilize IoT devices that use widely available networks with tracking capability. A research and development company Dutamas Tiara Abadi PLT has stepped up to develop an IoT device to address this challenge. The general work principle of the IoT device to generate data and share with other stakeholders in the construction industry is shown in Figure 3.16.

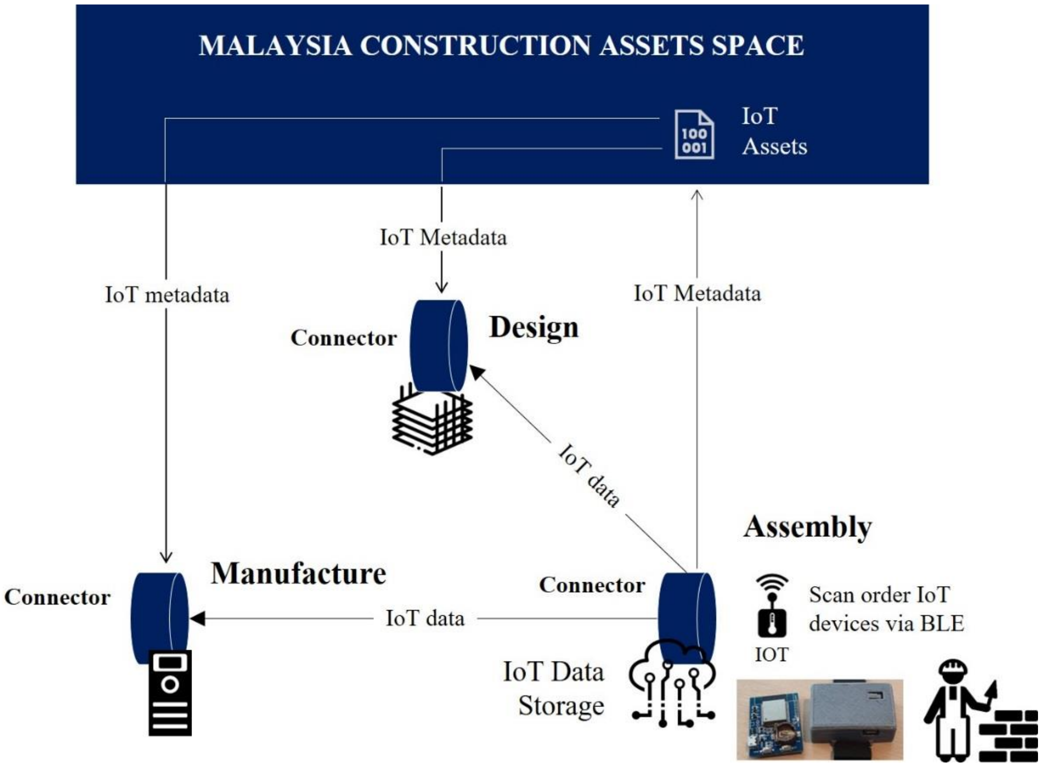


Figure 3.16: IoT network via BLE connected to MaCAS

The IoT device uses Bluetooth Low Energy (BLE) to scan other devices and collect information as shown. After scanning, data will be stored on the device. The information will be sent to the cloud via Wi-Fi periodically or when available. The work principle is shown in Figure 3.17.

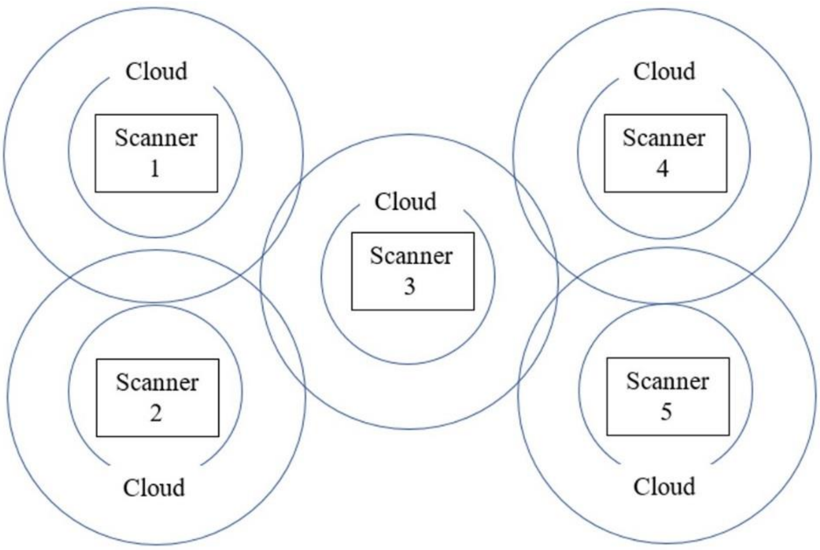
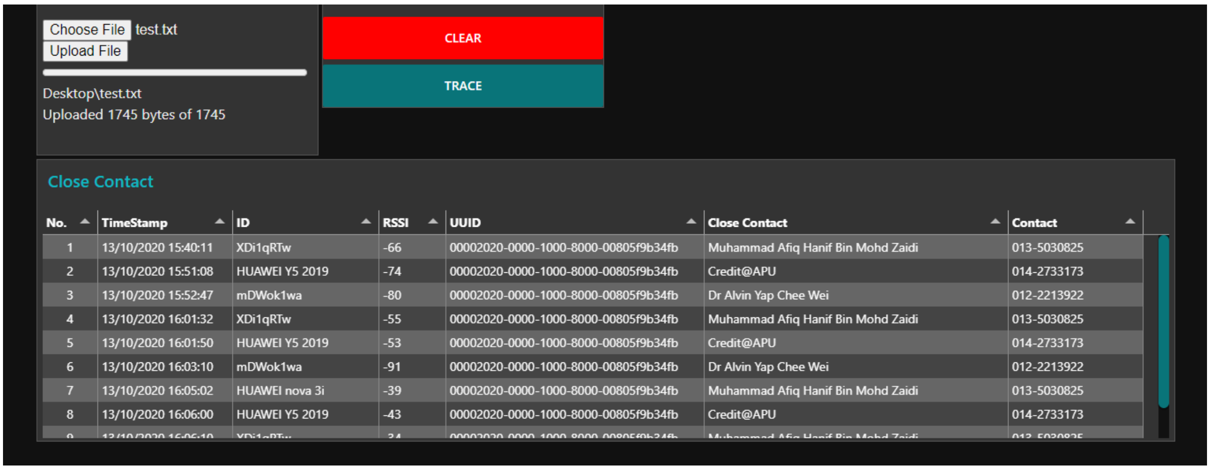


Figure 3.17: The framework of IoT device at application level

Both BLE and WiFi networks are widely available and this availability increases the adoption of IoT devices in construction. With BLE, the IoT device can scan each other within the range of 100m and each device has the capability to send data to the cloud individually. The BLE of the IoT device operates on the bandwidth of 2.4GHz ISM Band (2.402 – 2.480 GHz Utilized). This frequency is aligned with the frequency allowed by MCMC. Figure 3.18 shows the IoT device with an enclosure.

Figure 3.18: The IoT Device in the Original Form with Enclosure

The data stored in the device will be transferred to the IoT data storage in the cloud. The stakeholders can request permission to acquire the data for analysis as shown in Figure 3.19. Results show the proximity of the devices and its owners. This can be useful for asset, staff tracking in quality control, maintenance and productivity.



No.	TimeStamp	ID	RSSI	UUID	Close Contact	Contact
1	13/10/2020 15:40:11	XDi1qRTw	-66	00002020-0000-1000-8000-00805f9b34fb	Muhammad Afiq Hanif Bin Mohd Zaidi	013-5030825
2	13/10/2020 15:51:08	HUAWEI Y5 2019	-74	00002020-0000-1000-8000-00805f9b34fb	Credit@APU	014-2733173
3	13/10/2020 15:52:47	mDWok1wa	-80	00002020-0000-1000-8000-00805f9b34fb	Dr Alvin Yap Chee Wei	012-2213922
4	13/10/2020 16:01:32	XDi1qRTw	-55	00002020-0000-1000-8000-00805f9b34fb	Muhammad Afiq Hanif Bin Mohd Zaidi	013-5030825
5	13/10/2020 16:01:50	HUAWEI Y5 2019	-53	00002020-0000-1000-8000-00805f9b34fb	Credit@APU	014-2733173
6	13/10/2020 16:03:10	mDWok1wa	-91	00002020-0000-1000-8000-00805f9b34fb	Dr Alvin Yap Chee Wei	012-2213922
7	13/10/2020 16:05:02	HUAWEI nova 3i	-39	00002020-0000-1000-8000-00805f9b34fb	Muhammad Afiq Hanif Bin Mohd Zaidi	013-5030825
8	13/10/2020 16:06:00	HUAWEI Y5 2019	-43	00002020-0000-1000-8000-00805f9b34fb	Credit@APU	014-2733173

Figure 3.19: Results of Scanning

3.9 References

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Chapter 4: Mobile communication and robotic technology

4.1   Introduction to mobile communication in construction industry

Construction industry involved multidimensional, interrelated and complex task. Its complex nature further confounded by involvement of diversified and physically dispersed stakeholders such as contractors, consultants, clients, suppliers and workers [1].

Construction projects involve participation of multiple organizations including clients, project managers, architects, consultants, contractors, material suppliers etc. and successful construction project management requires effective intra and inter organization communication between all the project team organizations. Intra organization communication is in the form of communication within head office, between head office and site office, between site office and mobile site staff and sometimes between different sites when these sites are being managed by a common resource pool. Inter organization communication is in the form of communication between site and other organizations like consultants and material suppliers and also between head offices of different organizations. In present scenario, project team organizations may be geographically separated and required communication can be achieved by the use of mobile communication technologies.

Communication of information, instruction, queries and approval has always been a herculean task and time consuming. Consequently, affecting the project's timely completion and quality issues such as error in construction due to mis-information. Hence, there is a need to have a collaborative and efficient communication system among these parties especially those who are away from a construction site yet involved in a project is crucial to achieve the intended target.

In order to reduce cost, avoid construction error and enhance productivity by eliminating process inefficiencies mainly attributed by lack of effective communication and collaborations is vital [2].

A mobile communication technology that is dynamic and provides information in real time. One piece of technology that can address this is the mobile phone which can be found at every construction site. "Their sheer ubiquity make them a natural fit as a platform upon which to put apps and tools easily accessible for workers, and they've enabled the industry to "cut the cord" when it comes to communications." [3].

Mobile technology is technology that goes where the user goes. It consists of portable two-way communications devices, computing devices and the networking technology that connects them. Currently, mobile technology is typified by internet-enabled devices like smartphones, tablets and watches.

Nowadays, construction site in developed nations have gradually embarked on mobile technology such as clocking in with mobile time cards, facial or biometric identification, site technician filing daily reports with his smartphone, or a supervising engineer's reviewing plans and specification on a tablet during a site visit.

Mobile communication and technology are able to assist in managing every aspect of a construction project, from preconstruction to scheduling, from project management and field reporting that eventually streamline construction processes and improve productivity. The two major aspect of mobile communication and technology in construction would be digital inspection and mobile correspondences or coordination.

Table 4.1: Comparison in upgrading in mobile network facility for private users and various industry sectors [4]

Major Features	3G Networks	4G Networks	5G Networks
Data Rate	Up to 2 Mbps	Up to 100 Mbps	10x to 100x increase
			10G+ peak rates CIR/EIR 1:10 10 Tbps network nodes
Bandwidth	5Mhz	100 MHz	1.30 Gbps
Frequency Band	Up to 2.4 GHz	Up to 8 GHz	bands below 6 GHz
Radio Access Technology	WCDMA	MC CDMA, OFDMA	should be valid for all sorts of radio access technologies, Flat IP Network
Switch Technique	Packet switch mostly	Digital	Both (Packet Switching and Digital)
Internet Protocol	IPv4, IPv6	IPv6	IPv6
End-to-End latency	131.3357 ms (on HSPA)	78.91807 ms (on LTE)	< 1ms, 5x reduction
Increased battery life for low power devices	-	-	>10x

With the rapid development in mobile communication network facility in terms of upgraded features, higher speed in data transfer, increasing data storage space and availability in the clouds, the future of mobile communication as a form of revolution in the construction industry in line with IR4.0 is never in doubt. Table 4-1 shows the potential and possibility in the future growth of mobile communication in benefitting the construction industry as a whole.

4.1.1. Digital inspection

1. Description of digital inspection:

   It starts with the conversion of paper forms into digital forms and transferring them onto a mobile platform. This process digitalizes a great number of manual processes on site and gives access to the various technologies available on a mobile phone or tablet.

   Paperwork can be processed in a faster manner and information can be captured more accurately and contain richer data. For example, a safety inspection could be completed by taking a picture on an application that would automatically capture the location, allow you to identify and tag issues and instantly share it with the relevant parties.

   In addition, inspections can be scheduled and tracked via mobile phone and each one can be enhanced with an additional layer of data captured by the mobile device.

2. Importance of digital inspection:

   The issues in construction industry that prelude towards adoption or need of digital inspection are:

   - Tedious paperwork in inspection and defect monitoring procedures
   - Quality, safety, health and environment monitoring issues

   The benefits that are expected from the adoption of digital inspection are:

- More streamlined and consistency in inspection and defect monitoring procedures with proper documentation kept for recording and auditing purposes
- Quality of work output is higher; safety and health issues are properly addressed to right people and system flow; and detrimental environmental effects to surrounding are minimized accordingly
- The right use of software or apps enables the above issues to be tackled conveniently and accessible to all authorized personnel, such as – Cloud based Aconex, Novade, Bentley, Finishline, Autodesk 360

4.1.2. Digital correspondences and coordination

1. Description of digital correspondences and coordination:

   As more manual site processes go digital, 'paper lag' or the time taken to compile and process data into an actionable report is reduced. Internet connectivity and cloud platforms can connect the site office with relevant stakeholders in their respective offices for better communication.

   By connecting to the cloud platform to aggregate and distribute data, a higher level of team collaboration can also be achieved by leveraging on the machine capability of coordinate processes, scheduling tasks and monitor progress.

2. Importance of digital correspondences and coordination:

   The issues in construction industry that prelude towards adoption or need of digital correspondences and coordination are:

   - Inefficiency in dissemination and distribution of documents e.g. drawings and instruction in addition to keeping track of implementation
   - Delay in obtaining approval and receiving decision due to staggered approval by approving authority e.g. sample approvals, request for information (RFIs), shop drawings, etc.
   - Lacking in timely progress and cost monitoring

   The benefits that are expected from the adoption of digital inspection are:

- Efficient and faster dissemination / distribution of documents e.g. construction drawings and instructions in addition to keeping track of progress in implementation
- No delay in receiving approvals and instructions as to work progress from upper management as well as approving Authority.
- Work progress and cost control monitoring will be well-supervised and under control to handle unforeseen circumstances
- Mobile communication enables efficient document management system, online approval process, progress monitoring, accessibility to view and to approve document so long as there is internet connection using a mobile smartphone.

4.1.3. Summary of importance and need to digitalize work processes in mobile communication for coordination purposes [5]

1. The construction industry is constantly evolving, but the one thing that remains the same is that construction projects require a enormous amount of coordination of people and resources in the field.
2. At present, construction companies need to find new ways to gain a competitive edge and mobile technology gives them the opportunity to do just that.
3. Construction managers have to keep track of their teams, schedules, daily progress, equipment, invoicing, working hours and more.
4. Mobile technology and construction management apps allow them to improve efficiency, reduce costs and streamline processes.
5. They also permit workers to collect real-time information and sent it to the office almost instantly.

4.1.4 **The currently available mobile technology**

Figure 4.1: Use of mobile technology is already here in the construction industry

The mobile technology for application in the construction industry is already well in place, albeit more in use in other industry sectors such as manufacturing, defense and medical, just to name a few. The problem faced by stakeholders in the construction industry is how to translate and to fully encourage the same application meaningfully as in those other industries or economic sectors.

Mobile Communication is the use of technology that allows us to communicate with others in different locations without the use of any physical connection (wires or cables). It is an electric device used for full duplex two-way radio telecommunication over a cellular network of base stations known as cell site. Figure 4-2 depicts the various mobile communication devices available to users over the years even up to today for personal use and for work purposes.

Figure 4.2: Various forms of mobile communication devices used over the years up to today

The advent of mobile communication technology goes hand in hand with the delivery system together with individual mobile devices. And telecommunication providers (both public and private) have been instrumental in providing resources to ensure proper both delivery and storage of data to the end-users, and the features include the following:

- Cloud Storage
- Web and Mobile based
- GPS navigation
- Instant messaging
- Servers
- Coding

Mobile Communication can be defined as the network of systems connecting field workers with other team members that are offsite. This connection would comprise of internet or cloud platforms, mobile computing technologies and software applications on mobile phones. Based on the different levels of connectivity, various types of systems can be connected together from simple messaging between parties to cloud base collaboration where files can be shared and referenced at the same time.

The increasing technological features within a mobile phone also increases its capability to record and report a variety of data points from photo, video, GPS location, LiDAR measurements to many others. As a matter of interest, LiDAR stands for Light Detection and Ranging, which is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances).

This data can either be directly shared with other parties or channeled through templates or digital forms to be compiled by online cloud platforms for reporting and analysis in real time.

4.1.5 The overall benefits of mobile communication in construction industry

Construction has always been a mobile industry. Projects aren't built in the office, they're done in the field, often in remote locations. Because of this, communication with the home office, offsite project managers, architects and owners, and other team members has always been a challenge. So too has been collecting and analyzing the volumes of data that accompanies each project.

As technology has advanced over the years, the construction industry was among the first to implement push-to-talk solutions to increase communication and collaboration. Today, as the cloud, mobile computing technologies and mobile applications are becoming the preferred way for most businesses to operate, contractors are implementing these technologies into their own operations.

Field employees can use the mobile or web-based applications to improve collaboration, simplify work access important project information and enter vital data from the jobsite to update back-office systems and reports, all in real time. And, most mobile apps allow you to continue working even if you're offline.

For instance, if work is being performed in a basement, tunnel or a place where mobile access is limited, a message can be written, photos can be captured, notes or data can be collected and entered. Later, the information can instantly sync with back-office systems and communications can be sent when mobile access is regained. This allows information to be captured without being forgotten.

Progressive construction companies are implementing mobile communication tools to improve their internal communication and increase engagement between management and job sites.

Some of the key reasons for adoption of mobile communication technologies is summarized as follows [6, 7, 8]:

1. Better Recordkeeping

Keeping records on paper is cumbersome and inefficient means. Reports can easily get lost or filed incorrectly and it's a slow way to get critical data and information like daily reports in the hands of decision-makers like project managers who rely on that information to keep a project on schedule and within budget.

Mobile technology allows for real-time data collection and transmission between the jobsite and project managers back at the office. Cloud-based solutions enable employees on the jobsite to submit timecards, daily reports, and requests for information (RFIs), work records, change orders, and other verified documentation.

Mobile solutions allow information to flow in real-time and documents can be recorded with date and timestamps along with GPS location data and digital signatures to ensure accuracy and authenticity.

Eliminating paperwork with electronic reporting can save hundreds of hours per year in redundant data entry and automatically organizes critical files hence no more shuffling through files looking for old reports.

2. Real-Time Collaboration

Being able to effectively communicate and collaborate is a key component of any successful construction project. When team members and stakeholders have access to the same information in real time, it streamlines the collaboration process and makes conversations more productive.

Mobile technology and cloud-based solutions allow everyone on a project to be able to review and update documents, reports, plans, and specifications in real time, keeping everyone on the same page as work progresses.

When issues arise on the jobsite, a worker can easily snap a few photos of the problem, create a report, and immediately send it off to be reviewed and quickly resolved. No more waiting for around for revised plan sheets to be delivered to the site, they can be pushed straight to your smartphone or tablet.

3. Improved efficiency, increased productivity

Workflows and processes can be better managed with the right cloud-based mobile solutions. Being able to schedule labour and equipment, conduct field inspections, manage change orders, document progress, and review plans and specs from a single device can greatly improve efficiency on a jobsite.

The ability to easily access and analyze all the project data collected from anywhere lets the user to decrease downtime, make better decisions faster, and improve productivity on your projects. With the right mobile solutions, they can get notified of issues or possible delays as quickly as they arise. This allows them to mitigate risks and avoid costly rework in a way that was wasn't possible just a decade ago.

When a centralized employee hub is the primary form of communication, it's easy for employees to track conversation threads and understand the message delivered. Managers can also use the platform to check for understanding and receive questions and feedback, in real time, from the project site. That means work will be done right the first time. It also means job site workers know exactly where to go to find the information they need immediately, saving precious time.

4. Improving on the bottom line

Managing construction operations has always involved a high level of coordination among different teams of contractors, sub-contractors and suppliers. Mobile technologies and the development of construction management app, companies can become more competitive, save time, reduce costs and improve workflow.

One study [6] found that the most dominant cause of poor communication is lack of effective communication which can consumes up to 50% of an employee's time. Implementing an effective employee communication tool can reduce construction costs by solving for the time suck created by poor communication. With more time to focus on the task at hand, jobs are completed in less time, allowing for a larger flow of projects at any given moment.

5. Create a safer working environment

Two-way mobile communication guarantees employees have easy access to important safety information, including emergency and crisis communication. Employees can quickly pull up information instead of having to search for a manual or call for help, which in certain emergency situations can be a matter of life and death.

Mobile communication also allows employees to report incidents quickly, giving management an accurate and immediate insight into workplace safety. It also gives employees a convenient way to offer safety feedback to both their colleagues and managers.

6. Optimizing tracking

Getting real-time information makes a big difference in the construction industry where companies always have multiple projects running at the same time. Their tasks usually involve lots of equipment, employees and material and managers often don't know what's happening or they may lose track of the equipment.

Having a construction management app will allow users to keep an eye on everything. Equipment is one of the major assets of any construction company. With mobile solutions, it's become quite easier to track and manage their usage. By logging the hours for which the equipment is used and keeping a track of locations it's put to work at, they can really improve their planning and use.

7. Mobile Office

Mobile technology allows users to stay connected and in the know wherever they need to be. This can save them countless trips from the jobsite back to the office to file reports, submit request for information (RFIs), or pick up revised drawings.

The smartphone or tablet devices can turn anywhere into a mobile office—the jobsite, your truck, the coffee shop, etc. Wherever they are, regardless of the time of day, they can quickly manage their projects to keep themselves moving.

Mobile technology isn't just limited to apps and software on a smartphone or tablet. Telematics data from heavy equipment, drones, smart hard hats, and virtual and augmented reality are all using mobile technology to improve safety, increase productivity, and improve project management processes on the construction site.

As mobile technology continues to expand to all facets of construction management, being able to adopt, adapt to, and leverage that technology will help users to get an edge on their competition and keep them moving in the right direction.

4.2 Government policies or directives in place

4.2.1 Government and related agencies

Malaysia is set to embrace the digitization economy in a big way when the then Prime Minister Muhyiddin Yassin embraced the Government's initiative in the launching of the Construction 4.0 Strategic Plan, 2021-2025 [9]. The CEO of CIDB, Datuk Ir. Ahmad Asri Abdul Hamid highlighted the essence of digitization: "The move was to encourage digital adoption by the industry players as Malaysia was set to launch the Industry 4.0." Construction 4.0 is a subset of Industry 4.0 applicable to the construction industry. And Construction industry is to produce RM3.4 trillion of GDP by 2030 according to Government sources. The move to digitization hence becomes an urgent task by industry players.

4.2.2 Industry stakeholders

The impact of Government's initiatives and set policies are immediately felt by industry stakeholders, and a number of them took their own steps and measures to capitalize on the set direction and directives being disseminated by various Government agencies.

Among them, the following are the initiatives carried by some of these corporations:

- Majority of global solutions providers are moving to mobile and cloud based applications by either making their solution accessible through a web browser, allowing connectivity through a mobile phone or adding an option for a server based installation instead of desktop. (Autodesk – BIM360, Oracle – Primavera Cloud, Novade – Quality Inspection, Procore – Project Management Pro). Refer to Figures 4A-1, 4A-2 and 4A-3 in Appendix 4.
- Solutions providers are also changing their business model to subscription-based revenue. This requires online connectivity for license verification, product updates and security patches.

4.3 Issues and challenges faced by the industry

4.3.1 A matter of cost: dollars and cents

An adoption of new technology or new system of operation would generally require a substantial amount of investment, and this would be expected too in the quest to climb onto the bandwagon of procuring hardware and software in order to make full use of mobile communication technology. Massive investment outlays are expected to be made by the mobile industry players, into both infrastructure, research and development (R&D). A written article [10] on mobile revolution in USA states the following:

- Companies in the mobile value chain invested US$1.8 trillion in infrastructure and R&D from 2009 through 2013, relying almost exclusively on private-sector funding.
- Many new and start-up companies are entering the mobile sector. In the past five years, venture capital (VC) investments in mobile have doubled as a

percentage of total VC investments, reaching almost 8 percent (US$37 billion) in 2014.

- To reap the economic benefit of fifth generation (5G) networks and beyond, mobile players will need to invest approximately US$4 trillion in R&D and capital expenditures by 2020.

But of course, in the above quoted investments, the amount shown are across all industries in general, so as a rule of thumb, perhaps the construction industry (similar to Malaysian context) would contribute about 5% to overall GDP. So, those initial investment figure from 2009 – 2013 would translate to US$90 bil (RM360 bil present); while the VC spending in 2014 would translate to US$1.85 bil (RM7.5 bil present); and investments into 5G would requires US$100 bil (RM400 bil present). All of these are just indicative or ball park figures at best, and are useful as approximate comparison in the present market value.

A wide range of functionalities exist across many different solutions. Costs are usually divided according to the following

- User based (each person pays for access to use the software)
- Project duration (a solution is purchased for a set duration of the project only)
- Project value (a solution purchased according to a percentage of the project value)
- Annual Construction Volume (ACV) / Revenue (unlimited plans purchased according to a company's ACV or revenue)

Using the CIDB Contractor Grade of G1 to G7 [11] as a guide, the costs can be estimated as a percentage of project value that they can be contracted for and adjusted according to what level of communication and collaboration is needed. Refer to Table 4-2 for further details.

Table 4.2: Comparison between grades of contractors registered with CIDB on their limits in tendering, investment and cap in project cost [9]

No	Contractor Grade	Tender Capacity	Investment %	Cost
1	G1 to G3	Up to RM1m	up to 1%	RM10k
2	G4 to G5	RM3m to RM5m	1% to 3%	RM30k to RM150k
3	G6 to G7	RM10m and above	2% to 3%	RM200k to RM1.5m

Examples:
G1 to G3 - small projects with subcontractors and suppliers.

- Mobile communication platform: Oracle Primavera Cloud, Powerproject Cloud

G4 to G5 - small to medium projects with coordination between subcontractors and engineering consultants and suppliers

- Mobile communication platform: Novade Site Management Platform

G6 to G7 - medium to large projects with multi-party stakeholders for various disciplines.

- Mobile communication platform: Procore Project Management Platform, Oracle Aconex

4.3.2 Adoption of new technology

With the challenges faced in adoption of new technology, it is never easy to convince stakeholders in the industry to embrace a technology which are relatively new and unntested in the industry, usually citing high cost of investment, impractical to use, reluctance to place trust on non-physical operations and business transactions, and many other obstacles.

These can be described in the following manner:

1. Challenges in adopting new technology require a change in mindset towards recognising the benefits and advantages gained from a productive workforce that is freed from menial and repetitive tasks.
2. Industry needs to understand the steps required to change a company's internal processes and identify the critical roles needed such as:
    - Product Champion
    - Influencers / Product Evangelist
    - Sponsors

4.3.3 Skills and knowledge upgrade

This is a major challenge in getting properly trained and qualified personnel in the corporations and industry to implement the use of mobile technology to push the boundaries of state-of-the-art knowledge and applications. In order to facilitate this unleashing of human capacity for this technology, the construction industry has to face the following challenges head-on:

1. Propose a phased approach to adopting mobile communication technology for inspection, communication and collaboration.
2. Acknowledge that change management across all relevant stakeholders will take time and there will be limitations further down the supply chain.

Table 4.3 highlights the phases in training of technical staff utilizing the right objectives and training resources.

Table 4.3: Phases in training of technical staff utilizing the right objectives and training resources

No	Phase	Cost	Solution Apps or software	Learning Objective
1	Phase 1 - Test	Free	WhatsApp, Google Apps, Microsoft Outlook	Create connectivity, monitor connections and test processes

				across all site operations.
2	Phase 2 – Pilot Project 1	RM10k to RM35k	Cloud based apps, online subscription	Test drive specific functionalities, limited adoption by department.
3	Phase 3 – Pilot Project 2	RM35k to RM60k	Service provider, desktop application	Cross discipline implementation, inter department communication, refine and freeze workflows and guidelines.
4	Phase 4 – Company Level	No data available	Global brands, AAA Solutions	Review processes and audit data generated.

4.3.4 Other challenges faced

Besides the main challenge of cost incurred, the other important issues faced are as follow:

1. The need to have good internet/ data connection, i.e. good quality and highly reliable physical infrastructure for proper connectivity and huge data transfer at acceptable speed.
2. Training the right people to adopt such technology and use of mobile communication as information sharing and at approval points.
3. Should be as overall process/system based rather than just only single or individually activity.
4. Worries on data/information privacy and loss of data upon transfer and storage.

5. Unable to use cloud-based solutions for public sector projects due to government policy on geolocation of sensitive data.
6. ‘Feature creep’ in existing solutions create a bloat of features and unnecessary solutions that distract from the core functionality of a solution.
7. Adoption of new technology will generally encounter resistance as the tendency for stakeholders is to avoid changes in their work methods, approaches and operations.

The benefits of mobile solutions in construction are clearly presented in the light of digitized technology already here, but many industry stakeholders such as contractors, suppliers, manufacturers are still adopting traditional methods. They are yet to implement strategies to leverage themselves in the new Age of Digitized Technology. At best, they may have embraced mobile technology in their personal spheres, but with no strategy to standardize the mobile technology into the work place as a whole so that their employees and associates can utilize and capitalize it to enhance their business competitiveness.

4.4 Proposed solutions and recommendations for relevant Authority / Agency

4.4.1 General description

Based on the various challenges as highlighted in Section 4.3, it is envisaged that the engine to kickstart the adoption of mobile communication technology in the construction industry shall be the Government with its many lead agencies, such as Construction Industry Development Board (CIDB) and Jabatan Kerja Raya (JKR) through the Ministry of Works. This is necessary since major investments are necessary, and incentive schemes from the Government would be the required impetus.

As a start, Government-driven apps and software development that would enables the construction industry to track project progress and cost. A typical example of this would be the development or application of a software that can be used to prepare physical and financial feasibility and monitoring, such as the S-curve projection in cash flow. This can be enhanced by real-time collection and updating of on-site data by using mobile tools (smartphone/tablet), including wide usage of visual progress photographs.

Other means by relevant parties to take actions include the following:

1. Taskforce to audit and vet through cloud based servers and certify that they are safe for use by Malaysian companies on local projects.
2. New training course on change management process for new technology adoption.
3. Kickstart adoption with basic FAQ on how to digitize the construction process with free tools, on a project basis or case-by-case.

4.4.2 Specific proposals and recommendations

The recommendations are tabulated in Table 4-4.

Table 4.4: Recommendations to be addressed by respective agencies within a proposed timeframe for follow-up actions.

No	Recommendation	Agency or organisation to address	Timeframe
1	• Provides fund to develop system or app that can be used by contractor and parties involved in construction • Promote the use mobile communication technology among construction industry stakeholders • Regulates the concept and technology involved • Produce guidelines and SOPs	CIDB	By 2025

2	• Driven by MBAM, to increase this adoption • Do more awareness program	Contractors	By 2030
3	• Add mobile technology into curriculum • Emphasize research on mobile technology • Collaboration with industry with research students	Universities (Public and private)	By 2030
4	• Include this as part of their KPI in government projects • Make training compulsory for departmental engineers and technicians	Jabatan Kerja Raya (JKR)	By 2030
5	• Embrace the mobile communication among members / industry stakeholders • Provide the required online and infrastructure platforms – software / hardware	IEM /ACEM / REHDA – or any other relevant learned societies or trade associations	By 2030
6	• Make available both infrastructure and accessibility of mobile communication network	Service providers of internet (MAXIS, DIGI, U-Mobile, etc)	By 2025
7	• Collaborate and co-operate with Government Ministry and Agency eg CIDB, to bring down initial cost of investment	Apps of software supplier/developer/distributor	By 2023

Note for Table 4.4: The above recommendations may have time and cost implications. Further study will have to be carried out should the recommended agency is agreeable to take the lead to initiate the course of action as required.

4.5 Application of UAV/Drone/ROV for inspection and mapping survey work in the construction industry

4.5.1 Introduction

From a study by McKinsey [12], the inefficiency of large construction projects in the construction industry typically require 20% longer duration than expected to complete and it is uncommon with 80% over budget.

Compared to other sectors, the construction industry has been slow in adapting to new digital technologies, despite of the well demontrated promising benefits in many aspects.

The use drone technology at affordable cost and manageable skill set required provides a quantum leap of efficiency improvements. It provides on-demand geo-spatial information at every cycle of the project stagesfrom inceptaiton feasibility, planning, investitation, pre-construction designs, construction management, operation managment, asset inepection, inventory and maintentance management.

4.5.2 Benefits of drone technology [13]

1. No limitation of site accessibility other than restriction of flight permission zone controlled by aviation authority
2. Reduced worker exposure, increased safety, especially for hazardous sites
3. Wide aerial view
4. Savings in cost and time (study, capital, maintenance & operation)
5. Rapid deployment on demand acquisition

6. Most updated comprehensive data with good accuracy
7. Better data collection and usage
8. Progress tracking and communication
9. Pre-construction and site planning
10. Quality control and assurance
11. Bid process preparation
12. Job site risk mitigation

4.5.3 Applications of drone technology

1. Aerial monitoring (environmental, flood inundation, traffic flow/disbursement, geohazards) & inspection at high (roof top inspection, pylons)
2. Earthwork (cut & fill) & stockpile monitoring (volumetric)
3. Land terrain mapping for large scale development & corridor mapping for linear infrastructure
4. 3D spatial and time sequence mapping (geotagging, video/thermal/multispectral camera and LiDAR for element & ranging detection)
5. Photogrammetry data processing for 3D terrain modelling and monitoring of incremental changes with time
6. Asset inventory inspection & maintenance management

4.5.4 The processes involved

1. Unmanned Aerial Vehicle (or UAV) is a tool and means for data acquisition from aerial locations
2. Suitable knowhow on appropraite deployment of acquisition sensors and configuration of survey
3. Value is in the data analyses with outcome result oreintated

4.5.5 The market potential of drone technology

With the wide spectrum of aerial applications for the appetite of respective sectors, the construction sector scores the highest growth rate (239%) followed by the mining sector (198%), agroculture sector (172%), surveying (171% and the real estate (118%) in 2018 as reported in The Asean Post [14].

This can be clearly seen in Figure 4-3.

Figure 4.3: Percentage growth in usage of drone technology by industry sectors [14]

In addition to that, there was an extract from Accenture [15] with a quoted statement as presented below.

“The market includes UAV manufacturers, operators, application developers, UAV systems integration and deployment providers, training and insurance companies. This list is not exhaustive and some start-ups cover several services.

To integrate UAVs into their businesses successfully, engineering and construction companies should draw up a roadmap aligned with their strategy, targeting the different alliances and phases of the transformation.”

Figure 4-4 depicts the amount of expected investment into the applications of UAV in work or business-related projects.

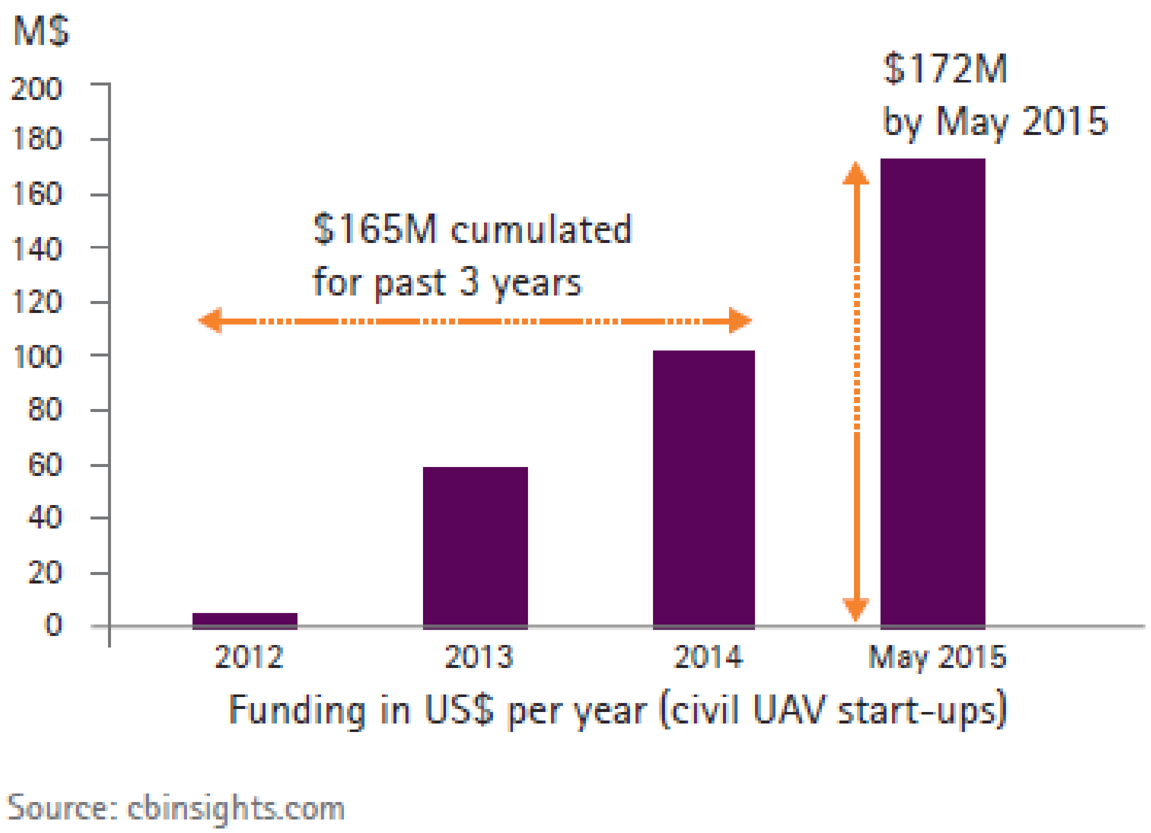

Figure 4.4: Investments into use of unmanned aerial vehicle for work-related projects

4.5.6 Deployment of UAV in Local Projects in Malaysia

Many construction companies around the world have started using drones as a vital tool in their projects. International companies such as Kier, Balfour Beatty, Vinci Construction and Mitie have started to use drones as a tool on site. On the Malaysian front, projects like the Tun Razak Exchange (TRX) and various rail projects such as the Mass Rapid Transit (MRT) extension extensively use drones for project monitoring and various land use analysis. It is becoming more and more commonplace in Malaysia for drone operation in data collection and analyses.

Examples of some local case study includes the using of drones in surveying for Building Information Modeling (or BIM) and Geographic Information System (or GIS) data as captured by Gamuda Engineering for Klang Valley Mass Rapid Transit (KVMRT) projects. [16]

4.5.7 Governing regulations on UAV applications

With exponential growth of drone/UAV application, standards and requirements by Civil Aviation Authority of Malaysia (CAAM), including safety and regulation training are formulated and enforced to ensure safe integration of drones and enterprise drone operations into the Malaysian airspace. Training academy [17] is also developed to cope with these institutional regulatory requirements (Regulation 140-144 under the Malaysian Civil Aviation Regulations 2016 (MCAR 2016)). Penalty and/or conviction will be imposed to those who commit offences by operating a UAS/drone without CAAM's authorisation. The penalty includes a minimum of RM50,000 and/or 3 years of imprisonment for an individual or a fine not exceeding RM 100,000 for a corporate body, if found liable.

On 26 March 2020, Civil Aviation Authority of Malaysia has issued a press release statement titled “Operations of unmanned aircraft system (UAS)/drone and transportation of dangerous goods by air requires CAAN authorization” [18]

As a matter of interest, any application shall be submitted to *drone.atf@caam.gov.my* at least 14 days before the proposed flight/activity, while payment of RM1,000 for unmanned aircraft systems of more than 20kg, and RM250 for drones below 20kg will need to pay.

4.5.8 Remote Operated Underwater Vehicle (ROV)

While drone is an air-borne device for survey and surveillance purpose, another close sibling of drone is underwater ROV, where the working area is aqueous environment with the similar capability. The underwater inspection is getting more handy with many inspection and monitoring of submerged marine structures, likes subsea cables and pipelines, intake and discharge of cooling water for plants, jetties and wharfs, offshore platforms, vessel inspections, dams and appurtenant structures, water reservoirs, bridge piers, etc. Sensors, scanning devices (sonar or LiDAR) and optical camara can attached to ROV for data acquisition, and gripping jaw with robotic arm for simple action manipulation on specific tasks. In some cases, ROV can be deployed for underwater rescue operation. ROV can reduce the risks of sending divers for underwater inspection with dangerous environment.

4.5.9 Conclusion & Recommendations

Through an astute observation in the great potential of the application of drone or UAV for airborne application and ROV for underwater application, these devices will help to provide efficient and safer inspection and survey works in either airborne or underwater environments, especially in the construction industry.

Incentives shall be provided to reduce the cost of purchase and training of certified operators for wide usage of these technologies.

Identifiable Government agencies involved shall be tasked to promote and encourage the use of such UAV and ROV technologies in the construction industry. These agencies are as listed in Table 4.5 with proposed timeframe and the cost involved would have to be further studied to reflect the realistic amount to market pricing.

Table 4.5: Recommendation for action by leading agency to promote and encourage the use of UAV and ROV technologies

No	Leading Agency	Timeframe	Cost
1	Construction Industry Development Board (CIDB)	By 2030	To be further studied
2	Ministry of Science, Technology and Innovation (MOSTI)	By 2030	To be further studied
3	Economic Planning Unit (as a key element of Ministry of Finance)	By 2030	To be further studied
4	Civil Aviation Authority (CAA) of Malaysia	By 2030	To be further studied

Note for Table 4.5: The above recommendations may have time and cost implications. Further study will have to be carried out should the recommended agency is agreeable to take the lead to initiate the course of action as required.

4.6 Autonomous robot in construction

4.6.1 Introduction

The construction industry is always perceived as a manual-intensive labour as a primary source of productivity. It is one of the least automated industries, in various fields of new commercial construction, renovation or demolition. Robots do not play a significant role in any step of construction.

With the advancement of technologies, robots are to be made adaptable to the construction industry. There are several new robots under development and in the early stages of deployment. Actually, there are increasing opportunities for robotic automation.

The application of autonomous robots has always been a challenge in the construction industry. This is possibly because of the perception that the construction is only for low-skilled labour work. Also, this is possibly because of low awareness on the possibility of having the construction industry to be automated, mainly because of the wide variety of work involved [19].

Despite popular doubt, autonomous robot can be applied in the construction industry with assurance. Autonomous robot works best in a controlled environment, where paths and tasks can be specified accordingly. This can be represented with repetitive tasks such as moving loads, site clearing, or even building a drain. Bigger projects will have the advantage of reaping bigger benefits with the deployment of autonomous robots [20].

4.6.2 Robot Framework in Construction

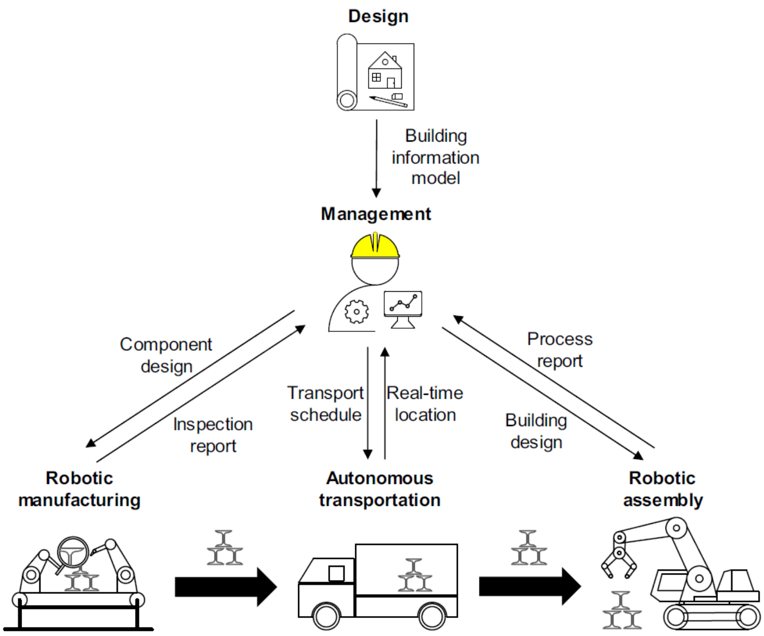

Figure 4.5: Framework of Construction Automation [22]

The implementation of robotic automation in construction begins with a framework. Cheav et al. have done a study on the implementation of robots in the construction industry. The elaborated framework shows that Management plays a vital role in construction automation. The process starts with Design where Building Information Model (BIM) are employed as a tool on automation. Robots can be used in the assembly of construction material, autonomous transportation, and manufacturing. Management has direct control on these processes and can schedule, access real-time process variables and process report at any time [21].

The framework on the autonomous robot can be replicated and applied in nearly all construction mobile machineries such as cranes, lorries, forklifts, tractors, and bulldozers. This results in more applications in construction. Great benefits can be reaped when the autonomous robots work as a team to accomplish a task.

On external work, for example, autonomous excavators dig up the soil and placed in the autonomous trucks, while the autonomous trucks get ready to ship the soil to a location for dumping. On internal work, autonomous robots can be used for wall finishing or wall painting. Further, the repetitive tasks can be programmed to be undertaken at night or when the human work is off. When the worker returns to work, the task is completed and ready for the next step.

Operators that were driving these vehicles can be up-skilled to control the vehicles at the control centre on-sites. At the control centre, human workers are now out of harm's way at construction sites and can focus on managing resources, such as scheduling supplies to the machineries or performing maintenance.

4.6.3 Applications

1. Earthwork

Earth work such as land levelling is an ideal task for autonomous robots, as the task is repetitive and can be controlled. For example, a plot of land of 1 acre can be an exhaustive task for workers. However, with autonomous robots of tractors and lorries, this can be delivered as long as the setting and path is configured.

2. Moving industrial supplies

Supposed the developer purchases construction material in bulk for a discounted price or purchases 1 week worth of materials. These supplies can be stored at a warehouse on-site and delivered to the local site when needed. For example, the lorry can be programmed to deliver 3 pallets of bricks daily to building A in a construction site. Other industrial supplies such as steel bars, cements, piping, and wiring can be delivered the same way.

3. Minor Construction Works

Building a drain with hundreds of meters in length accurately requires substantial resources such as mapping and monitoring. However, with the help of GPS, autonomous robots on tractors can perform repetitive tasks effortlessly. The same tasks that would take workers a day to complete can be reduced to hours.

4. Wall Painting – Interior Work

Wall painting is a skilled work that can be done equally well or better by robots. So long as the wall area of the painting is set, the robot can complete painting the wall rapidly.

As a range of industries from technology to automotive increasingly rely on high-tech capabilities, the construction industry is keeping up with this forward movement. A main way the construction industry is using technology is through robotics. Construction firms are utilising robots for bricklaying, demolition, rescue, 3D printing and other areas. This technology is used for building, cement, mining, tunnelling and other components of construction work. This capability could help the industry as it has difficulty finding enough workers and to help it move forward in a changing world. It can also help with areas like disaster management and help the industry improve productivity.

Robot application in construction is a trend across the world. Some major examples include Swedish companies Brokk AB, Husqvarna and Conjet AB; Chinese companies Giant Hydraulic Tech and Beijing Borui Intelligent Control Technology; German company TopTec Spezialmaschinen GmbH; Japanese companies Shimizu Construction and Fujita Corporation; and US companies Alpine Construction Robotic and Cazza [20].

4.6.4 Markets

The global market for construction robotics also represents a huge opportunity for developers and suppliers. It could grow from $22.7 million in 2018 to $226 million by 2025, predicts Tractica. Research and Markets estimates that the market will grow to $126.4 million by 2025 [23].

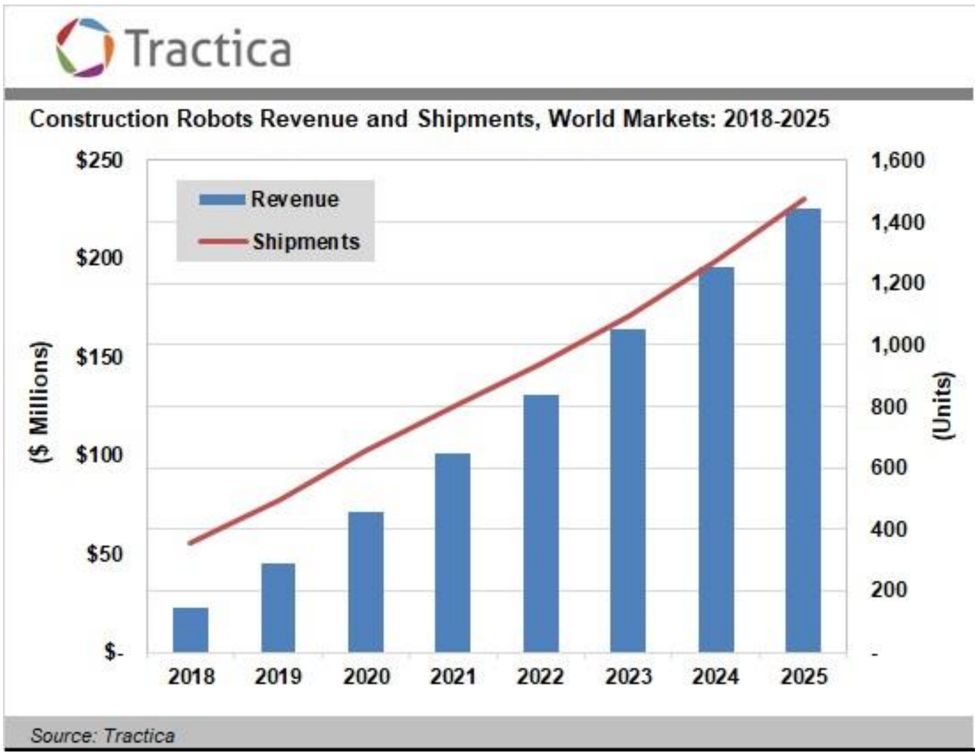

Figure 4.6: Robot Revenue and Shipment of the World Market [24]

According to the International Federation of Robotics and the Robotic Industries Association, the construction robotics market will experience a compound annual growth rate (CAGR) of 8.7% between 2018 and 2022. Research firm IDC is more bullish, predicting a CAGR of 20.2% [23].

Automation and digitization are driving a revolution in the construction industry, which has historically been slow to adopt new technologies. From design through final inspection and maintenance, the full benefits of construction robotics have yet to be realized.

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APPENDIX 4A Mobile Communication and Robotic Technology

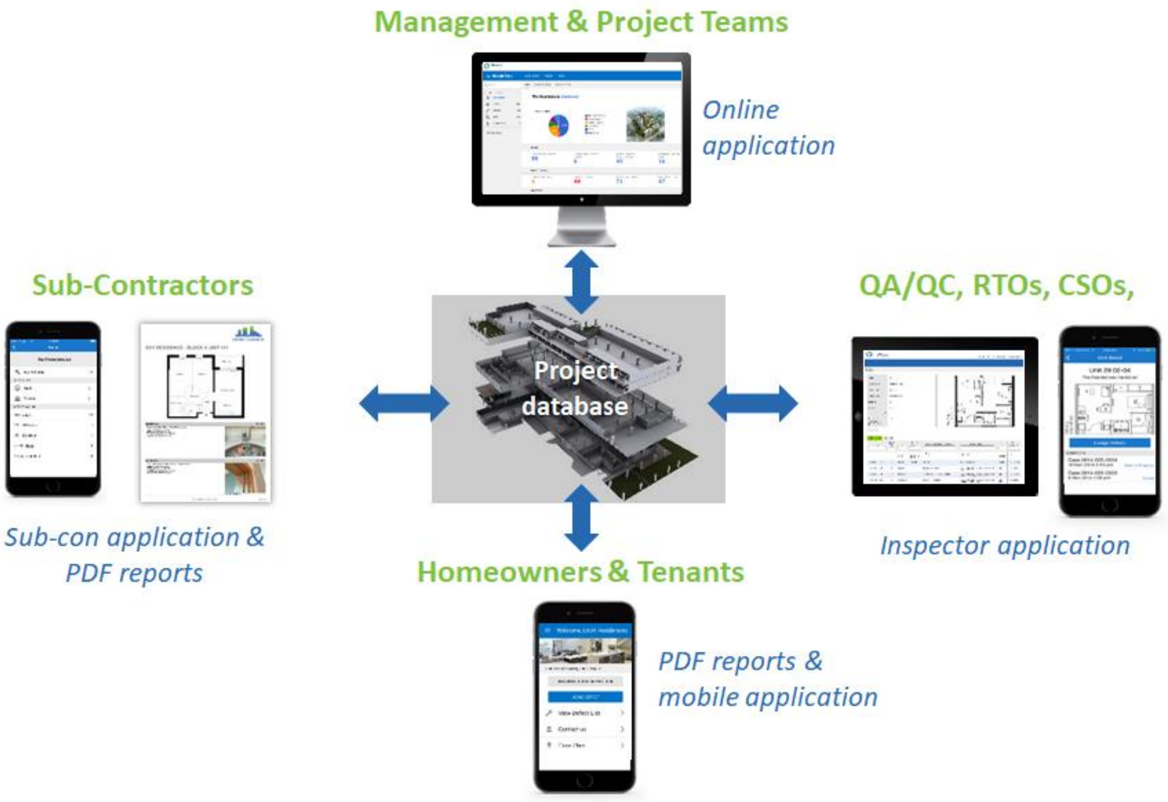


Figure 4A.1: Novade Mobile Platform for Site Management

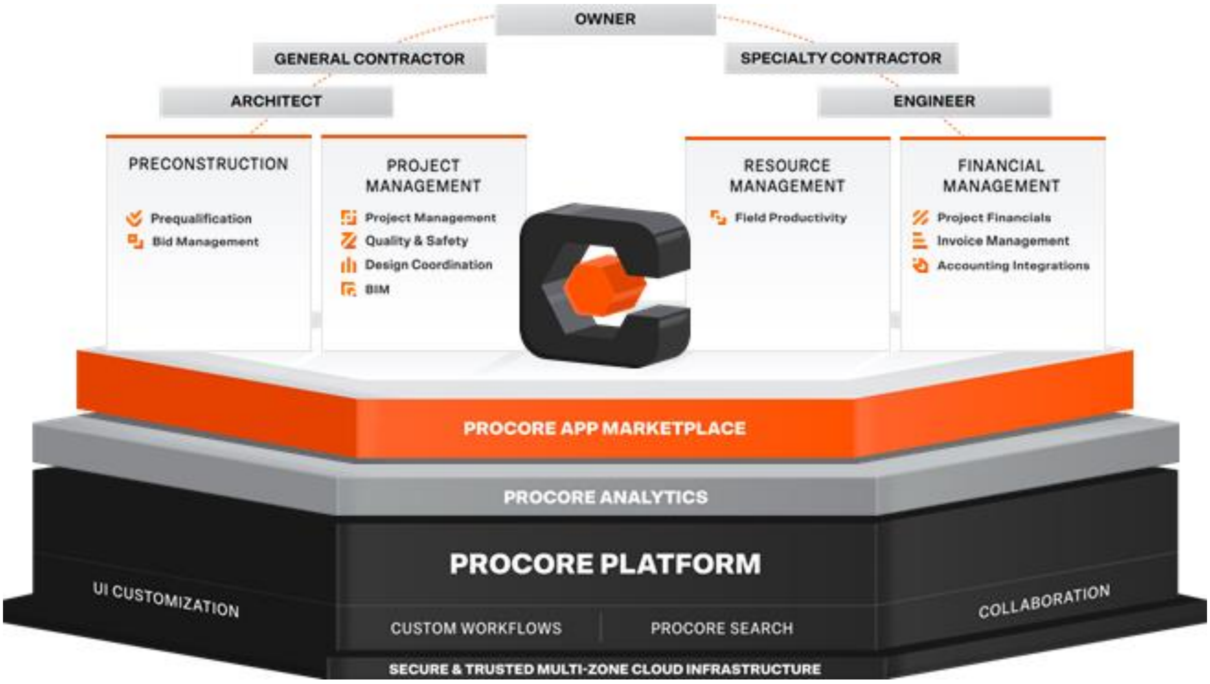


Figure 4A.2: Procore Platform for Construction Site Project Management

Figure 4A.3: BIM360 Mobile Communication Platform

Chapter 5: Human resource and capacity building for Construction 4.0

5.1 Introduction to human capital and capacity building

By extracting the definition and general frameworks of human capital in Wikipidea [1], human capital is a collection of traits – where all the knowledge, talents, skills, abilities, experience, intelligence, training, judgment, and wisdom are possessed individually and collectively by groups in a population. These capital deemed as resources are the total capacity of the people that represents a form of wealth that can be harnessed and directed (through proper training and guidance) to accomplish the goals of the nation or state or a portion thereof.

Many theories explicitly connect investment in human capital development to education, and the role of human capital in economic development, productivity growth, and innovation has frequently been cited as a justification for government subsidies for education and job skills training.

The new concept of task-specific human capital emphasizes that in many cases, human capital is accumulated specific to the nature of the task (or, skills required for the task), and the human capital accumulated for the task are valuable to many organisations requiring the transferable skills.

Human capital is an intangible asset, and not owned by the organisation employing the personnel. If viewed from a time perspective, it consumes time in one of these key activities:

- Knowledge/Knowhow (activities involving single individual),
- Collaboration (activities involving more than one persons),
- Processes (activities specifically focused on the knowledge and collaborative activities generated by organizational structure and society)
- Absence in attendence/Non-availability (annual leave, sick leave, holidays, etc.).

Despite the lack of formal ownership, organisation can always gain its benefits from high levels of training, in part because it creates a working culture for cohesion.

This working group focuses on the Human Resource requirments of one of the enablers, namely people, with capacity building and excellence in Research, Innovation, Commercialisation and Entrepreneurship (RICE) of Construction 4.0 Strategic Plan (2021-2025) by CIDB [2].

5.2 Current scenario in addressing human capacity in construction technology know-how

When engaging with a new technology, there will be three stages of development in terms of adaptability and eventual adoption:

1. Inception Stage for exposure to the availability of the technology or products, appreciating its features and understanding its working principle;
2. Application of technology to harvest its benefiting efficiency and effectiveness for productivity improvements; and lastly
3. Continuing R&D for improvements and wider applications.

5.2.1 Inception stage

At the inception stage, availability of personnel with good understanding of the working principles of the explored technology, knowing the products and technologies available in the market is critical. To ensure right decision of adopting appropriate technology or products, this will need competent and knowledgeable personnel in the relevant field of specialisation. Conference and exhibition conventions are good avenues for exposure to the marketable cutting-edge technology and products. For human capital aspects, personnel involved in task forces of respective technological portfolio to explore, survey, assess feasibility, acquire and prepare blueprints of technology adoptions shall be given sufficient budget to attend international convention and exhibition.

5.2.2 Application stage

At application stage, personnel with hand-on operation to familiarise the features of the products and resolving interfacing problems in the integration processes of technology for collective efficiency improvements are needed. Earlier incubation stage is needed to push the deployment to reach a critical mass for mass adoption in the industry. To ensure sustainability, many good success stories will be the key driving forces to encourage extensive deployments. This is where government incentives will help adoption rates in the industry, especially for Small Medium Enterprise (SME).

5.2.3 Continuous improvement stage

In the last stage, collaboration to gather the industry needs among the developers, technology operators and customers will be useful to extend the capability and capacity of the evolving technology or/and products with application research & development can prolong the life span of the technology or/and products in the market.

5.2.4 Summary of process chain in human capital

To attain the above objectives, human capital and capacity building is needed to prepare the necessary work force to support the key components and entire supply chain in the proposed Construction 4.0. This shall include the following:

1. Adequate STEM knowledge-based training for school students, graduates in the planning and managing processes, cross disciplinary collaboration, and skills for operation (diploma holders/technologists with good vocational skills) will be essential.
2. Centres of excellence and learned institutions of respective trades shall be established to keep track and update the industry with newest available technology and products worldwide, and to provide training and accreditation of qualified personnel to support the proposed Construction 4.0.
3. Financial supports to these Centres of Excellence or/and learnt institutes shall be provided to maintain the continuous development, human capital (skill sets

for various levels of technology) and capacity building of the respective technological realms.

5.3 Interaction with previous findings to address common human capital issues

The IEM Position Paper Committee formed have the following working groups to cover the key components for the coverage of Construction 4.0.

- Smart Construction
- Smart Materials
- Data Centric
- Mobile Communication Technology
- Robotic / Drone / Autonomous
- Connectivity
- Human Capital

Hence, the Human capital and capacity building working group will cover substantial common components in supporting the other seven working groups proceeding in parallel.

5.4 Initiatives by WG on Human Capital for data collection

5.4.1 Questionnaires for Human Capital & Resource Development

As there will be different requirements on the competency of personnel, type and level of skill set and also the the resource development to support the respective working groups mentioned above, structured questionaires to the respective working groups will be an effective way to development the policy on the human capital and resource deelopment. The basic details of the respondants are given in **Appendix 5A**.

a. Which skillset(s) or Know-How(s) are inportant in the era of Construction 4.0? (**Appendix 5B**)

Summary of survey : Data Mangement/Conectivity, Smart Construction/Smart Materials, Remote/Mobile Technology are most selected (more than 50% in preference with decending order). Surprisingly, Autonomous/Robotics is about 43.6%, in which the robotics in construction industry are still as well perceived and popular as manufacturing sector, probably many construction processes are not as routine and ease of automisation as manufacturing. BIM, software programming, artificial intelligence and data analytical capability are also highlgthed.

b. What quality of work force or human capital would be most significant in the way Construction 4.0 will lead the construction industry forward in the next 20 years or more? (**Appendix 5C**)

   Summary of survey : Lifelong Learning Approach/Willingness to Upgrade, Project Management/Human Interaction Skills, Adaptability/Willingness to Change, Mathematical & Physical Science/Digital Technology Knowledge have more than 70% in preference of choices with decending order. The survey outcome seems emphsising more towards the expected quality upgrading of exiting work force. Some long-term demand on STEM to potential future work forces from students is saddlely revealed. Knowledge management and culture of change in mindset breakthrough in the industry and comparable remuneration for Construction 4.0 are suggested by respondents.

c. In what best way the quality of the work force can be upgraded or enhanced to keep up with the trends in Construction 4.0? (**Appendix 5D**)

   Summary of survey : Re-train existing workforce to adapt to new technology/To employ more fresh graduates with new mindsets, Revamp or to review the existing university teaching syllabus in science, IT and engineering fields to focus on core areas as highlighted in Question (a) above, Re-train or to recruit more knowledgeable or qualified teachers and lecturers at school and university levels, Enlarge the pool of students in STEM from primary to post-secondary levels are generally the collective consensus.

d. Professional Accreditation / Certification could be one method to regulate the professionals in specialized areas to ensure effective implementation of Construction 4.0. You may indicate which of the Disciplines below would require such Accreditation / Certification. (**Appendix 5E**)

   Summary of survey : Traditional engineering fields (Chemical/Civil/Electrical & Electronic/Mechanical), Project management / environmental impact assessment / economic viability, Specialized areas (fire technology, risk and safety, disaster management, etc), Proprietary products and services to support construction work are having more than 50% in perference with decending order. This is typical accredition of engineering disciplines involved in construction at present stage and is unlikely to alter.

e. What is the best Incentive / Initiative which the Government can provide to promote the Capacity Building of the Human Capital to capitalize on Construction 4.0 in taking the national economy to the next few levels? (**Appendix 5F**)

   Summary of survey : Subsidies in training and upskilling, Grants and monetary incentives / tax breaks, Cost reduction in technological facility and equipment, Preferential employment of technical savvy people in civil service, Establishing centre of excellence (COE) or learned institutes (in areas as specified in Question (a) above seem to have strong preference in responding to the question. It is believed that the respondents view the investment to attain full implementation of Construction 4.0 will be heavy and thus are looking for strong incentives from the government to encourage the industry to engage with the human capital building to reach critical mass for self-sustaining ecology. Effort to stop brain drain to keep talent by the government is desperately needed. Unlearn the present mulpractices and relearn the best new practices to adapt to Construction 4.0 is highlighted.

f. What are the benchmarking Conferences, Exihibition or Conventions which Learned Society such as IEM can organise to build up Human Capital in specialized areas to meet the needs of Construction 4.0? (**Appendix 5G**)

   Summary of survey : Equipment, tools and systems for design and construction, Updated or new areas of Expertise (such as Remote Sensing, Digital Control, Block Chains, etc), Innovation in human resource management, Traditional engineering fields, Social media and impact to society and technology are in decending order of preference. The survey outcome indicates adoption of available tools, equipment, services and technology for design and construction through the convention (exhibition, expo or trade show) is topmost preferred option traditionally. Emphasis on environmental, professional ethnics, occupational safety and health, and techical standards/guidelines is expected.

5.5 Issues identified by Government's initiatives and national plans for Construction 4.0

5.5.1 Construction 4.0 Strategy Plan (2021-2025) from CIDB [2] Relevant to Human Capital Development

This strategic plan starts with vision of transforming the construction industry of the nation with Mission Statements (Sustainable, Productive & Smart), Objectives (Venture, Attract, Shape & Transform), Core Vaues (Sustainability & Resiliency, Productivity, Integrity, Safety & Health, Well Being) over the 12 Emerging Technological Sectors below

Short-Term (within a year)

1. Prefabrication & Modular Construction
2. Building Information Modelling
3. Autonomous Construction
4. Augmented Reality & Virtualisation
5. Cloud & Realtime Collaboration
6. 3D Scanning & Photogrammetry

Medium-Term (in three years)

7. Big Data & Predictive Analytic
8. Internet of Things

Long-Term (in five years)

9. 3D Printing & Additive Manufacturing
10. Artificial Intelligence

11. Blockchain
12. Advanced Building Materials

The enablers to support the strategic plan are People, Economy, Integrated Technologies, and Governance. Out of these, People and Integrated Technologies are highly related to human capital and resource redevelopment in the 12 technological sectors mentioned above. It is the digital revolution of integrating the cyber-physical system for greater productivity and efficient collaborative working environment.

Out of the world benchmarking of the 4th IR [3], Malaysia is ranked 26th in position. The Build Environment 2050 adopted by UK focuses solely in construction, which is very relevant to this position paper. The high impact factors for the future of IR4.0 in Malaysia are Simulation & Modelling, Digitalisation & Virtualisation, Smart Construction.

The following documents highlighted the importance of education, skills, training could be useful in developing the human capital and resource developments under this position paper.

a. Built Environment 2050, UK
b. Ireland's Roadmap to Digital Transition for Construction, Ireland
c. The Scottish Construction Industry Strategy 2019-2022, Scotland

The issues related to people in the implementation of Construction 4.0 are tabulated below.

a. Existing education programmes not aligned with IR4.0
b. Readiness of workforce
c. Difficulties in recruiting high-skilled talent and future ready workforce
d. Lack of research and development activities
e. Diversity of talent based on generation differences (who are savvy at solving complex issues)

f. Lack of employee readiness and strong resistance to change and technologies
g. Organisations are not wholly ready to support the digital transformation
h. Changes in job pattern
i. Lack of awareness or clarity of IR4.0
j. Emigration of highly trained or qualified workforce
k. Dependency on foreign talent
l. Unclear of current revolution status

Construction 4.0 is not only about technology, but the ability to allocate the right people at the right place and at the right time to ensure the transition is successful. The technological adoption to construction processes requires the future workforce to be equipped and ready with new skills to enable them to adapt to the changing industry environment. Human capacity is critical as Construction 4.0 advocates the values of growth and resilience. The readiness of participants in the industry to be aware of the latest technological advancement and receptive to change is vital to ensure continuous competitiveness of human capital. The industry would be able to achieve the next level by adopting the next set of strategies, such as educating potential candidates, deliverable of knowledge, training and upskilling the existing employees. Without the participation of new talents, Construction 4.0 would suffer from slow progress and risk missing the digital transformation.

The two strategic thrusts below in the strategic plan are relevant to human capital and resource development.

Strategic Thrust 1 (Building Capacity – **Appendix 5H**): The rapid growth of technological changes requires current and future talents to be competent and well trained. The construction industry requires an agile workforce, who are bright, ready and willing to deliver this transformational change. Strategies to nurture talents for all construction stakeholders should be the foundation of a comprehensive workforce ecosystem.

Strategic Thrust 2 (Excellence Research, Innovation, Commercialisation and Entrepreneurship – RICE – **Appendix 5I**): A strategic programme for innovation is required with the aim to support RICE activities. Recognising the importance of RICE in Construction 4.0, a holistic RICE programme that covers all research deficiencies will ensure significant potential and benefits in transforming construction industry. A collaborative research effort between industry, academia and the government will produce an impactful research portfolio with potential to move towards an applied approach.

In the concluding part of the strategic plan revealing the roles and responsibilities of government, industry, academia and society, academia shoulders significant roles in human capital development, industry covers the resource development on technology, society emphasises on collaboration and competence development, and government takes care on the innovation, regulations and financial supports, in which there are obvious contribution in the human resource development.

5.5.2 National Fourth Industrial Revolution (4IR) Policy [4]

Despite Construction is categorised as supporting sectors with primary emphasis on manufacturing sector, the Nation Fourth Industrial Revolution (4IR) Policy has the following strategies (S1, 2, 3 & 5) under the policy thrust on Rakyat that fit into the opportunity of human capital and resource development in this position paper as in Figure 3-5 Strategies and initiatives of Policy Thrust 1 (**Appendix 5J**).

The impacts of 4IR have the benefit of new job creation and risk on job redeployment due to change in skill requirements, which will need support of human capital and resource development.

The 4IR-related policies related to human capital and resource development in the blueprint lists down the following.

a. Malaysia Education Blueprint (2013-2025) : Shift 7 : Leverage ICT to scale up quality learning across Malaysia
b. National Workforce Human Capital Development Blue print (2018-2025) : Outline the role of Human Resources Development Fund (HRDF) in talent development related to digitalisation, automation and Industry 4.0

c. Framing Malaysian Higher Education 4.0 : A guideline for higher education institutions in adapting to the changing demands of the 4IR

Following the above, one of the crucial building blocks need to be put in place to pave the way for Malaysia to successfully embrace the 4IR. These building blocks are grouped into four themes as a case for change. The theme relevant to human capital is “Talent needs to be 4IR-ready to address current and future demands”, in which an extract from the theme in the policy is given below.

“*As 4IR transforms the society, the required skill sets also change. The current talent pool must be equipped with the necessary skills to develop and use the 4IR technologies. This is a significant challenge that will require reskilling, upskilling and a lifelong approach to education and development. In addition, coherent policy surrounding labour issues and adequate social safety nets are necessary to help local talent thrive in the 4IR era.*”

Focus areas in the policy are illustrated in Figure 3-2 (**Appendix 5K**).

In summary, the salient points in the National Fourth Industrial Revolution (4IR) Policy can be concluded as below.

a. Establishing industrial led, sectorial based 4IR-skills development centre
b. Matching talent pipeline with the future economy needs
c. Equip future workforce with 4IR skill sets in school, higher education institutions (HEIs) and vocational education and training (TVET) institutions
d. Upskill and reskilling the civil servants and public sector

5.5.3 Malaysia Digital Economy Blueprint [5]

In this blueprint, Construction is one of the main sectors including Agriculture, Manufacturing and Services. The relevant sections to human capital and resource development are extracted in **Appendix 5L** with highlighted box-out.

5.6 Conclusions on Human Capital / Capacity Building

There are numbers of strategy plans, governmental policies and blueprints embarking to Construction 4.0, Industry Revolution 4.0 and digital economy, where construction sector plays vital roles in providing better, safer, faster, efficient and effective industry ecology and also support other sectors in the forthcoming digital economy. Human capital and resource development shall leverage on these planning strategies in the initiatives and efforts steered by the government to advance the adoption of technology for future construction sector. The human capital and resource development in this position paper shall well eco with the actions in implementing and executing these strategies and plan with well laid foundation stones.

5.7 Recommendations for Human Capital / Capacity Building

Recommendations by IEM in upskilling and reskilling of present and future workforces from industry sectors and, also public sector to adapt in the ecology of Revolutionised Construction 4.0. This is shown clearly in Table 5.1.

Table 5.1: Recommendations for Human Capital / Capacity Building efforts

No	Description of recommendations	To be addressed by relevant Governmental Agency	Timeframe
1	Human capital capacity building and preparedness for future workforces at all levels from school, TVET, HEIs, where IEM can provide members with respective expertise for the training.	Ministry of Education, Ministry of Higher Education, and both public and private universities, colleges nationwide.	By 2025
2	Accreditation of Industry-led training content for the stakeholders is suggested. With the wide spectrum of IEM members, IEM can work with all professional bodies and regulatory bodies to accredit the training courses that are on demand from the industry.	Board of Engineers Malaysia (BEM) as part of JKR	By 2025

3	Resource development by establishing Centres of Excellence (CoE) and training centres on respective sectors is vital for up keeping on the R&D of advanced technologies. The industry related centre of excellence and training centres include, but not limited to Construction Research Institute of Malaysia (CREAM) under Construction Industry Development Board (CIDB), Centre of Excellence for Engineering & Technology (CREaTE) under Jabatan Kerja Raya (JKR) in Melaka, Malaysia Global Training Centre (MGTC) under Multinational Corporations (MNC) in Cyberjaya	Construction Industry Development Board (CIDB) and JKR as part of Ministry of Works	By 2025
4	Assist in creating platforms and venues for technical and technology promotional events (workshops, short courses, seminar conferences and convention/expo/exhibitions) to facilitate exchange of industry practices, development of technologies and tools, exhibition of technological products and professional services. Ministry of International Trade and Industry (MITI) shall be the good platform to facilitate the international trade promotion with the aforementioned events organised.	Ministry of International Trade and Industry (MITI)	By 2025
5	Suggestion of incentives (tax incentives) and fundings (e.g. HRDF) from governmental policies to technology adoption and voluntary trainers in digital training and certified courses for school students, undergraduates, post-graduates and working professionals. Economic Planning Unit (EPU) under Prime minister’s Department and Human Resource Development Corporation (HRDCrop) under Ministry of Human Resources (MOHR) shall be the contact	Ministry of Finance, Economic Planning Unit (EPU), Ministry of Human Resources.	By 2025

	agencies in engaging on the policy of incentives and funding for HCRD.		

Note for Table 5.1: The above recommendations may have time and cost implications. Further study will have to be carried out should the recommended agency is agreeable to take the lead to initiate the course of action as required.

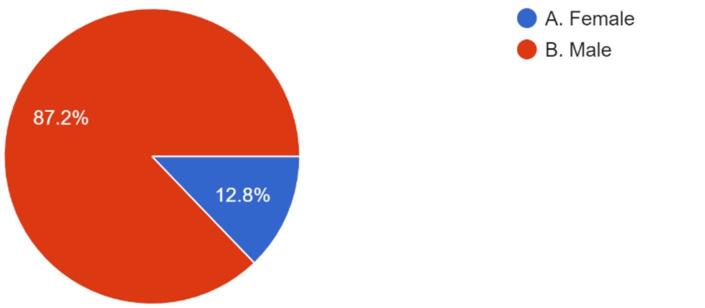
5.8 References

1. Wikipedia, the free encyclopedia, (2022) 'Human Capital', https://en.wikipedia.org/wiki/Human_capital
2. Construction 4.0 Strategic Plan (2021-2025) – Construction Industry Development Board (CIDB), published on 2020 by CIDB Malaysia.
3. World Economic Forum (2018) 'Readiness for the Future of Production Report 2018', 4IR Benchmarking Insight Report in collaboration with A.T. Kearney. https://www3.weforum.org/docs/FOP_Readiness_Report_2018.pdf
4. Economic Planning Unit of Malaysia (EPU) (2021), 'National Fourth Industrial Revolution (4IR) Policy'.
5. Economic Planning Unit of Malaysia (EPU) (2020), 'Malaysia Digital Economy Blueprint'.

Appendix 5A

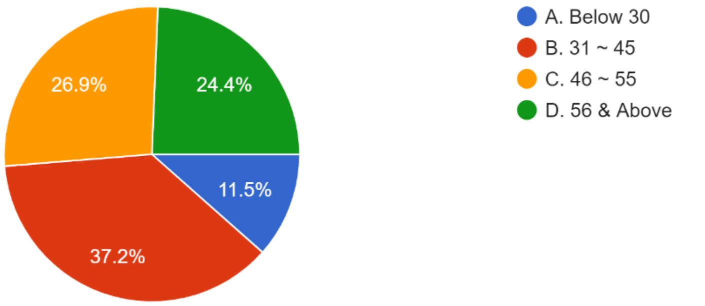
1 (a). Gender

78 則回應



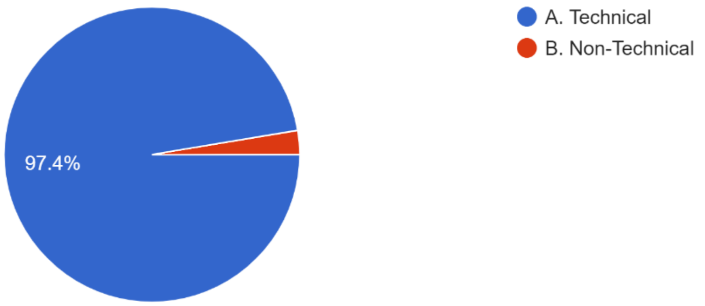
1 (b). Age Range

78 則回應



1 (c). Are you a Technical or Non-Technical Personnel?

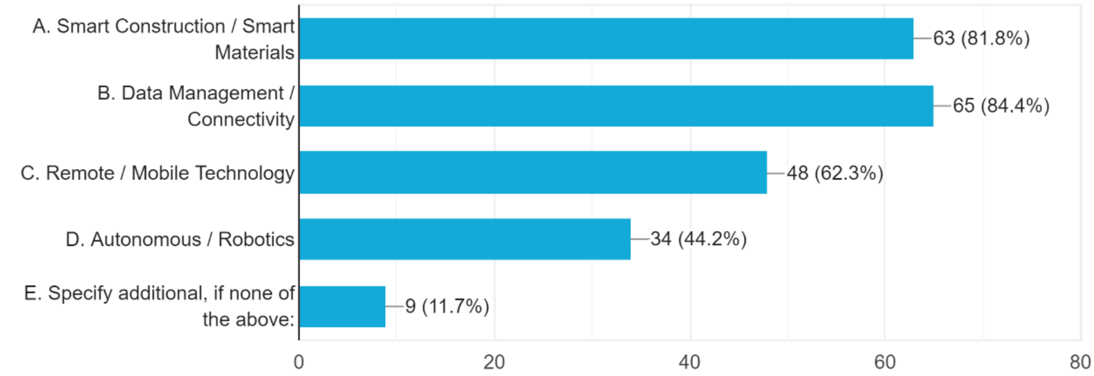
76 則回應



Appendix 5B

2. Which Skillset(s) or Know-How(s) are important in the era of Construction 4.0? You can tick more than one.

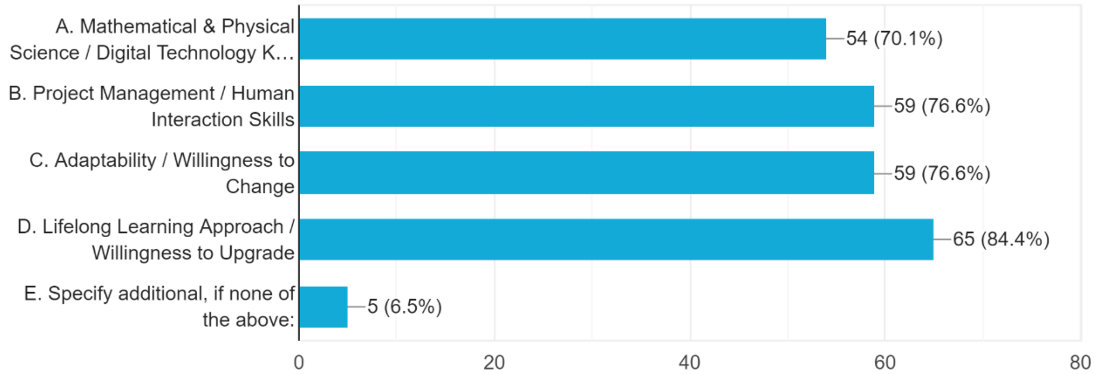
77 則回應



Appendix 5C

3. What quality of work force or human capital would be most significant in the way Construction 4.0 will lead the construction industry forward in ...next 20 years or more? You can tick more than one.

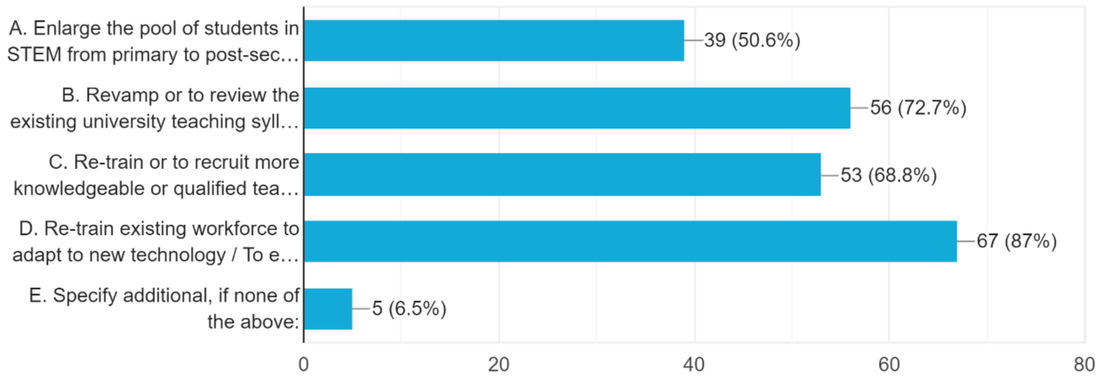
77 則回應



Appendix 5D

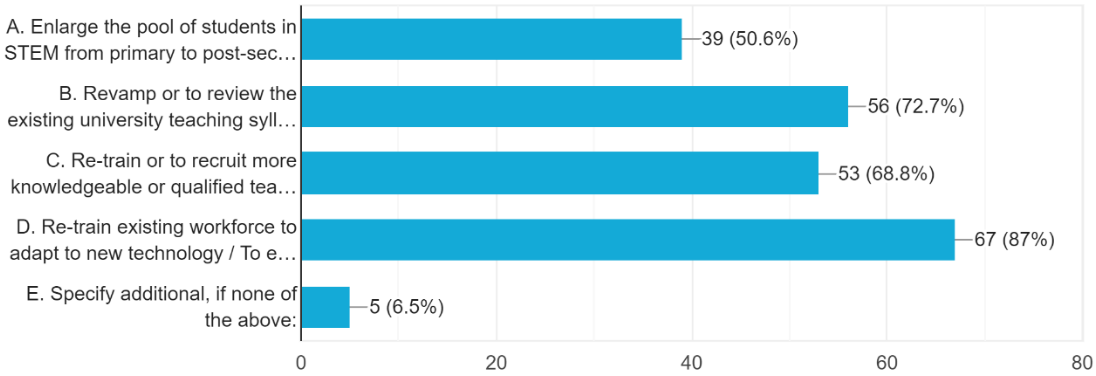
4. In what best way the quality of the work force can be upgraded or enhanced to keep up with the trends in Construction 4.0? You can tick more than one.

77 則回應



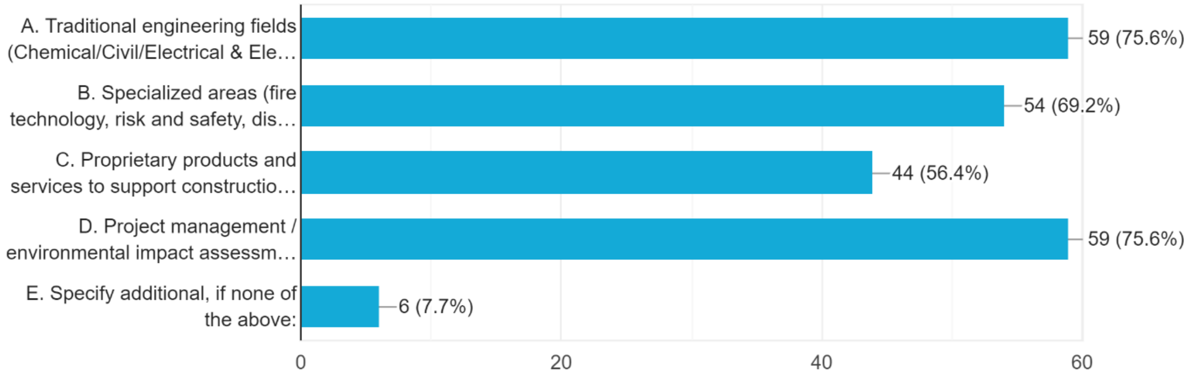
Appendix 5E

4. In what best way the quality of the work force can be upgraded or enhanced to keep up with the trends in Construction 4.0? You can tick more than one.
77 則回應



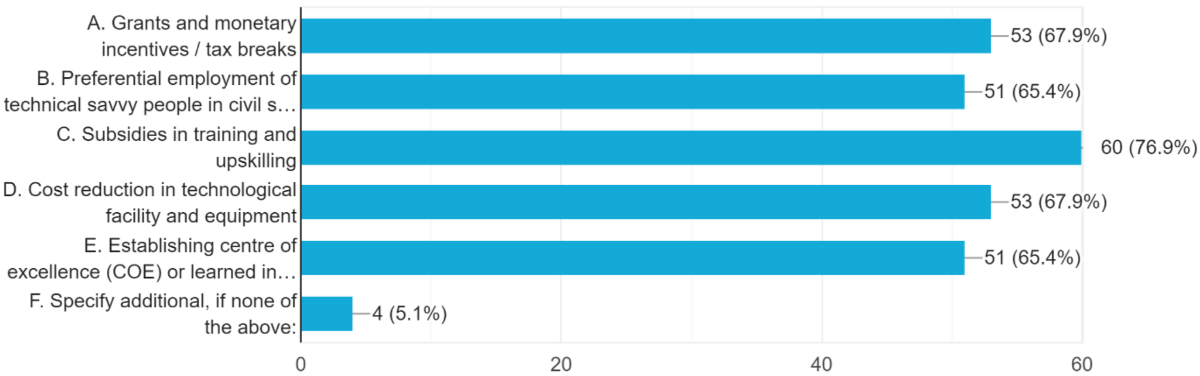
Appendix 5F

5. Professional Accreditation / Certification could be one method to regulate the professionals in specialized areas to ensure effective implementatio...tation / Certification. You can tick more than one.
78 則回應



Appendix 5G

6. What is the best Incentive / Initiative which the Government can provide to promote the Capacity Building of the Human Capital to capitaliz...o the next few levels? You can tick more than one.
78 則回應



Appendix 5H

Initiative — **Building Capacity**

Current state

- As of 2019, the construction industry vacancies are dominated by low-skilled jobs. Competent digital talents are scarce. Malaysia lack a proficient, conversant and experience vendor education system to educate and train employees in the latest digital trends. The industry often recruits foreign experts from the United Kingdom, United States or Singapore to offer expert training to employees.
- In Higher Education, curriculum in tertiary institutions are not kept in-pace with the rapid changes taking place in the industry. Very few universities have robust industry–linked curriculum or research programs to meet the needs of the industry. This led to the lack of skilled talents to fill technical and digital posts.

STRATEGIC OBJECTIVES	ENABLERS	CASE FOR CHANGE	AIMS	TIMELINE
1 Preparing future workforce for Construction 4.0	People Governance	• Inadequate highly skilled talents • Readiness of students for IR4.0 workplace • Difficulties in recruiting talented and future ready workforce • Lack of employee readiness as well as strong resistance to changes and new technologies • Potential of emigration of highly trained or qualified people • Dependency of foreign talents	Develop and deliver Construction 4.0 awareness and programme for stakeholders	• 2021 Short Term
			Develop apprenticeship program for construction 4.0	• 2021 Short Term
			Enhanced skills programme for construction supply chain towards Construction 4.0 implementation (Training module and competency)	• 2021 Short Term
2 Create mechanisms to support innovators and technology adopters	Economy Integrated Technologies	• Education syllabus is not in sync with the increasing demand of the industry • Lack of financial support	Establish Technopreneurship Development Initiatives and Programme (TDIP) for construction industry players to shift towards digital transformation process.	• 2023 Medium Term
			Prepare graduates for Construction 4.0 technologies by integration of STEM (Science, Technology, Engineering and Mathematics) and Technical and Vocational Education Training (TVET).	• 2021 Short Term
			Nurture an active community of integrated technology adopters.	• 2021 Short Term
			Provide high impact program with supporting initiative in Construction 4.0. By: Awards/Incentives/Competition/Conference	• 2021 Short Term
			Readiness assessment to gauge the Construction 4.0 level of competency for stakeholders	• 2021 Short Term

Appendix 5I

Initiative: **Excellence Research, Innovation, Commercialisation and Entrepreneurship (RICE)**

Current state: Based on National Survey of Research and Development (R&D) in Malaysia 2017:

- Among the 11 selected Asian countries, Malaysia ranked 6th with 1.4% of R&D expenditure per GDP. Singapore ranked 4th with 2.1%. Malaysia was ranked higher than Indonesia, Philippines, Thailand, Hong Kong and India in terms of the ratio of R&D expenditure per GDP. Business enterprises accounted for 56.6% of total R&D expenditure spent in 2016 for Malaysia.
- Many businesses have commented that the R&D process is burdensome, decision-making periods were too long and research not suitable for their needs. The findings of the survey also indicated the lack of collaboration by all the organisations. While, the impact of research is poor and could not be maximised due to unavailable research findings. It can be due to publication fees or articles processing charges (APC) are expensive.

STRATEGIC OBJECTIVES	ENABLERS	CASE FOR CHANGE	AIMS	TIMELINE
1 Strengthen Quadruple Helix: Government - Industry - Academia - Civil Society partnership for Construction 4.0 innovation & technology transfer	Governance Economy	• Lack of collaboration among stakeholders • No specific incentives or financial support from government for IR4.0 technologies development	Attractive incentive to encourage the sustainability of the RICE programme	• 2023 Medium Term
			Utilise high-impact R&D output in technology innovation for commercialisation	• 2025 Long Term
			Create financial mechanism for R&D funding linked to Construction 4.0	• 2021 Short Term
2 Driving research and innovation in Construction 4.0	Integrated Technologies People	• Uncertainty of environmental sustainability effect in the future • No clear national policy, guidance or framework • Potential of emigration of highly trained or qualified people	Improve evidence-based approach for the construction industry	• 2021 Short Term
			Utilise leading talent to stimulate creativity and innovation	• 2021 Short Term
			Enhance home-grown technology labs to trial and showcase local innovation	• 2023 Medium Term
			Develop and improve R&D in order to promote, deliver and provide smart construction initiatives with technological changes to build a competitive industry	• 2023 Medium Term

Appendix 5J

Figure 3-5: Strategies and initiatives of Policy Thrust 1

5 STRATEGIES	12 INITIATIVES	
S1 Industry-led upskilling and reskilling of the existing workforce for the 4IR	Initiative 1:	Establish industry-led, sectoral-based 4IR-skills development centres
	Initiative 2:	Incentivise industry to upskill and reskill talent in 4IR areas
S2 Match the talent pipeline with the future needs of the economy	Initiative 3:	Establish an AI-enabled data platform to facilitate human capital planning
	Initiative 4:	Reconcile labour policies with talent pipeline projection and other 4IR- related incentives to gradually reduce foreign labour dependency
S3 Equip future workforce with 4IR skill sets	Initiative 5:	Scale up exposure to 4IR technologies among the young generation and encourage innovation by making all schools in Malaysia "My Digital Maker Champion Schools"
	Initiative 6:	Enhance and implement PAK-21 in all public schools to develop humanistic soft skills for future workforce to be 4IR-ready
	Initiative 7:	Enhance 4IR-related courses in higher education institutions (HEIs) and technical and vocational education and training (TVET) institutions through better programme design and delivery
S4 Provide equal access to 4IR opportunities across the population	Initiative 8:	Rationalise and enhance collaboration to ensure equal access to 4IR learning opportunities for all
	Initiative 9:	Provide incentives to minimise the risk of job displacements
	Initiative 10:	Enhance formal social protection mechanism for gig workers
S5 Upskilling and reskilling the civil servants	Initiative 11:	Introduce a 4IR Innovation Accelerator, dedicated to driving adoption of 4IR technologies in public sector at all levels of government
	Initiative 12:	Provide 4IR-related training to all civil servants

Beneficiary groups: Businesses Society Government

Appendix 5K

Figure 3-2 : Highlights of new and enhanced initiatives in the National 4IR Policy based on the four policy thrusts

Focus areas	Human capital development	Infrastructure improvement	Regulations improvement	Technology adoption and innovation
Examples of new initiatives in the National 4IR Policy	• Ensuring coherence of labour policies • Addressing job displacement due to 4IR • Accelerating the implementation of 4IR within the public sector	• Developing 4IR Innovation Parks and Application Centres	• Developing 4IR ethics framework • Introducing co-solutioning approach in addressing regulatory issues	• Developing 4IR Business Platform • Introducing Government Experience Lab
Examples of enhanced initiatives from the existing policies in the country	• Mobilising co-investment fund for 4IR technology adoption by industries • Prioritising research, development, commercialisation and innovation (R&D&C&I) funding for technological innovations • Adopting agile regulatory approach and expand regulatory sandbox • Establishing data driven policies and improve data sharing environment • Introducing specific legislation on cyber security			
Other highlights of the National 4IR Policy	• Aligned to the SDGs and WKB 2030 • Aims to seize growth opportunities arising from 4IR • Includes both ecosystem and sectoral approach with government facilitating private sector innovation and application of technologies to cope with 4IR • Leverages cross-platform collaborations and private sector for solutions • Prioritises change management as one of the key focus areas for implementation • Emphasises the need to embed trust and inclusivity within the digital society			

Appendix 5L

Figure 3-1: Malaysia Digital Economy Blueprint

MALAYSIA DIGITAL ECONOMY BLUEPRINT

VISION

To be a regional leader in the digital economy and achieve inclusive, responsible and sustainable socioeconomic development

OBJECTIVES

- Encourage industry players to become creators, users and adopters of innovative business models under the digital economy
- Harness human capital that is able to thrive in the digital economy
- Nurture an integrated ecosystem that allows society to adopt digital economy

6 THRUSTS

22 STRATEGIES

1 Drive digital transformation in the public sector

- **S1:** Managing change for effective digital transition
- **S2:** Leveraging digital technology to improve workflow efficiency and productivity
- **S3:** Enhancing digital skill sets of civil servants
- **S4:** Utilising data to improve government services
- **S5:** Increasing scope and quality of online services for better user experience

2 Boost economic competitiveness through digitalisation

- **S1:** Facilitating digital adoption, access and effective use of digital technology across all firm sizes & digital maturity level
- **S2:** Accelerating industry development by enhancing local participation
- **S3:** Streamlining regulatory requirements to respond to digital economy and encourage innovative business models
- **S4:** Developing digital industry cluster and driving entrepreneurial activity

3 Build enabling digital infrastructure

- **S1:** Utilising regulatory measures to expand infrastructure coverage
- **S2:** Leveraging digitalisation to address legacy challenges
- **S3:** Enhancing digital technology infrastructure capabilities

4 Build agile and competent digital talent

- **S1:** Integrating digital skills into education at primary and secondary level
- **S2:** Shifting focus of vocational and tertiary education from job-specific skills to competencies and adaptability
- **S3:** Reskilling current workforce with the digital skills needed to stay relevant
- **S4:** Ensuring that gig workers are protected and equipped with the right skills

5 Create an inclusive digital society

- **S1:** Increasing inclusivity of all Malaysians in digital activities
- **S2:** Empowering special target groups in the society to participate in the digital economy through entrepreneurship

6 Build trusted, secure and ethical digital environment

- **S1:** Strengthening safety and ethics in digital activities and transactions
- **S2:** Enhancing institutions commitment to personal data protection and privacy
- **S3:** Improving cross-border data transfer
- **S4:** Increasing cyber security uptake among businesses

48 NATIONAL INITIATIVES

28 SECTORAL INITIATIVES

S2: Leveraging digital technology to improve workflow efficiency and productivity

5 Introduce the Digital-First programme to enhance Federal and state levels usage of cloud services

OBJECTIVE:

- Shift towards a digital-first mindset through business process reengineering
- Empower work mobility by maximising digital storage usage

DESCRIPTION OF INITIATIVE

- This initiative focuses on two main areas, namely reducing the usage of physical storage files by shifting towards the cloud first strategy and adopting a paperless culture in everyday work
- This initiative will also identify and adopt necessary technologies to enable paper-free workflows and transactions

OUTCOME

- Optimisation of government resources and automation of tasks through establishment of digital workflows
- Improved accessibility to data and information through centralisation of data storage in the cloud
- Improvement of remote work approach among civil servants

Timeline: Phase 1 (2021 - 2022)

LEAD	TARGET
MAMPU	• 80% of cloud storage across the government in 2022 • Circular on remote work approach by 2021

S3: Enhancing digital skill sets of civil servants

6 Develop "Digital Transformers" to groom highly skilled civil servants comprising technical experts and professional ICT-related talent

OBJECTIVE

- Equip talent with the right skill sets in specific areas
- Create a pool of highly skilled civil servants who will steer digital transformation
- Reduce dependency on external vendors or experts in technical services

DESCRIPTION OF INITIATIVE

- This initiative aims to develop two pools of in-house talent, namely specialised technical talent including data scientists, cyber security experts and programmers as well as subject matter experts with skills to plan and execute a strategic digital agenda such as employees with experience in economy, supply-chain management, business development and planning
- This includes creating attractive career paths to retain talent
- This initiative will also include long-term plans for continuous training and upskilling in technical areas

OUTCOME

- Empowerment of ICT-related talent with skills to steer digital transformation
- Decrease dependency on external vendors or professional services

Phase 1 to Phase 2 (2021-2025)

LEAD	TARGET
MAMPU and JPA	250 certified trainers under Digital Government Competency and Capability Readiness programme by 2025

S3: Enhancing digital skill sets of civil servants

7 Develop and upskill civil servants with digital skills, across all grades and schemes

OBJECTIVE

Equip civil servants across all grades and schemes including top management, with digital skills

DESCRIPTION OF INITIATIVE

- This initiative aims to upskill civil servants through well planned digital training modules and continuous training. Training will be mandatory
- This is also to establish a digital development cluster at the National Institute of Public Administration (INTAN)

OUTCOME

- Civil servants with a holistic set of digital skills to enhance service delivery
- Improved public training institution capabilities

Timeline: Phase 1 to Phase 2 (2021 - 2025)

LEAD	TARGET
JPA	• Establishment of a digital development cluster by 2022 • 100% civil servants to possess digital literacy in 2025

S4: Utilising data to improve government services

8 Establish data-driven policy development and improve the data sharing environment to ensure data quality

OBJECTIVE

- Maximise data usage for improved policy analysis and development as well as optimise machine-readable data
- Provide more services in MyGDX for data utilisation and facilitate data sharing by agencies

DESCRIPTION OF INITIATIVE

- This initiative aims to enhance evidence-based policy development
- Establish guidelines for open data to ensure data is open by default, accessible, reliable, reusable, comprehensive, comparable and interoperable
- Expand MyGDX service catalogues to include all potential ministries and agencies to facilitate more data sharing
- Ministries and agencies to produce their own open Application Programming Interface (API) to share real-time and aggregated data

OUTCOME

- Establishment of open data guidelines to produce data with transparency, integrity and accountability
- Improvement of Malaysia's position in open data global rankings

Timeline: Phase 1 to Phase 2 (2021 - 2025)

LEAD	TARGET
MAMPU	• 50% data must be machine -readable, with access to the data through APIs • All ministries and agencies to develop access to data through APIs • All ministries and agencies to use MyGDX

S1: Integrating digital skills into education at primary and secondary level

1 Introduce "My Device" programme to ensure all students in Malaysia can access digital learning

OBJECTIVE

Enable all school students to have access to digital learning

DESCRIPTION OF INITIATIVE

- This initiative aims to introduce the "My Device" programme where all students will have access to devices, through various mechanisms, depending on their household income levels
- The programme will be setup through public-private-people partnerships, where students will be provided with data plans and devices with strict security settings. This is to ensure the effective use and control of the device

OUTCOME

- Enhanced learning experience
- Digitally well-equipped students
- Narrowed digital divide

Timeline: Phase 1 to Phase 2 (2021-2025)

LEAD	TARGET
Ministry of Education (MOE)	Each school student to have access to individual digital device

S1: Integrating digital skills into education at primary and secondary level

2 Introduce digital packages to ensure all schools in Malaysia have good connectivity

OBJECTIVE

Equip all schools with good internet connectivity to facilitate digital learning

DESCRIPTION OF INITIATIVE

- This initiative aims to provide good internet connectivity in schools to facilitate online learning through the introduction of special digital packages
- Identifying financing models with contributions from the private sector and CSOs to support the implementation of this initiative

OUTCOME

- Students have equal access to internet connectivity to embrace digital learning

Timeline: Phase 1 to Phase 2 (2021-2025)

LEAD	TARGET
MOE	All schools have access to internet connectivity

S1: Integrating digital skills into education at primary and secondary level

3 Adopt digital technology through collaboration with the private sector to enhance overall learning environment

OBJECTIVE

Provide a platform for managing online teaching and learning in primary schools

DESCRIPTION OF INITIATIVE

- This initiative aims to accelerate the adoption of digital technologies within the current curriculum and existing subjects to create a more interactive learning environment and instil confidence in students on digital technologies from a young age
- The current Digital Educational Learning Initiative Malaysia (DELIMa) will be expanded in terms of content and coverage to be more effective
- The digital technologies can also be leveraged to improve the quality of STEM education in secondary schools

OUTCOME

- Digital technology is embedded in the delivery of education
- Development of creative thinking among students

Timeline: Phase 1 to Phase 2 (2021-2025)

LEAD	TARGET
MOE	All schools adopt digital solutions and technology in the delivery of education by 2025

S1: Integrating digital skills into education at primary and secondary level

4 All schools in Malaysia to be Digital Maker Schools

OBJECTIVE

- Equip students with creative thinking and digital innovation skills
- Transform students from consumers to producers of technology

DESCRIPTION OF INITIATIVE

- This initiative aims to expand the number of Champion Schools across the nation
- This programme will equip students and teachers with the necessary digital skills and tools to cultivate adaptability skills and innovative mindsets through activities and competitions
- My Digital Maker Champion Schools will require support from industry players in the forms of financing, co-development of concepts, and training

OUTCOME

- Students with ability to adapt, create and innovate with digital technology

Timeline: Phase 1 to Phase 3 (2021-2030)

LEAD	TARGET
MOE and KKMM	2,500 My Digital Maker Champion Schools by 2030

S1: Integrating digital skills into education at primary and secondary level

5 Introduce "My Digital Teacher" programme to encourage teachers to fully embrace the use of digital tools and technology

OBJECTIVE

Upskill teachers to embrace technology in teaching and learning, as well as administrative work

DESCRIPTION OF INITIATIVE

- This initiative aims to roll out a professional development programme for teachers, who will be equipped with the knowledge and digital tools to improve teaching skills and work organisation
- Co-creating a tech-based innovative solution with tech companies to enhance teachers' work organisation relating to learning plan development, teaching aids and reporting

OUTCOME

- Higher technology utilisation rate among teachers
- Enhanced capacities and capabilities of teachers in utilising digital technology
- Reduction in time spent on administrative work

Timeline: Phase 2 (2023-2025)

LEAD	TARGET
MOE	All teachers undergone My Digital Teacher training programme by 2025

S1: Integrating digital skills into education at primary and secondary level

6 Expand an open access knowledge bank to house teaching materials for educators

OBJECTIVE

Create a knowledge bank for education materials in digital format

DESCRIPTION OF INITIATIVE

- This initiative aims to develop a knowledge bank that contains materials where their quality and standards fulfil MOE and Ministry of Higher Education (MOHE) guidelines
- The content include a list of teaching material in e-format such as workbooks and practice papers as well as teaching sources such as videos and podcasts
- The knowledge bank will have a seamless interface to enhance user experience

OUTCOME

- Educators to have access to teaching material through open access knowledge bank

Timeline: Phase 2 (2023-2025)

LEAD	TARGET
MOE and MOHE	Establishment of an open access knowledge bank by 2025

S2: Shifting focus of vocational and tertiary education from job-specific skills to competencies and adaptability

7 Expand public-private collaboration through Malaysia Board of Technologies (MBOT) to ensure the graduates are equipped with skills needed by the industry

OBJECTIVE

Strengthen the role of MBOT in establishing the performance standards of industry players in their partnership with HEIs

DESCRIPTION OF INITIATIVE

- This initiative aims to align curriculum design of HEIs and in-demand digital skills of the industries
- This will also leverage existing partnerships between Government, academia and industry, through (MBOT) and its Technology Expert Panels (TEP)
- This initiatives also provides opportunities for participating industry players to assess future workforce capabilities, and increase students agility in becoming quality workforce

OUTCOME

- Improved coordination and interaction between industry players, HEIs and students
- Improved capability of students to be future work-ready

Timeline: Phase 1 to Phase 2 (2021-2025)

LEAD	TARGET
MOSTI and MOHE	All HEIs in Malaysia are strategic partners in the MBOT

S3: Reskilling current workforce with the digital skills needed to stay relevant

8 Launch the "Social Entrepreneurs Circle" programme to equip social entrepreneurs with digital skills and provide a networking platform

OBJECTIVE

Ensure that social entrepreneurs can access support related to networking, mentoring and coaching for them to grow

DESCRIPTION OF INITIATIVE

- This initiative aims to offer mentoring, coaching, networking and digital skills development designed to help social entrepreneurs grow through digitalisation and increase their footprint and impact
- The programme involves access to webinars hosted by international social entrepreneurs, online training on digital technologies to improve their business processes, as well as monthly networking sessions
- Upskilling programmes will include training in data science and cyber security as well as mentoring from established digital companies and start-ups
- An inclusive business model, which is commercially viable, bankable and for-profit will be introduced to provide systemic solutions to problems faced by vulnerable groups

OUTCOME

- The growth of social entrepreneurs in Malaysia
- Malaysia as a regional hub for social entrepreneurs

Timeline: Phase 2 (2023-2025)

LEAD	TARGET
MEDAC	All social entrepreneur will become members in the Social Entrepreneur Circle by 2025

S3: Reskilling current workforce with the digital skills needed to stay relevant

9 Introduce a training programme for senior managers to improve digital skills

OBJECTIVE

Encourage senior management to acquire relevant digital skills and embrace the digital culture at the workplace

DESCRIPTION OF INITIATIVE

- This initiative aims to enhance the digital technology skills of senior management
- MOHR via HRDF will drive this programme, which can be carried out through online platform (e-learns) in collaboration with technology providers

OUTCOME

- Senior managers who are equipped with digital skills
- Narrow the digital gap among employees

Timeline: Phase 2 (2023-2025)

LEAD	TARGET
MOHR	50% of senior management in Government-linked companies (GLCs), multinational companies (MNCs) and MSMEs to participate in the programme by 2025

S3: Reskilling current workforce with the digital skills needed to stay relevant

10 Streamline reskilling initiatives by various government agencies onto a centralised portal for ease of access

OBJECTIVE

Give employers and employees access to information on skills training and job availability through a centralised portal

DESCRIPTION OF INITIATIVE

- This initiative aims to centralise information on all existing upskilling and reskilling training initiatives by different agencies onto the MYFutureJobs portal
- All training programmes will be streamlined to optimise resources and enhance effectiveness
- Companies will be able to access customisable training programmes, while employees will be able to explore career opportunities through this portal

OUTCOME

- Establishment of a single point of reference for employers and employees

Timeline: Phase 2 to Phase 3 (2023-2030)

LEAD	TARGET
MOHR	MYFutureJobs as a single platform for upskilling and reskilling programme for all employers and employees in Malaysia by 2030

S3: Reskilling current workforce with the digital skills needed to stay relevant

11 Introduce professional upskilling programmes related to the digital economy

OBJECTIVE

Develop and upskill the workforce's digital skills in areas such as cyber security, content creation, data analytics, system integration, AI and other relevant professional skills

DESCRIPTION OF INITIATIVE

- This initiatives aims to upskill the workforce in specific digital skills for professional development and allows professionals such as data scientists, data analysts, cyber security workers and AI specialists to share knowledge, expertise and skill sets
- Increase awareness on the Global Accredited Cybersecurity Education (ACE) Certification Scheme which defines the competencies expected of skilled cyber security personnel. The certification supports the continuous development of individuals in mitigating cyber-related threats, as well as grooms effective cyber defenders
- Upskilling programmes for digital skills will be undertaken either by local universities, or through online masterclasses. Training carried out for workers by companies will be eligible for tax deduction

OUTCOME

- Workforce equipped with specific skills in digital economy that allows them to grow in tandem with the nation's digital economy
- Enhanced cyber security capabilities and standards among companies

Timeline: Phase 2 (2023-2025)

LEAD	TARGET
MOHR	Develop professional digital talent including 20,000 cyber security knowledge workers and 30,000 data professionals by 2025

S4: Ensuring that gig workers are protected and equipped with the right skills

12 Introduce the "GigUp" programme to equip gig workers with versatile skills

OBJECTIVE

Ensure that gig workers from various educational backgrounds are given the skills to improve their employability and mitigate the precarity of their job

DESCRIPTION OF INITIATIVE

- This initiative aims to encourage companies that employ gig workers, including technology companies, start-ups and even larger companies, to invest in training gig workers
- Training will be subsidised via HRDF on existing online platforms such as Coursera, Udemy, edX and Codeacademy

OUTCOME

- Enhanced skills and improved employability of gig workers in sharing economy

Timeline: Phase 1 to Phase 2 (2021-2025)

LEAD	TARGET
MOHR	All gig workers in sharing economy participate in the "GigUp" programme by 2025

	INITIATIVES	OUTCOMES	TARGETS
AGRICULTURE	Promote smart farming adoption through a centralised open data platform amongst industry players	Increased digital adoption and generated new business models by accessing the open data platform and identifying specific cost-cutting measures	1. To have machine-readable data, with access through API 2. Contribute to creation of at least 5,000 start-ups by 2025 3. Increase in digital adoption rate across businesses
AGRICULTURE	Create more local digital platforms to enable access to 'Farm to Table' digital marketplace	Increased participation in digital marketplace and sales of farmers	1. Increase in digital adoption rate across businesses 2. Contribute to creation of at least 5,000 start-ups by 2025 3. Contribute to 30% uplift in labour productivity across all sectors
CONSTRUCTION	Increase and accelerate the construction industry's adoption of digital technologies throughout the construction project lifecycle	Increased the adoption of digital technologies in the construction industry	1. To have machine-readable data, with access through API 2. Contribute to creation of at least 5,000 start-ups by 2025 3. Increase in digital adoption rate across businesses
CONSTRUCTION	Expand HRDF claimable programme to cover new and CIDB organised digital skills training programmes	More workers adept at relevant digital technologies	1. Contribute to 30% uplift in labour productivity across all sectors 2. Top 15 under the Skills pillar in the WEF Global Competitiveness Index
CONSTRUCTION	Intensify research, development, commercialisation and innovation (R&D&C&I) in emerging digital technologies in centres of excellence for sustainable construction	Increased the number of buildings and infrastructure which feature emerging digital technologies and sustainability	1. Top 20 under the Knowledge and Technology pillar in the Global Innovation Index 2. Contribute to 30% uplift in labour productivity across all sectors
CONSTRUCTION	Introduce an enhanced mechanism to accelerate the roll out of smart cities	Increased partnership between cities and industry and technology partners to roll out smart cities	1. Contribute to creation of at least 5,000 start-ups by 2025 2. At least five smart cities established by 2025

BOLD AND NEW INITIATIVES

are the high impact initiatives and have great importance on achieving the vision of the Blueprint

NATIONAL

T1

Initiative 10: Enhance Government Online Services Gateway (GOS Gateway) with integrated systems for greater ease of doing business

T2

Initiative 6: Empowering local champions and stimulating investment through digital industry clusters

T4

Initiative 1: Introduce "My Device" programme to ensure all students in Malaysia can access digital learning

Initiative 2: Introduce digital packages to ensure all schools in Malaysia have good connectivity

Initiative 5: Introduce "My Digital Teacher" programme to encourage teachers to fully embrace the use of digital tools and technology

Initiative 6: Expand an open access knowledge bank to house teaching materials for educators

Initiative 12: Introduce the "GigUp" programme to equip gig workers with versatile skills

SECTORAL

Agriculture: Promote smart farming adoption through a centralised open data platform amongst industry players

Healthcare: Accelerating the usage of the Malaysia Health Data Warehouse (MyHDW) with the inclusion of blockchain

Chapter 6 Summary

With the advent of the Construction 4.0 as discussed and tabulated in this position paper, the construction industry in Malaysia has the opportunity to leapfrog to more efficient production, new business models and value streams. The following are summaries of recommendations put forth by all the Working Groups as described earlier in their respective sections.

A) Smart construction and materials

Table 6A.1: Recommendations to be addressed by respective agencies

No	Recommendation	Agency to address	Timeframe
1	Monitor and provide subsidy for implementation of BIM	CIDB	By 2025
2	Implementation of BIM on local district level	Kementerian Perumahan dan Kerajaan Tempatan (KPKT)	By 2025
3	Specification of construction methodology and monitoring on government project	Kementerian Kerja Raya (KKR)	By 2025
4	Implementation of BIM on government pilot project	Kementerian Kerja Raya (KKR)	By 2025
5	Formulation of standard and guidelines on building and infrastructure	Standards Malaysia	By 2025
6	Build up teams of trainers with BIM skills	Kementerian Sumber Manusia	By 2025
7	Inclusion of smart construction courses in university class and for fresh university graduates	Kementerian Pengajian Tinggi (KPT), Institut Pengajian Tinggi (IPT)	By 2025

Table 6A.2: Suggested adoption target on smart Construction in line with the Construction 4.0 Roadmap 2021-2025

No	Number of related companies undertaking in YEAR/state subsidy in RM	2021	2022	2023	2024	2025
1	BIM	No: 0 SS: 0	No: 5 SS: 1M	No: 10 SS: 2M	No: 30 SS: 6M	No: 50 SS: 10M
2	VDC	No: 0 SS: 0	No: 5 SS:0.5 M	No: 10 SS: 1M	No: 30 SS: 3M	No: 50 SS: 5M
3	IDD	No: 0 SS: 0	No: 5 SS: 0.5M	No: 10 SS: 1M	No: 30 SS: 3M	No: 50 SS: 5M

B) Big data management and connectivity

Table 6B.1: Recommendation for action by leading agency to address needs of the Construction Industry

No	Leading Agency	Stakeholders	Timeframe	Cost
1	Ministry of Works (Kementerian Kerja Raya – KKR)	i- MAMPU ii-Ministry of Finance (MOF) iii-Jabatan Peguam Negara iv-Economic Planning Unit (EPU) v-ICU - Unit Penyelarasan Pelaksanaan JPM vi-Jabatan Kerja Raya (JKR) vii-CIDB	By 2025	The development efforts will be undertaken via a series of public-private partnerships, with the private sector contributing funds and expertise.

		viii-BEM ix-IEM x-GLCs (e.g. TM)		

Table 6B.2: Recommendation for action by leading agency to co-ordinate integration and data sharing

No	Leading Agency	Stakeholders	Timeframe	Cost
1	Malaysian Administrative Modernisation and Management Planning Unit (MAMPU)	i) Ministry of Works ii) Economic Planning Unit (EPU) iii) ICU - Unit Penyelarasan Pelaksanaan JPM iv) Jabatan Kerja Raya (JKR) v) CIDB vi) BEM vii) IEM viii) GLCs (expert in ICT)	By 2025	Depend on the mutual agreement (percentage ratio) between the Government and the private sectors.

Table 6B.3: Recommendation for action by leading agency to monitor real-time data usage

No	Leading Agency	Stakeholders	Timeframe	Cost
1	Economic Planning Unit (EPU)	i) ICU - Unit Penyelarasan Pelaksanaan JPM vi) Ministry of Works vii) Jabatan Kerja Raya (JKR) viii) CIDB ix) BEM x) IEM	By 2030	To be further studied

C) Mobile communication and robotic technology

Table 6C.1: Comparison in upgrading in mobile network facility for private users and various industry sectors [4]

Major Features	3G Networks	4G Networks	5G Networks
Data Rate	Up to 2 Mbps	Up to 100 Mbps	10x to 100x increase
			10G+ peak rates CIR/EIR 1:10 10 Tbps network nodes
Bandwidth	5Mhz	100 MHz	1.30 Gbps
Frequency Band	Up to 2.4 GHz	Up to 8 GHz	bands below 6 GHz
Radio Access Technology	WCDMA	MC CDMA, OFDMA	should be valid for all sorts of radio access technologies, Flat IP Network
Switch Technique	Packet switch mostly	Digital	Both (Packet Switching and Digital)
Internet Protocol	IPv4, IPv6	IPv6	IPv6
End-to-End latency	131.3357 ms (on HSPA)	78.91807 ms (on LTE)	< 1ms, 5x reduction
Increased battery life for low power devices	-	-	>10x

Table 6C.2: Comparison between grades of contractors registered with CIDB on their limits in tendering, investment and cap in project cost [9]

No	Contractor Grade	Tender Capacity	Investment %	Cost
1	G1 to G3	Up to RM1m	up to 1%	RM10k
2	G4 to G5	RM3m to RM5m	1% to 3%	RM30k to RM150k
3	G6 to G7	RM10m and above	2% to 3%	RM200k to RM1.5m

Table 6C.3: Phases in training of technical staff utilizing the right objectives and training resources

No	Phase	Cost	Solution Apps or software	Learning Objective
1	Phase 1 - Test	Free	WhatsApp, Google Apps, Microsoft Outlook	Create connectivity, monitor connections and test processes

				across all site operations.
2	Phase 2 – Pilot Project 1	RM10k to RM35k	Cloud based apps, online subscription	Test drive specific functionalities, limited adoption by department.
3	Phase 3 – Pilot Project 2	RM35k to RM60k	Service provider, desktop application	Cross discipline implementation, inter department communication, refine and freeze workflows and guidelines.
4	Phase 4 – Company Level	No data available	Global brands, AAA Solutions	Review processes and audit data generated.

Table 6C.4: Recommendations to be addressed by respective agencies within a proposed timeframe for follow-up actions.

No	Recommendation	Agency or organisation to address	Timeframe
1	• Provides fund to develop system or app that can be used by contractor and parties involved in construction • Promote the use mobile communication technology among construction industry stakeholders • Regulates the concept and technology involved • Produce guidelines and SOPs	CIDB	By 2025

2	• Driven by MBAM, to increase this adoption • Do more awareness program	Contractors	By 2030
3	• Add mobile technology into curriculum • Emphasize research on mobile technology • Collaboration with industry with research students	Universities (Public and private)	By 2030
4	• Include this as part of their KPI in government projects • Make training compulsory for departmental engineers and technicians	Jabatan Kerja Raya (JKR)	By 2030
5	• Embrace the mobile communication among members / industry stakeholders • Provide the required online and infrastructure platforms – software / hardware	IEM /ACEM / REHDA – or any other relevant learned societies or trade associations	By 2030
6	• Make available both infrastructure and accessibility of mobile communication network	Service providers of internet (MAXIS, DIGI, U-Mobile, etc)	By 2025
7	• Collaborate and co-operate with Government Ministry and Agency eg CIDB, to bring down initial cost of investment	Apps of software supplier/developer/distributor	By 2030

Table 6C.5: Recommendation for action by leading agency to promote and encourage the use of UAV and ROV technologies

No	Leading Agency	Timeframe	Cost
1	Construction Industry Development Board (CIDB)	By 2030	To be further studied
2	Ministry of Science, Technology and Innovation (MOSTI)	By 2030	To be further studied
3	Economic Planning Unit (as a key element of Ministry of Finance)	By 2030	To be further studied
4	Civil Aviation Authority (CAA) of Malaysia	By 2030	To be further studied

D) Human resource and capacity building for Construction 4.0

Table 6D.1: Recommendations for Human Capital / Capacity Building efforts

No	Description of recommendations	To be addressed by relevant Governmental Agency	Timeframe
1	Human capital capacity building and preparedness for future workforces at all levels from school, TVET, HEIs, where IEM can provide members with respective expertise for the training.	Ministry of Education, Ministry of Higher Education, and both public and private universities, colleges nationwide.	By 2025
	Accreditation of Industry-led training content for the stakeholders is suggested. With the wide spectrum of IEM members, IEM can work with all professional bodies and regulatory bodies to accredit the training courses that are on demand from the industry.	Board of Engineers Malaysia (BEM) as part of JKR	By 2025
	Resource development by establishing Centres of Excellence (CoE) and training centres on respective sectors is vital for upkeeping on the R&D of advanced technologies. The industry related centre of excellence and training centres include, but not limited to Construction Research Institute of	Construction Industry Development Board (CIDB) and JKR as part of Ministry of Works	By 2025

	Malaysia (CREAM) under Construction Industry Development Board (CIDB), Centre of Excellence for Engineering & Technology (CREaTE) under Jabatan Kerja Raya (JKR) in Melaka, Malaysia Global Training Centre (MGTC) under Multinational Corporations (MNC) in Cyberjaya		
	Assist in creating platforms and venues for technical and technology promotional events (workshops, short courses, seminar conferences and convention/expo/exhibitions) to facilitate exchange of industry practices, development of technologies and tools, exhibition of technological products and professional services. Ministry of International Trade and Industry (MITI) shall be the good platform to facilitate the international trade promotion with the aforementioned events organised.	Ministry of International Trade and Industry (MITI)	By 2025
	Suggestion of incentives (tax incentives) and fundings (e.g. HRDF) from governmental policies to technology adoption and voluntary trainers in digital training and certified courses for school students, undergraduates, post-graduates and working professionals. Economic Planning Unit (EPU) under Prime minister's Department and Human Resource Development Corporation (HRDCrop) under Ministry of Human Resources (MOHR) shall be the contact agencies in engaging on the policy of incentives and funding for HCRD.	Ministry of Finance, Economic Planning Unit (EPU), Ministry of Human Resources.	By 2025

Chapter 7 Conclusions

In conclusion, the Position Paper Committee has undertaken a thorough study into the intricacies of Construction 4.0 as the next technological leap for the industry. Their views and opinions on this very important topic on how to adapt and to adopt Construction 4.0 for the betterment of the construction industry, the engineering profession and all the stakeholders involved are presented in this position paper.

From learning in depth about smart construction and smart materials, to the intrigues of Big Data management and the importance of reliable connectivity, the scope is very wide highlighting the daunting and challenging tasks ahead. As to the now widely accepted mobile technology and remote control devices, there is much optimism to get full support from key stakeholders at the top (i.e. Government) right down to the lower levels (i.e. individual mobile device users). A number of local construction corporations (such as MMC-Gamuda) are already implementing the use of drone technology in their tunneling projects.

And finally to the idea of harnessing human capital as an invaluable resource to be utilized and trained up so as to get the right people for capacity building. This will require support from IHLs to train engineers, technologists and technicians to take up positions in the industry and playing key roles in the near future to capitalize on the path to adopting elements in Construction 4.0.

With the recommendations put forth in this paper for action plans and timelines to follow by key stakeholders among the identified Government agencies and key institutions and organisations, we are confident that the construction industry will thrive and will improve by leaps and bounds, once the concept of Construction 4.0 (in line with IR 4.0) are fully adopted and be supported by all parties concerned, be they at Government agencies and all relevant stakeholders in the industry.

Acknowledgements

It has been a long but fruitful journey which was embarked by the IEM Position Paper Committee on Revolutionizing Construction 4.0, with the final completion of the Position Paper. For that the PP Committee would like to give thanks and salute the contributions and support given by their represented Organisations, the invited members of IEM and invited experts in attending various webinars and technical meetings organised by the PP Committee in preparing this document. Our thanks also go to IEM President Ir Ong Ching Loon (also in his capacity as Chairman of Position Paper Coordinating Committee) for his trust and belief in this PP Committee to complete the task given and to deliver the final paper for deliberation and approval by IEM Council. Last but not the least, special thanks and appreciation go to the hardworking IEM Secretariat staff in charge of this PP Committee - their dedicated support and timeliness have been a God sent.