PERBADANAN PRODUKTIVITI MALAYSIA

CONSTRUCTION & BUILT ENVIRONMENT PRODUCTIVITY NEXUS

DIGITAL ROADMAP FOR SITES PREPARATION

PREFACE

Digital Roadmap for Site Preparation is developed as a guide to enable Government, industry and academia within the construction industry to respond to the rapid changes towards the Fourth Industrial Revolution (IR4.0). This roadmap is specifically drafted for site preparation in the construction industry. This document aims to provide guidance to digitally transform Malaysian construction, with focusing on activities within site preparation towards the next industrial revolution.

This document consists of Malaysia's construction industry overview, that includes current trends impacting today's construction industry and overview on activities within preparing sites for construction. This document is also highlighting 12 disruptive technologies identified by The Construction 4.0 strategic plan that can be adopted in the industry, pointing out examples on areas or activities where these technologies can be applied and pointing out solutions that are already available in the market and technologies that are under development that could be available in the near future.

This digital roadmap addresses 4 key enablers that support the Construction 4.0, which are People, Integrated technology, Governance and Economy. This document highlights what needs to be done on each enabler, enhancing them in preparing for digital transformation.

This document also provides guidance to the construction industry on disaster recovery plans should the industry be experiencing acts of nature or cyberthreats. The roadmap also provides guidance on how to get started with digital transformation, highlighting available grant and funding support provided by government agencies in launching the industry towards embracing digitalisation.

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

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CONSTRUCTION INDUSTRY IN MALAYSIA

CONSTRUCTION INDUSTRY OVERVIEW

Construction, defined by The United Nations as comprising economic activity directed to the creation, renovation, repair or extension of fixed assets in the form of buildings, land improvements of an engineering nature, and other such engineering constructions as roads, bridges, dams and so forth (*Directorate, O.S., 2001*).

Technically, construction is the organised interconnected process of assembling and installation of building materials and equipment using certain processes, in accordance with predetermined design, approved blueprints and specifications. It involves planned coordination to build a structure at a construction site and usually comprises teams that consist of 4 major disciplines which are management team, architects, engineers and contractors. In today's perspective, construction is a broad term. construction includes the processes or steps that involve in the creation of infrastructures, all projects and activities involve or associated during infrastructures service cycle which covers repairs and maintenance works, any works to expand, extend and improve the infrastructure and ultimately demolition, dismantle, repurpose or decommission when the infrastructures service cycle come to an end. All construction activities must comply with local laws and regulations which include building laws, labour law, safety compliance and environment compliance.

According to Malaysia Standard Industrial Classification (MSIC) 2018, Construction covers new construction, alteration, repair and demolition. Installation of any machinery or equipment which is built-in at the time of the original construction is included, as well as installation of machinery or equipment after the original construction but which requires structural alteration in order to install (*Malaysia Standard Industrial Classification, 2018*) Construction is expended to three separate divisions which are construction of buildings, civil engineering and specialized construction activities (*Malaysia Standard Industrial Classification, 2018, p.13*). Construction is further divided into subdivisions as tabulated below:

Construction of Buildings	Civil Engineering	Specialised Construction Activities
Construction of buildings	Construction of roads and railways Construction of utility projects Construction of other civil engineering projects	**Demolition and site preparation** Electrical, plumbing and other construction installation activities Building completion and finishing Other specialised construction activities

Source: extracted from Malaysia Standard Industrial Classification (MSIC) 2018

Examples of completed modern major construction in Malaysia's history are government complexes Putrajaya, The tallest twin towers in the world Petronas Twin Towers, The Exchange 106, KLIA, Penang second bridge and ongoing projects such as Bandar Malaysia, Forest City, Tun Razak Exchange, Pan Borneo Highway and MRL East Coast Rail Link.

Every construction project involves detailed steps or phases that compose a collection of activities within a project. As stated in National Construction Policy 2030, there are four important phases in the construction process, namely the pre-development phase including design and consultation, the development phase, the maintenance phase and demolition phase (*National Construction Policy, 2030, p.14*).

Although most construction projects differ in complexity, size and scope, nearly all follow the same completion phases. A well-defined process can inform stakeholders on critical decisions governing the project to assure higher chances of success along the way. These phases are also important so that the construction can be done in an agreed timeline, where cost is kept under control. Such activities within phases, to name a few are design, procurement, planning, site preparation, electrical installation, plumbing, heat and air-conditioning installation, inspection and many more. The construction industry consists of specialised people that work with each other in certain projects or development. They are project management, architects, designers, engineers, surveyors, contractors, sub-contractors, suppliers and labour force, each with specific roles and responsibilities, all working together to fulfil the needs of the client or owner of the project.

In Malaysia, the construction industry is governed by the Construction Industry Development Board (CIDB), a government agency under the Ministry of Works Malaysia. CIDB was established under the Construction Industry Development Board Act 1994 (Act 520) to regulate, develop and facilitate the construction industry towards achieving global competitiveness. The Board advises the federal and the State Governments, as well as other stakeholders on matters affecting or connected with the construction industry. Basically, CIDB is entrusted to enforce the Malaysia Standard mandated.

Construction sector brings an unprecedented impact on the world's economic development. High quality buildings and infrastructures, made possible by the construction sector, ensures a country to enjoy better social development including education, logistics transportation, industrialization, sustainable development and urbanization. It also plays a significant role in the economy of the country in terms of its contribution to revenue generation, capital formation and employment rates because most projects involve labour intensive processes. This extends to other sectors serving to bring about income and employment in the transport, commerce and manufacturing industries.

Construction is one of the prominent contributors to the economics of a country with regard to the gross domestic product (GDP), total employment and the socio-economic development of the country. Construction is the major market for building materials, products and services offered by other economic sectors such as manufacturing, finance and utilities. Due to this, the construction sector's health is sensitive, subjected to the performance of the overall business cycle. As such,

construction’s performance is one of the primary economic indicators closely monitored by the government to analyse the overall economic well-being of a country.

Report from Quarterly Construction Statistics First Quarter 2022 Department of Statistics Malaysia stated that value of construction work done even though contracted 6.1% to RM29.5 billion in the first quarter 2022 (*Department of Statistics Malaysia Official Portal*, 2022) still, a continued improving year on year basis, and the value is rather impressive considering amid ease of pandemic restriction after almost two years of movement control orders. On the other hand, GDP from construction in Malaysia increased to RM12922 million in the first quarter of 2022 from RM12565 million in the fourth quarter of 2021, the increment is mainly due to reopening of economic activities post covid-19 pandemic.

In the Twelfth Malaysia Plan (2021 – 2025), construction is one of the five economic sectors which continue to serve as drivers of economic growth, creating jobs for Malaysians and generating export earnings. In 2020, the construction sector contributes 4% to the nation's GDP (*Twelfth Malaysia Plan, 2021-2025, p. 49*). From 2016 to 2020, the construction sector contracted marginally by 0.7% per annum mainly contributed by sluggish construction activities during the Eleventh Plan period. However, construction is expected to expand by 4.2% per annum, driven by the civil engineering and residential buildings subsectors, supported by several government initiatives (*Twelfth Malaysia Plan, 2021-2025, p. 68*).

Today, the construction industry faces many challenges such as, rising cost of building materials, not many projects available on the plate with fierce competitions, skilful labour shortages, widening skills age gap, slow in adopting new digital technology due to lack of budget and resistance to change.

The Edge Market article dated Feb 5, 2022, reported that Malaysia’s construction sector has flourished over the last decade, when the industry benefited from numbers of huge infrastructure jobs across the country. But things have changed since 2019. Despite many proposals to roll out more megaprojects prior to that, fiscal constraints faced by the federal government, and later the Covid-19 pandemic, slowed down some plans and brought others to a screeching halt. The smaller pool of projects have also resulted in more competition, particularly when foreign players have entered the picture and as the industry faces other pandemic challenges, such as rising costs and labour shortages (*The Edge Markets, 2022*). Nevertheless, construction remains one of the biggest industries, contributing to the nation's GDP. With rapid advancement in digital technologies, the construction industry needs to start embarking into smart construction.

TRENDS IMPACTING CONSTRUCTION INDUSTRY

Construction industry is rather slow in adopting digital transformation as compared to other industries worldwide. This is likely due to the complexity of the construction industry itself, fragmented, often involving huge investment that there's not much left for innovation. However, construction industries must adapt and participate with the digital evolution that is now making waves at an exponential pace throughout every industry in the world.

A 2015 McKinsey Global Institute (MGI) analysis found that the construction industry was among the least digitized industries in the total economy across assets, usage, and labour (*McKinsey & Company, 2020*). In order to grow further, the construction industry must accelerate their adoption of digital technologies. Construction industry is considered as the backbone of other industries, it provides infrastructure for other industries to bloom. Thus, it is relevant for the construction industry to speed up with digital transformation. In construction perspective, digital transformation employs the potential of digital technologies to revolutionise their operations to become more productive, efficient, cost saving and safe. Digital transformation can be applied across management level and operations level, both on-site and office.

This next revolution in the digital age is called The Fourth Industrial Revolution (4IR). 4IR in a simpler word refers to how disruptive technologies like artificial intelligence (AI), automation, robotics, augmented reality (AR), machine to machine (M2M) and internet of things (IoT) are mixing with human physical lives, changing the way people live and work. Disruptive Innovation or Technology describes a process by which a product or service initially takes root in simple applications at the bottom of a market and then relentlessly moves upmarket, eventually displacing established competitors (*Christensen Institute, 2017*). A disruptive technology displaces a well-established product or technology because of its superiority. Examples of disruptive technologies of the 4IR are Artificial intelligence (AI), Internet of Things (IoT), Robotics, Virtual reality (VR), 3D printing or additive manufacturing, Smart sensors, Big data and predictive analytics, Augmented reality (AR), Data visualization, Cognitive computing, Location detection, Customer profiling, Blockchain, Quantum computing and Cloud computing.

Construction 4.0 is the construction industry version of 4IR. It represents the digitization and automation of the construction industry. Construction players are starting to embrace digitalization and cutting-edge smart technology to plan, model and build so that the work can be executed efficiently and effectively with minimum human error. For example, in industrial manufacturing, modules of prefabricated buildings are manufactured and assembled in the factory then delivered to the construction site as and when needed, incorporating latest technology with just-in-time manufacturing philosophy. This method saves time and money, which translate to shorter lead time in completing the project. 3D printing is also an example of technology adapted in construction 4.0, currently starting gaining traction around construction material preparation. Custom made parts which are not mass produced, are digitally designed using CAD software and printed for use in a specific build.

Digital technologies such as building information modeling (BIM), laser scanning, cloud computing, augmented reality and artificial intelligence (AI) are revolutionising how building structures are planned and designed. Augmented reality, virtual reality and 3D simulations enable people to view digital twins, experience and even get the real feeling by virtually walking inside and surrounding the building before construction work commences. Data can be collected, analysed and stored way before the start of the build. Another important data that can be analysed first hand is the human interaction with the building. By this, buildings can be designed as occupant centric as possible. Constructing structure and building will be faster than ever, with better quality.

Construction manufacturing started to follow trend in manufacturing sector using technology instrument systems to utilise sensors, robots and drones to aid production build through to completion. The use of these instruments increases output with better quality control, with minimal human error due to fatigue and repetitive work. Construction manufacturing also is now using Internet of Things (IoT) devices which can feed and receive real time data, making great use of software, sensors and other technologies that connect and exchange data across multiple devices via network and increasing production's speed exponentially.

Climate change also contributes to global trends towards digital transformation. The construction industry is urged to change the building methods in order to reduce carbon emissions. If not, the situation is about to become even more alarming over the forthcoming decades because of the increase in world populations, thus reducing carbon footprint is paramount.

In addition, construction waste is becoming a serious environmental problem world-wide, especially in third world countries with poor waste management and lack of enforcement. Digitalisation enables the construction industry to continue with the development of an effective waste management system and good recycling, repurposing policy.

The covid-19 pandemic recently has caused a serious labour shortage, especially skilled labour within the construction industry, which is slowing down productivity. Digital technology can address this issue with the use of good project management software, intelligent mobile apps, IoT-enabled machines, on-site sensors, Artificial Intelligence (AI), to name a few. These digital technologies reduce workforce workload, allowing them to empower their skills and focus on value added tasks.

As construction companies begin to embrace Construction 4.0, the scope for implementing construction technology and realizing its benefits will widen. Below are benefits of Construction 4.0 to construction industry as a whole:

1. Improving cost and time performance
   The 3D models created using BIM enables construction projects to be planned in detail, decision making can be done effectively, project inefficiencies, error and delays can be avoided or resolved earlier, and waste generated can be cut to a minimum. Automation saves time and money by reducing human error margins and increasing the rate of build. The construction industry will gain more by adopting digital tools.

2. Raising productivity
   Automation drives productivity as more of the routine work that took too much of workers time can now be delegated to machines. Automation can also produce higher quality results because human error is brought to a minimum, mundane and dangerous jobs can be done by the robots. Programming and monitoring prefabricated manufacturing processes using computing technology, production will become more consistent and efficient. Resources can focus on other important areas. Project management software aligns team player's workflow, making it everyone on the same page with no information lagging, thus enabling collaboration between members reducing time wastage.

3. Improving sustainability
   Digital twins, Artificial Intelligence, Augmented Reality and prefabrication help improve construction and operational efficiency to reduce waste, reduce carbon footprint, lowering energy use and the associated environmental footprint of construction activities.

4. Modernizing the industry
   The construction sector is typically regarded as manual labour-intensive sector, less attractive to female and younger tech savvy workforce. This sector needs to reinvest in workforce revitalized training initiatives by adopting digitalization. By embracing digitalization, the construction industry should be able to attract a new generation of skilled professionals. Modernizing processes through the adoption of innovative digital technologies can create new jobs and future-proof the industry.

5. Improving site safety
   Safety is a top priority in managing construction sites. Digitalization can lessen the risks at work sites. Automation is able to reduce physical risks to workers, and the use of smart surveillance, augmented and virtual reality removes the dangers of site visits. Through digitalization also, the flow of information at the site become almost instant, increased connectivity onsite means construction professionals are able to communicate more effectively and avoid unnecessary accidents.

6. Reducing inefficiencies and waste
   Prototypes and BIM 3D modeling enable decision making to be made earlier and avoid catastrophic error before a build begins. By doing this, it lowers the financial and reputational risks to building owners, designers and contractors. Testing 3D models enables designers and engineers to evaluate a building's effectiveness by examining its capacity to retain energy, survive adverse weather conditions and even future maintenance costs can be predicted. Digitalization minimizes the use of paper since all communications, reports can be done online and information can be stored in cloud storage systems.

It is without a doubt that technology will bring benefits to the construction industry. There are more advantages to incorporating technology in construction activities. However, albeit Construction 4.0 comes with many advantages, but some obstacles need to be tackled before it can be more extensively adopted. Below are challenges in implementing Construction 4.0:

1. Impact on workers
   A rise in automation could result in the diminishing of many traditional method, skilled jobs. Digital transformation is reducing dependency on people, some workers may lose their jobs. The role of architects, engineers and management may fundamentally change, compelling these professionals to focus more on working indoors and less on construction sites.

2. Start-up costs
   Some construction companies can find it difficult to embrace Construction 4.0 because of the start-up cost associated with it, they need to invest on new digital tools, technologies and may need to hire trainers to train their workers on how to use such technologies in their works. Whereas, initial cost might not be an issue for large companies, it will be unfair for smaller businesses and self-employed contractors unable to remain competitive in the industry.

3. Training requirements
   Emerging technologies require workers to go on a learning curve. Before digital innovation can be incorporated into the workplace, workers must be trained on how to use digital tools in their daily tasks. Digital literate workers will be in high demand, education institutions will need to reinvent their courses, as to generate a new breed of young technological oriented graduates.

4. Resistance to change
   Some people will find it difficult to embrace new digital technology since they are already comfortable with their proven way of doing work and completing the task, especially with older generation workers. Construction 4.0 revolution is inevitable, the company with the help from government agencies need to highlight the benefits of new digital technology in the construction industry so that no one is left behind.

5. Cyber Security
   With the advancement of the technologies in computing and network, they are more likely prone to cyber-attack. Cyber threats also grow in volume, sophistication and technique, finding ways on how to breach an organization's system unlawfully. Companies need to invest in good cyber security against unauthorised access to data centres and computing systems. A strong cyber security should be able to protect the company's system from malicious attacks by hackers, spammers designed to access, extort their operating system, and sensitive data that potentially disable or disrupt their operations.

   Cyber threat is a serious threat to almost all sectors. Interpol's ASEAN Cyber Threat Assessment 2020 reported that the first half of 2019 saw a rise in botnet infections, phishing scams, ransomware and other types of attacks. In fact, Malaysia ranked among the top three countries in ASEAN for mobile banking malware detection. In the US, growing ransomware attacks and their ransom value have had serious implications for critical industries and their impacted customers (*Eng S, 2022*).

These issues need to be addressed in parallel with digital transformation. Improvement and rectification can be done along the way because these issues will not be solved overnight, some may take years to improve. Construction industry

cannot afford to wait until all the problems being tackled then only start embarking into digital transformation. The advancement of digital technologies is so rapid that the construction industry needs to change now in order to stay competent in today's competitive market.

MALAYSIA INDUSTRY TRANSFORMATION PLAN

Following the adoption of digital tools in other industries, Nation's construction industries also must reshape itself in order to keep abreast with emerging digital technologies. Local construction industries need to use digital technologies to change a construction business model and provide new revenue and value-producing opportunities. They need to prepare themselves in moving to a digital business and utilising digitisation to improve construction processes. There are a lot of opportunities for digitalization at each construction phase and activities within. Minister in the Prime Minister's Department (Economy) Datuk Seri Mustapa Mohamed in a press release in 2021, said that Malaysia must seize digital transformation opportunities, as not only are they critical for Malaysia's economic recovery efforts, but they also enhance the country's future economic resilience (*MIDA, 2021*).

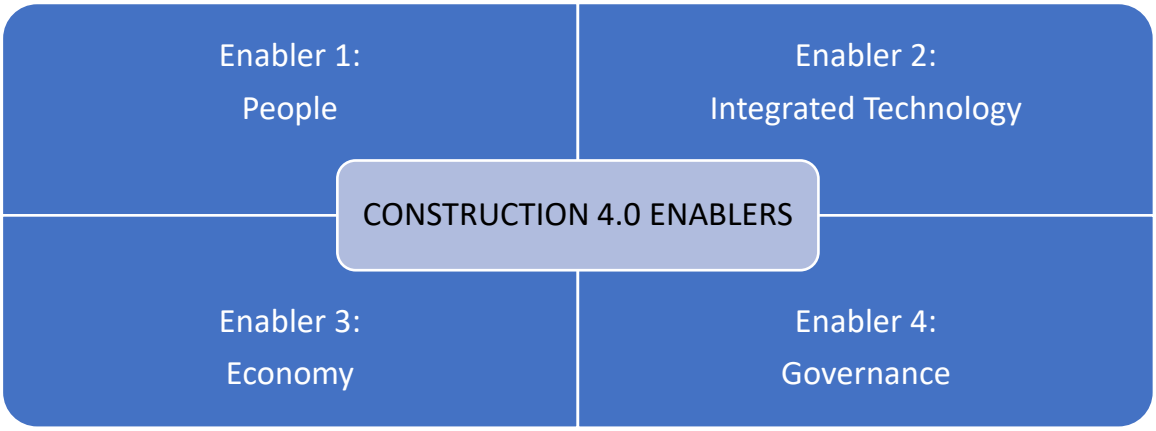
The digital economy is expected to contribute 22.6% of Malaysia's gross domestic product (GDP) and create over 500,000 jobs by 2025, said Science, Technology and Innovation Minister Datuk Seri Dr Adham Baba. Dr Adham said Malaysia has placed priorities on expanding the adoption of digital consumer tools, e-commerce and digital payments by attracting, training, and retaining digital talent, fostering digital entrepreneurial ventures, providing fast fibre optics and mobile broadband Internet access, as well as coordinating innovation between universities, businesses and digital authorities (*Ahmad, A. 2022*).

However, BURSA Malaysia Bhd chairman Tan Sri Abdul Wahid Omar in his welcoming address at the World Digital Economy and Technology Summit on June 28th 2022, has warned that Malaysia will lag behind if it is slow in adapting to the digitalisation of the economy. He noted that digitalisation has helped economies enhance competitiveness and productivity across a wide range of sectors. The use of big data and the rise of online platforms have accelerated this process over the past decade. He also said digitalisation had contributed to an increased regional and global economic integration, including through international capital flow and trade dynamics. (*Jaafar F., 2022*)

In order to embed digitalisation into the construction activities systematically, a proper roadmap is needed. The construction digitalisation roadmap serves as a reference material for construction practitioners to oversee construction digitalisation in Malaysia. The roadmap is called the Construction 4.0 Strategic Plan developed by CIDB. The main objective is to provide reference to local construction players in gearing up for the fourth industrial revolution (IR 4.0). The roadmap summarises the background, approach, strategies, personnel involved, tools, expected roadblock and action plan based on extensive industry consultations and accompanied with key

milestones at certain checkpoint. Digitalisation is about leveraging technologies to continuously improve business processes.

The implementation of the Construction Strategy Plan 4.0 will be driven by 4 enablers as below (*Construction Industry Development Board*. 2021):



The Construction Strategy Plan 4.0 has identified 12 main technologies categorised as disruptive technology which will change the future of construction landscape as below:

CONSTRUCTION 4.0 12 DISRUPTIVE TECHNOLOGIES
• Building Information Modeling (BIM) • Prefabrication and Modular Construction • Autonomous Construction • Augmented Reality and Virtualisation • Cloud and Realtime Collaboration • 3D Scanning and Photogrammetry • Big Data and Predictive Analysis • Internet of Things (IoT) • 3D Printing and Additive Manufacturing • Advanced Building Materials • Blockchain • Artificial Intelligence (AI)

Apart from Construction 4.0 Strategic Plan, construction players may also refer to Malaysia Industry Transformation Plan such as Malaysia Productivity Blueprint, Twelfth Malaysia Plan, National Construction Policy 2030, National Fourth Industrial Revolution (4IR) Policy and National Internet of Things (IoT) Strategic Roadmap as a guidance to embrace IR 4.0.

MALAYSIA INDUSTRY TRANSFORMATION PLAN	
Construction 4.0 Strategic Plan	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 revolution
Malaysia Productivity Blueprint	Developed to accelerate implementation of productivity improvement strategies, initiatives and programmes at the national, sectorial and enterprise level through 5 strategic thrusts which are talent, technology, incentive structure, business environment and productivity mindset
Twelfth Malaysia Plan	Known as 12MP, is a development roadmap for 2021 to 2025 presented by Prime Minister Datuk Seri Ismail Sabri Yaakob to achieve a prosperous, inclusive and sustainable Malaysia
National Construction Policy (NCP) 2030	NCP 2030's main objective is to digitalise the construction sector in Malaysia. NCP 2030 will accelerate technology adoption in all work processes including before, during and after construction
National Fourth Industrial Revolution (4IR) Policy	National 4IR. Policy is aimed at increasing the country's readiness in harnessing the potential of 4IR. The policy is set to transform Malaysia into a high-income nation driven by technology and digitalisation
National Internet of Things (IoT) Strategic Roadmap	The National IoT Roadmap aimed to make Malaysia the premier regional hub for IoT development and to leverage the industrialisation of IoT as a new source of growth for the economy
National 4.0 Industry Policy (Industry4WRD)	The Industry 4WRD policy focuses mainly on digitally transforming Malaysia's manufacturing sector and its related services to embrace industry 4.0. The policy envisions Malaysia as a strategic partner for smart manufacturing, a primary destination for high-technology industry and a total solutions provider for the manufacturing sector in the region
Malaysia Digital Economy Blueprint	Digital Economy Blueprint aims to bring up the country's level of preparedness in dominating the digital economy. It provides the foundation to enable digitalisation to thrive nationwide

SITE PREPARATION OVERVIEW

As described earlier, construction covers wide ranges of activities, in order to address discussion effectively, this roadmap will be focusing on site preparation, which per MSIC 2008, falls under specialized construction activities division. Site preparation includes activities of preparing a site for subsequent construction activities, including the removal of previously existing structures. (*MSIC, 2008, p.260*).

Construction site preparation works are critical for any project. Prior to beginning with construction projects, the site must be prepared to make sure the site is accessible, safe, free from any dangerous elements. Site preparation involves activities in prepping the site so that construction activities later on can be carried out with no complications. The site needs to be comprehensively assessed, planned and managed by professionals in making sure the site is prepared according to the specifications that have been set in the drawings and comply with a set of regulations instructed by local regulatory bodies. Often, land where the structure or building is going to be built is far from perfect. Some adjustment may be needed, the construction site may have obstructions like, vegetation that need to be removed, original building including its old foundation may need to be demolished, uneven or sloping ground that need to be excavated and filled, loose soil that need to be compacted and also underground services especially in cities need to be mapped and relocated, if necessary. These obstructions may create drawbacks for construction works and must be addressed before prior to main construction works. Site preparation allows any site complication to be identified upfront so that it can be rectified before construction begins. Failure to do so can result in project delays, pending permits, increase in cost and may bring complication to the overall plan of the project. Thus, it is important to prepare a construction site before the main construction activities start.

Site preparation has a number of important steps. These are initial works that need to be done before executing most construction works. Some of the activities can be done concurrently and some are not required, depending on the nature of the construction site. Typically, site preparation falls under the responsibility of the contractor of that project. Activities within site preparation are clearly defined in Jabatan Kerja Raya JKR's Standard Specification for Building Works, latest edition 2020. The document provides comprehensive works and requirements that the construction industry must comply with in construction projects. This Standard sets out the level of technical performance and characteristics required to promote an adequate, safe and well-maintained building. Listed below are key activities in site preparation where digital transformations are feasible, extracted from Standard Specification for Building Works, 2020.

1. Document management
   Site preparation requires a variety of documents to be prepared. Documentations like form of contracts, drawings, specifications and addendums, bill of quantities, printed forms, lab reports, permits for regulatory bodies and local municipal authorities and many more. These documents must be stored on-site for easy access. These documents are usually in hardcopies and stored in the site's office or in desktop or hard drives.

2. Site investigation
   The purpose of a site investigation is to determine the engineering properties of subsurface conditions of where the building of structure will be built. It includes the properties of soil, rock and underground water underneath the site and how these elements will affect the planned development. The information collected will be used to establish parameters for building foundation and substructure design. Site investigation involves geotechnical works and soil testing using in-situ equipment and also laboratory testing.

3. Relocation of existing utilities and services
   Construction sites could be sitting on networks of utility lines, pipelines that run underground especially if the construction site is in urban areas. A detailed utility map is needed to show the positioning and identification of buried pipes and cables so that the constructor can liaise with the respective utility service provider to relocate or reroute it away from the construction site. This can be done using underground utility mapping. Utility mapping is important to construction projects as it will avoid potential safety issues for the workers and people surrounding the site, and to avoid utility service disruption that can cause inconvenience and losses.

4. Demolition of existing structures
   Site preparation may involve demolition of existing or old structures including its foundation. Existing structures need to be removed from the site as if not doing so, it will disturb the foundation works of the new structure.

5. Site clearing
   A construction site needs to be cleared first in preparing the site for excavation and earthworks. Site clearing includes the removal and disposal of vegetations, rubbish, unwanted materials, debris, unwanted structures and waste generated from topsoil stripping and grading.

6. Site excavations and earthworks
   Excavation work is defined as the removal of earth, rock or other material in connection with construction or demolition works using tools, machinery or explosives to form an open face, hole or cavity *(Ismail, H.B., n.d.)*. Earthworks are the processes of moving soil or unformed rock which involves cutting, filling and compaction to reconfigure the topography of a site to achieve design levels (*Construction Site Earthwork Calculation*.,2012)

7. Material Procurement
   Procurement is the process of acquiring the required materials and services for the construction project. The materials and services required from registered suppliers are selected, ordered, invoiced and paid and delivered to the site. Procurement team is responsible for ensuring materials or services ordered are in accordance with required specification and quality within agreed pricing. Procurement team needs to be set up during site preparation prior to construction commences.

8. Assets management
   Site preparation involves the use of a fleet of equipment to clear trees, ground levelling and moving materials within the site, these activities require the use of heavy equipment such as excavators, backhoe, bulldozer, compactors and dump

trucks. All of this equipment must be monitored and maintained to ensure optimal use with a high productivity level.

9. Workforce management
   Site preparation requires a team of workers to work and operate the equipment. These workers need to be efficiently managed for ease of work coordination and work scheduling, safety and compliance. Workforce management is needed to enhance productivity of workers on site.

10. Environmental monitoring
    Noise, vibration, dust, water and air quality of a construction site need to be properly monitored and managed to protect workers, surrounding community and environment.

11. Site Surveillance System
    It is important for construction sites to have reliable surveillance systems to secure the site as well as to protect the expansive equipment, tools, materials and fuels against theft and vandalism as well as keeping both the public and workers safe.

Site preparation is a fundamental part of the construction process and it needs to be done correctly to make sure the site is prepared according to the requirements in project's blueprints. This is to prevent any complication that might arise during construction. Nowadays, construction sites are much easier to prepare due to the rise of digital tools that ease the processes within.

SITES PREPARATION DIGITAL TRANSFORMATION

Sites preparation utilises a wide range of equipment from heavy machinery such as excavators, bulldozers, backhoe for clearing, excavation, earthworks, grading and compacting to laboratory equipment for soil testing. Computer, mobile devices and data storage for communication, progress reporting and record retention. Laser for positioning, radar for soil utility mapping and many more. Site preparation has many ways to incorporate new technologies into the workflow and have many areas where digital tools can be used. Site preparation is the ideal place for construction players to kick starts on digital transformation in their projects.

The use of IoT sensors and smart machinery can improve efficiency on-site. For example, sensors that are placed in the warehouse can detect when materials are running low, integrate it with procurement management software, and automatically trigger a centralized system to place orders. Wastage produced at construction sites can be greatly reduced which leads to lowering carbon footprint. This translates to an increase in efficiency and productivity. A hardhat, a simple personal protective gear which has been protecting workers from head injuries, has been digitalised (*Biggs, J., 2021*) . Smart hardhat has the ability to monitor the wearer's location in real-time, able to make hands-free video and audio calls, even equipped with a proximity sensor to detect if the wearer is near to a dangerous situation, temperatures of detects a worker has fallen.

Construction Site Preparation Digital Roadmap serves as a guidance to construction industry players to undertake digital transformation in their activities as early as adopting the use of digital tools during site preparation stage, doing so will increase productivity throughout the next phases of construction with upholding safety and efficient cost control. Data collected from a construction site is very essential and critical to enable better project planning and allows the construction team to make critical decisions along the progress of the project. Thus, it is justifiable to start doing so at the early stage of on-site activities, which is site preparation.

THE CONSTRUCTION 4.0 DISRUPTIVE TECHNOLOGIES

YB Dato' Sri Haji Fadillah Bin Haji Yusoff has said in The National Construction Policy 2030 (*National Construction Policy 2030, 2022*) that the construction sector in Malaysia is experiencing a diverse and dynamic transformation ensuing the trends and disruptive technologies being introduced and adopted globally.

A disruptive technology is one that displaces an established technology and shakes up the industry or a ground-breaking product that creates a completely new industry. The term disruptive technologies was invented by Harvard Business School professor Clayton M. Christensen in his 1997 best-selling book, "The Innovator's Dilemma" (*Clark, P. 2014*).

Application of disruptive technologies in construction is broad. It can be adopted on the site as early as the site preparation stage. A cloud-based project management

system makes collaboration and communication easier and efficient. Augmented reality and virtual reality once developed for gaming, now is used to support real-time site inspection, and virtual equipment fittings on-site. Construction management software comes with transparency at all phases of construction projects since all information is recorded and accessible across team players. Building information modeling (BIM) creates a 3D model, allowing users to simulate design and changes using data gathered from multiple disciplines.

Simple yet advanced technology like GPS tracking, tracking software helps to monitor assets and delivery lead-time. Drones are now used to do surveying, aerial photographing during site preparation, mapping, inspection on areas inaccessible to humans, security and even transporting materials. 3D printing set on-site, able to print urgently needed parts without having to wait longer lead-time ordering it from the vendor. Artificial intelligence (AI) and machine learning are able to collect data and use it to predict outcomes, improve safety, and are able to do jobs on dangerous sites autonomously. Robotics can be used to perform difficult, monotonous jobs, improving quality and speed. Blockchain electronically stored ledger, contractual processes and paperwork with utmost data security.

Digitalisation and disruptive technologies are enabling data-driven practices on managing construction projects at the same time increasing workforce productivity and safety. For example, smartphones allow projects to be managed remotely, managers just need their smartphone, installed with project management apps, backed by strong internet connectivity.

The Construction Strategy Plan 4.0 has identified 12 disruptive technologies under Strategic Thrust 3: Smart Integrated Technologies, Innovation and Infrastructure, one of the objectives is to enhance collaboration of disruptive technology and data center repository. The use of these technologies will alter the future of the nation's construction landscape. Below are 12 disruptive technologies:

1. Building Information Modeling (BIM)

National BIM Steering Committee (2013) defines BIM as Modeling technology and associated set of processes to produce, communicate, analyse and use digital information models throughout the construction project life-cycle. BIM is characterised as a data-rich, object-oriented, intelligent, and parametric digital representation of a building's facilities. The characteristics of BIM have led to the development of independent models which can fulfil the needs of stakeholders in extracting and analysing all the information required in the supply chain. Overall, BIM is a model-based framework for multidisciplinary collaboration that encompasses design, analysis, construction, operation, and data management (*CIDB BIM Guide 5, 2019*).

Building Information Modeling (BIM) is the highly efficient dynamic collaborative 3D model process that allows architects, engineers, project management and contractors to plan, design, visualise, run simulation, analyse data, perform cost estimation and construct a structure which consist of all the information mentioned within one 3D model. BIM manages not just simple geometric information on construction elements but all of the information on a project, including documents, technical data, material

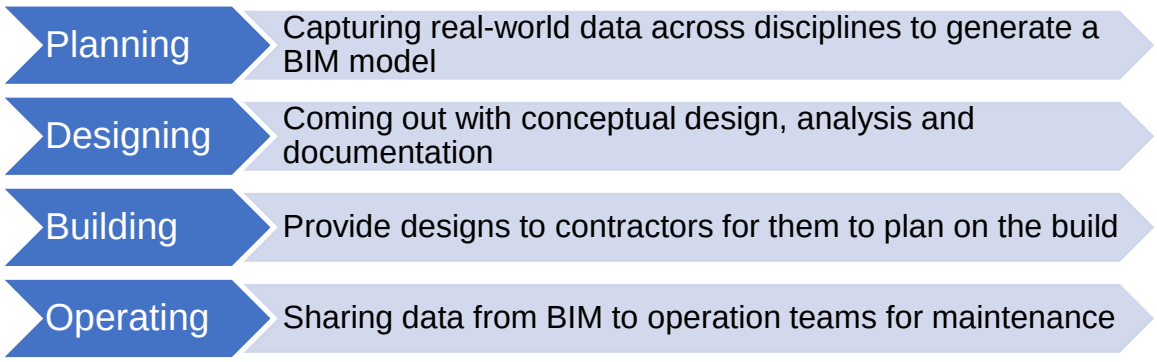
specifications and cost. BIM can also be used by operation and management of the building upon the completion stage. The information within BIM is useful for maintenance work of the building.

BIM consists of elements, the components that formed into a BIM model. These geometric components in 3D, store various collaboration data from architects, project management, engineers, and contractors. The changes in the elements will be visible to everyone in the team. The strength of BIM is its ability for collaborative working and data sharing across different disciplines.

BIM is a process used to design and construct infrastructures. The process involves different design tools and methods with the objective is to make every stage of construction and design efficient, cost-effective and safe. BIM is more than just a design software, BIM is more than that, BIM is a comprehensive process for creating and managing all of the information with regards to the particular project. BIM generates building information models, which contain extensive digital descriptions for every aspect of the project. BIM has features that are very useful for the design and at the same time facilitate project management. BIM improved project scheduling by allowing design and documentation to be done at the same time. BIM provides better coordination and clash detection, a feature that detects inconsistencies in the geometric designs of the various features such as structure, mechanical equipment, electrical and other disciplines in constructing a building. BIM improves productivity by streamlining everyone in the construction team on the same platform, productivity can be further improved with the integration of BIM and modular construction. BIM mitigate risk and reduce cost, with proper planning, unexpected increase in cost and risk can be avoided. BIM improves onsite collaboration and communication; BIM ecosystem allows teams to share project models and coordinate planning ensuring everyone has insight of the latest status of a project. BIM has a feature that can perform cost estimation at the early stage of the project. BIM allows project visualisation during the pre-construction stage, which gives greater overview from the beginning. BIM improves safety by highlighting potential safety hazards upfront, BIM also improves the overall quality by allowing designers to virtually construct the building which enables them to identify any irregularities upfront. BIM also can be used as facilities management after project completion (*Hall, J., 2018*)

In modeling, architects use BIM to make and experiment and identify potential problems with the detailed 3D model of the structure. All information about the project is stored in cloud-based software that team players can have access to. By using the models and data collected, architects are able to come out with the most efficient, cost-effective construction workflow for the project. The constructor will then construct the project and be able to relook at the BIM model and adjust as needed. Everyone who has access to the BIM model will be made aware of the changes. After the completion of the project, BIM can be passed over to clients for maintenance and future renovations.

The processes in BIM involve these steps:



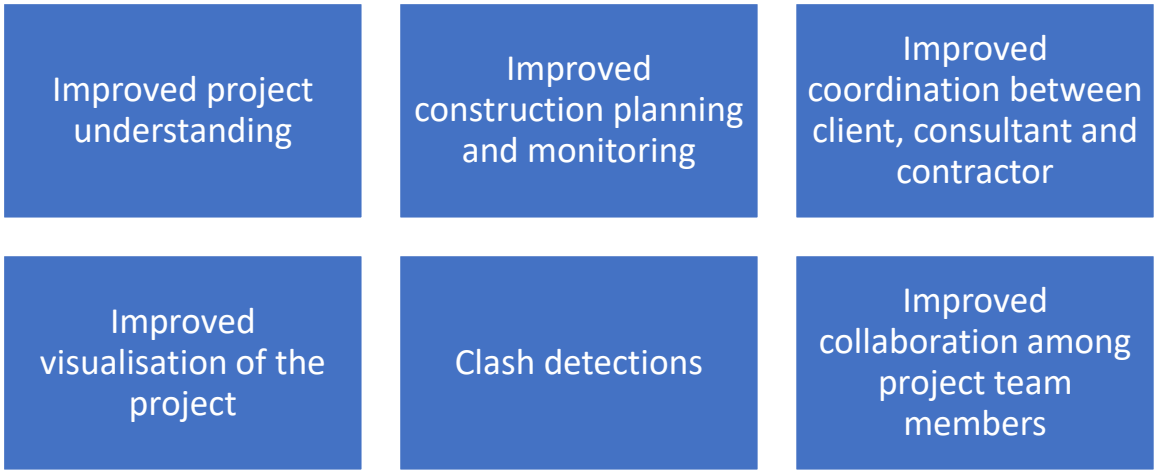
The use of BIM in the construction industry is still progressive where it will take some time for the industry to reach full collaborative integrated level. BIM is categorised by maturity level based on technological progress and level of information sharing across different disciplines that involve in one particular project. Level that ranges from 0 to 3. The level indicates how BIM is used and to what extent information is shared and managed throughout the project.

Construction Industry Development Board (CIDB) has identified Building Information Modeling (BIM) implementation in Malaysia's construction industry through stages as below:

Building Information Modeling (BIM) Stages		
Level	**Business Model**	**Description**
0	Manual and Isolated	The simplest form of BIM, with no collaboration, 2D CAD is used mainly for use within one discipline. Distribution by paper and digital prints
1	Partially Collaborative, single disciplinary modeling	Typically, it consists of a combination of 3D for conceptual work, 2D for drafting and statutory approval and information. Data is managed and use within one discipline
2	Collaborative, multi-disciplinary	Each discipline uses its own 3D CAD models but not on a single, shared model. However, collaboration occurs when design information is shared via a common file format. Each discipline will then be able to combine external data into their own model to create a federated BIM model
3	Integrated, fully collaborative	Also called as Open BIM, where every discipline is using a single, shared project model which is stored in model server or other network-based technology, usually in cloud-based computing. Level 3 allows all disciplines to work on the same model simultaneously which eliminates clash of information. Advantages of using level 3 BIM are simplifying communication, allowing collaboration between team members with seamless information sharing

A survey conducted by CIDB showed that BIM in Malaysia is mainly used among professionals at the design stage. Architects are the leading adopters of BIM with 42%, followed by civil engineers at 21%, contractors at 13% and quantity surveyors at 12% (*Sarah, 2018*)

Based on CIDB BIM Project Guide, A Guide to Enabling BIM in Projects, 2019, has identified 6 top benefits of BIM implementation for construction organisations which are:



Examples of BIM software market are Autodesk's Revit, Autodesk's AutoCAD and AutoCAD LT, Graphisoft ArchiCAD, Vectorworks Architect, Tekla Structures, SketchUp, Navisworks, Aurora and STAAD.Pro.

It is without a doubt that BIM is a disruptive technology that has revolutionised the construction industry at unprecedented level, by simplifying the process of building design allowing collaboration and sharing of information between multidisciplinary teams with one common goal. BIM is growing, and keeps on unfolding new trends by enabling other disruptive technologies to be integrated with BIM, to become a much more powerful tool for the construction industry. BIM can be integrated with drones, Artificial Intelligence, 3D laser scanning, Internet of Things (IoT), Big Data, Augmented Reality and Virtual Reality, cloud computing, 3D printing, prefabrication and modular construction.

2. Prefabrication and Modular Construction

Prefabrication refers to the manufacturing of construction objects off-site, usually in a factory away from the construction site, transported to the site and assembled on-site. The prefabricated objects can be customised for that particular construction or building. The prefabricated objects may include doors, stairs, wall panels, floor panels, the entire bathroom or room.

Modular construction refers to a process in which a building is constructed off-site in modular form. Buildings are manufactured in modules going through assembly lines in a factory, under controlled parameters, using the same materials and design to the same standards as conventional on-site build. These modules will be assembled on-site to become a complete unit of the structure of the building. The structure will have the same standards and specifications just like the one built on-site. The controlled process in manufacturing allowed modules to be built faster, create less waste and minimise construction error.

Prefabrication and modular construction are suitable under these conditions; The construction site is located in remote areas or highly populated cities where site area is limited. The building elements are complicated, require a special manufacturing process. The building is made of multiple similar units like hotel rooms, or dorms and the building is urgently needed, thus needing to be built in a tight schedule.

Covid-19 outbreak that started in Wuhan in 2019 has caused existing hospitals not able to cope with the influx of patients. This has triggered the Chinese Government to build two hospitals in Wuhan in less than two weeks. This engineering feat was possible due to the prefabrication and modular fabrication technology, which allows buildings to be completed in a fraction of the time as opposed by traditional methods (Tobias, M., 2021).

There are many benefits associated with prefabrication and modular construction such as quick turnaround time, where construction can be completed within a shorter period compared to conventional methods, all materials required for prefabrication or modular are properly calculated, thus minimising material waste. There will be increased productivity because fabrications are done in a controlled environment, not affected by the weather, so workers can work without interruptions. In addition, safety will be improved.

Conventional construction methods require a longer timeline because it follows a linear approach, where many activities are dependable on earlier tasks. Earlier tasks need to be completed first then only possible to proceed with the next tasks. For example, structural components cannot be installed until the groundwork and foundations are completed. In turn, building envelope components cannot be installed without the underlying structure. With prefabrication, structural components and building systems can be manufactured offsite, even if the groundworks and foundation are not complete. In other words, prefabrication transforms construction from a linear process to a parallel process (Tobias, M., 2021).

Master Builders Association Malaysia (MBAM) president Tan Sri Sufri Mhd Zin notes that the industry's response to modular construction systems has been pretty much neutral before and during the pandemic. However, he sees more developers and contractors beginning to adopt such systems in view of a possible shortage of foreign labour in the country (*Lee, R., 2022*).

The commonly available modular construction system in Malaysia is the two-dimensional precast component, which is cast off-site, then transported and installed at the final location. There is also the three-dimensional volumetric precast component, which is completely assembled at the factory with almost 80% of finishing trades, which will be transported to and assembled at the final location. The adoption

in the country is limited to concrete prefabricated bathroom units and steel container conversions to cabins (*Lee, R., 2022*).

Real Estate and Housing Developers' Association (Rehda) Malaysia president Datuk Soam Heng Choon observes the same trend, but believes property developers' interest in modular construction systems has increased (*Lee, R., 2022*).

The challenges that impede the adoption of modular construction systems include; The lack of expertise from the design stage to construction and installation. Economies of scale as a way of keeping costs down are particularly challenging while the current input cost is still high. The restrictive Uniform Building By-Laws (UBBL) 1984 (a building code that provides the minimum requirements for the control and construction of street, drainage and building in local authorities' areas) (*Lee, R., 2022*).
Examples of a modular construction company in Malaysia are:

a. Red Sea Johor / Selangor under Red Sea International
   Provide in-house design, engineering and construction of housing, multi-storey products and hotels.

b. Modular Construction Services (M) Sdn. Bhd,
   Supplying falsework and formwork equipment.

c. Solid Horizon Sdn. Bhd.
   Specialises in converted container

d. Petra Modular (M) Sdn. Bhd.
   The first modular manufacturer to obtain Intelligent Building System (IBS) impact certification.

3. Autonomous Construction

Autonomous construction is the use of robotic systems on construction sites. Robotic systems are able to reduce construction time and increase safety by replacing workers in dangerous operations. The autonomous vehicles operate using LiDAR sensors, detecting obstacles and global positioning system (GPS) technology. This allows the vehicle to know its exact location on site and can be interconnected to other autonomous vehicles, communicating with each other for coordinated action. Such technology already exists in car passenger applications but maybe still far to reach because of the nature and complexity of the construction site. But there is now an effort to retrofit existing construction vehicles by adding sensors, cameras, GPS and Wi-Fi to transform ordinary vehicles into semi-autonomous. Examples of semi-autonomous technology that are already available in the global market are (*Hayes, M., 2021*): Bauer subsidiary Rammtechnik's Operation Control for piling rigs. Caterpillar's Cat Command remote-control stations that give operators to control their machine remotely. Jailbot, a semi-autonomous mobile drilling robot, specifically engineered to

drill ceiling holes. It uses BIM data to accurately locate itself within the building before drilling.

Benefits of autonomous construction are greatly improved safety and working conditions. Able to be operated at dangerous construction sites for example deep mining and tunnels. Greater productivity and efficiency and able to tackle the shortage of highly skilful workers. However, the start-up cost may be high and smaller companies might not be able to justify it.

According to Works Minister Fadillah Yusof, with the anticipated introduction of robotic applications at construction sites by 2030, the industry will exponentially reshape the way infrastructure, real estate and other built assets are designed, constructed, operated and maintained (*Free Malaysia Today, 2021*).

4. Augmented Reality and Virtualisation

Augmented Reality (AR) is the integration of digital information with the real-time environment of a user. AR allows users to experience a real-world environment with generated information superimposed on top of it. AR is able to blend digital and 3D components with the individual view of the real world. AR can be experienced using smartphones or glasses.

Virtual Reality (VR) is different from AR. VR is a virtual environment that is artificially created using software and displayed to users through a headset. AR uses an existing real-world view and blends virtual information on top of it, while VR totally immerses users into the virtual world.

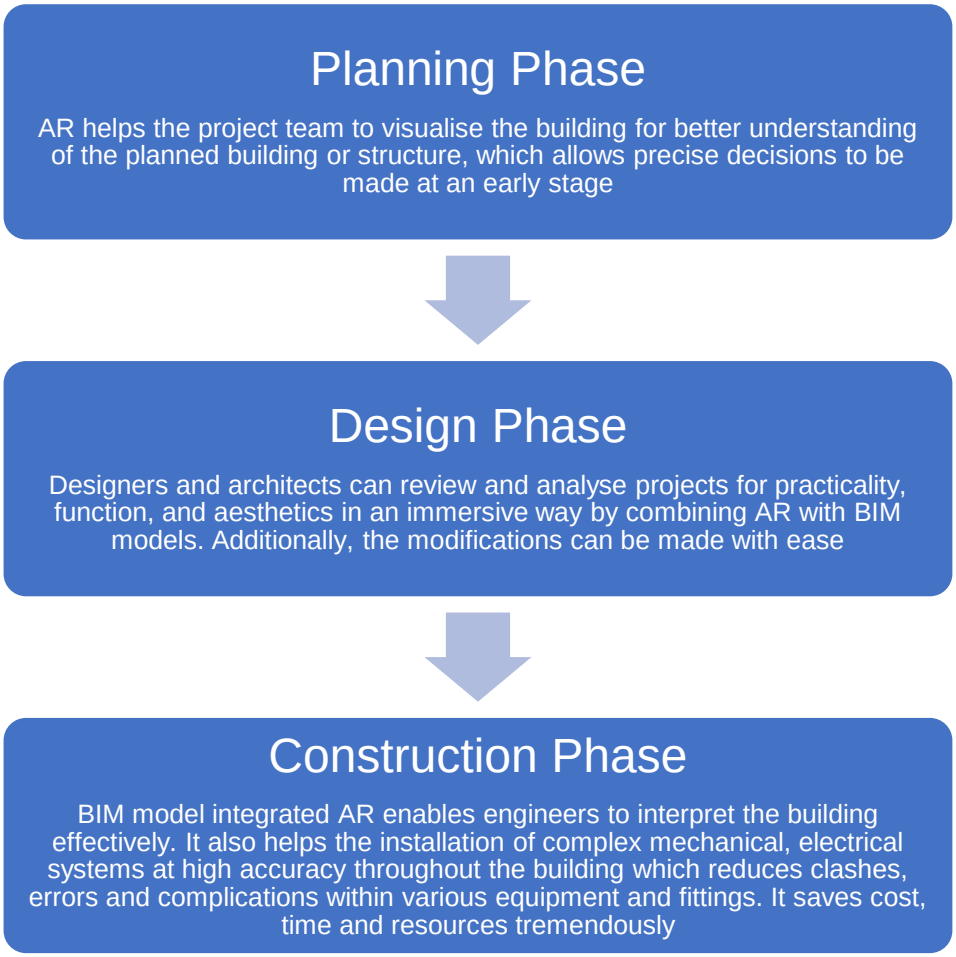
For comparison, VR is a digital environment that mimics the real environment, while AR is digital elements layered on top of the real environment. Both AR and VR are now already finding their way in the construction industry. They are indeed very useful in construction. For example, VR can be used as a simulator, training modules that resemble real-world environments and conditions that permit the user to conduct training for new staff and conduct virtual walks off-site. It can also be used to generate interactive, rich detailed 3D models of the elements as visual representations of the building for potential clients. Collaborating with BIM allows digital representation of elements in 3D form for more accurate interpretation.

Overall, AR can be used in the construction industry to enhance efficiency, improve safety in construction sites, optimize teamwork and collaboration and training. AR allows engineers to measure, confirm with the specification of equipment installation, and the placement of the equipment, whether there is a clash or conflict with other equipment as they walk through an empty building. Problems or issues can be detected and resolved at an earlier stage saving time and cost. Management is able to monitor the progress of the building off-site. AR and VR also can be used as visual representations that generate real life viewing to potential clients or stakeholders. AR can be integrated with BIM to provide an accurate overview of the project in 3D model. Suppliers are also able to harness the power of AR through AR product viewing which helps the procurement team or technical team to overlay the virtual equipment on the

actual site to look for product's form, fit and function before deciding on purchasing such equipment.

The integration of BIM with AR provides a collaborative user experience by allowing users to view BIM 3D models via AR smart glasses or via smartphones or tablets. Project data, information can be managed and shared swiftly with the rest of the project team. AR can be leveraged to visualise BIM models for the project team to make decisions, take necessary actions thus improving design process deliveries and quality of the work.

The advantages of integrating AR with BIM are substantial because it empowers projects deliverable at every construction phase.



Examples of AR technology that are developed to be used in construction and can be found in the global market are Akular AR, GAMMA AR, Arvizio, ICT Tracker, The Wild and VisualLive.

In Malaysia, A team from MMC Gamuda KVMRT (T) Sdn. Bhd. (MGKT) has developed an AR app called BIMAR, that produces virtual 3D overlays of design and construction elements which are overlaid on a real-time screen camera captures of the worksite. BIMAR is developed in-house using BIM, Unity and Apple software. The BIMAR app has been customised to enable rapid, large-scale roll-out across mega infrastructure

projects, and enhanced with other digital and cloud enabled functions (Free Malaysia Today, 2020). The app greatly minimises errors while saving time and improving the accuracy of their construction validation during its test implementation for the works on the MRT Putrajaya Line Project (*Free Malaysia Today, 2020*).

5. Cloud and Realtime Collaboration

Cloud computing is considered the foundation of the construction digital revolution since the construction industry involves sharing of information across stakeholders, engineers, architects, general contractors and subcontractors. These people do not sit in the same office. Often, the workplaces are far from each other making collaboration a challenge. Since collaboration is key to the success of a construction project, the adoption of disruptive technology like a cloud is important. Before this, information was shared back and forth using emails, and up to some extent it became tedious work. With the cloud, it is possible to access information anywhere and anyone among team members. The cloud-based system enables collaboration in the construction by streamlining project coordination and scheduling, file storage and sharing, improved document security, data processing can be done faster and simplifies communication across team members.

In Malaysia, cloud-based collaboration has been used in major construction projects, for example Malaysia's Mass Rapid Transit Corporation (MRCT) has designed and built Klang Valley Mass Rapid Transit (KVMRT) SST line using Microsoft Azure Package. The project's 1500 engineers and construction managers were using Azure Virtual Machines, Azure Storage, Azure Active Directory and Azure Cognitive Search from Bentley Systems to collaborate by using a connected data environment. This reduces error and design conflicts, improve collaboration efficiency by 35% (*Microsoft, 2020*)

Another example of the use of cloud technologies in Malaysia is Permodalan Nasional Berhad (PNB) which boosted its digitalisation by using Alibaba Cloud. PNB now is in the midst of addressing its operational challenges through the utilisation of premium support services and Elastic Compute Services (ECS) offered by Alibaba Cloud (*Kumar, A, 2022*).

Examples of the cloud service providers besides Microsoft Azure and Alibaba Cloud are Oracle Primavera Cloud, TM One Collaboration Services, Sage Business Cloud, Amazon Web Services, Google Cloud, TIME Cloud Services and Maxis Right Cloud.

6. 3D Scanning and Photogrammetry

3D Scanning is a means of using the laser to map an area with high accuracy. 3D Scanning is also called high definition surveying and uses lasers to capture detailed data such as dimensions and their connection to one another. The process of scanning uses a specific technology known as LiDAR (Light Detection and Ranging). A point cloud image is produced that replicates the scanned objects with a high level of accuracy. The data is then exported to BIM modeling and CAD programs to develop 2D CAD drawings or 3D models. The models and drawings created using point cloud data help Architecture, Engineering and Construction industry to plan, design and build effectively and accurately.

3D laser scanning is used in construction for mapping existing sites, design validation, progress evaluation, 3D building model creation, coordination and collaboration on-site and matching project plan with output. Advantages of using 3D laser scanning are improving quality and accuracy, providing immediate real-time information, cost savings, reducing manual labour and streamlining coordination.

Photogrammetry is a form of 3D scanning that uses photographs and triangulation to create an accurate model of a site or a structure. Photogrammetry scanning can be performed at close range, via satellite or from air using a drone. During construction, photogrammetry can be used to monitor progress and analyse any problems that arise as they occur (*Phan, A., 2018*).

Malaysia has a few companies that provide 3D laser scanning and photogrammetry services such as, GLE Plant Logic Engineering, IPM Professional Services Malaysia, Aries Marine and Otimo Energy.

7. Big Data and Predictive Analysis

The construction industries produce a huge amount of data every day. Sometimes it is difficult to retrieve relevant information due to the large quantity of data stored in various computers in various formats like docs, sheets, PDFs, videos and CAD. On top of that, physical data like drawings, plans, bills, tenders, checklists and many more are stored in files at site and office. Big data is generally a large quantity of data stored in a single source. Big data gathered data and analysed data from unstructured sources such as cameras, sensor equipment and smartphones. Big data can be used in construction planning and estimation, building design and modeling, building construction, maintenance and facility management.

Real-time data analytics capable of updating the maintenance team if any preventive maintenance needs to be arranged to extend asset’s performance and durability. Predictive analytics is a new advanced form of data analytics, it will help the construction industry by using data to identify trends and help the industry to identify potential problems upfront. Predictive analytics is a process that uses existing and past data to reveal patterns, trends and relationships. Predictive analytics are able to anticipate future problems by probability. The construction team should be able to see the potential issue and choose when to address the issue based on their potential

probability. Predictive analytics use together with big data allows the construction industry to anticipate problems, reduce costs, mitigate risk and make better decisions.

Universiti Teknologi Malaysia (UTM) senior lecturer of the Faculty of Built Environment & Surveying Dr. Zafira Nadia Maaz believes that the deployment of big data analytics could help in predicting trends, prices, scenarios and many other types of information that could benefit various industries in the long run, even the construction industry (*Focus Malaysia*, 2020).

Examples of predictive analytics software available in the market are AVEVA Predictive Analytics, BIM 360 Construction IQ, IBM SPSS, 6sense, Radius, IBM SPSS Statistics and Appier.

8. Internet of Things

The Internet of Things (IoT) describes the network of physical objects that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. These devices range from ordinary household objects to sophisticated industrial tools (*Oracle, 2022*).

IoT in construction usually involves the use of internet-connected sensors which are located around construction sites or in the form of wearables to the workforce. IoT devices are capable of collecting data about activity, readings, performance and condition of the building and the wearer. This data is sent to a central database computer to be analysed. IoT applications in construction are huge. For example it can be used for real-time site monitoring, machine control, construction safety, equipment maintenance, tracking labour working hours, and project management. The application of IoT in construction has huge implications for productivity, cost reduction, safety and security of construction projects.

Application of IoT enabled devices in the construction industry is extensive, transforming the industry into a smarter, highly efficient and safer work environment. Safety can be improved at construction sites by using IoT smart sensors. IoT wearables can be incorporated with personal protective equipment such as hardhats, smartwatch, smart boots or even clothing. These devices use wireless connectivity such Wi-Fi, Bluetooth, or RFID to transmit data to the dashboard or mobile app. These wearable devices help to detect dangerous elements, prevent accidents and monitor worker’s vital signs. Workers' heartbeat, body temperature and other vital signs can be tracked thus alerting management should anything happen to the workers. Sites can be monitored using IoT cameras, sensors to ensure a safer working environment, noise level, dust and vibration can also be monitored using IoT enabled sensors.

Nowadays, the use of IoT devices is becoming the norm in the construction industry. With the emergence of new technologies in the market, expected IoT devices to be integrated with other technology, bringing huge benefits to the construction industry.

9. 3D Printing and Additive Manufacturing

Additive manufacturing is the industrial production name for 3D printing, a computer-controlled process that uses CAD software and data to create three-dimensional objects by depositing materials in layers. 3D construction printing (3DCP) is a new construction method that builds buildings by depositing materials like concrete, plastic, polymer or metal in layers using dedicated software and hardware. 3D construction printing is expected to save time, effort and material because the frame and walls of the building can be printed either on-site or off-site in modular form. Workers just need to install fittings like windows which also can be printed, plumbing and electricity installation. 3D printing is ideally used together with Industrialised Building System (IBS) modular construction. 3D printing of preconstructed parts is done and assembled in the factory. It will shorten the supply chain by manufacturing components from a digital design model with minimum human intervention.

Some of the 3D construction printing available in the market are Icon Vulcan, PERI 3D, BetAbram P1, COBOD BOD2, Maxi Printer, CyBe RC 3Dp, MudBots and Total Kustom StroyBot 6.2.

While in Malaysia, KA BINA Consultancy Group Sdn Bhd is the country's first 3D printing hub for construction. KA BINA is the sole distributor of COBOD 3D printer construction machines for Malaysia and Singapore. At the time of writing, KA BINA itslef is equipped with 2 units of gantry system COBOD BOD2 which are able to print 3 Axials, X, Y and Z axis. KA BINA sells and leases printers, provides consultancy and training on 3DCP technology.

In 2021, Sarawak Consolidated Industries Bhd (SCIB) purchased 3D construction printers and design software from COBOD. SCIB plans to utilize 3DCP as part of its expansion plan. SCIB group managing director and chief executive officer, Rosland Othman believes that having 3DCP at their disposal will allow them to reduce the construction period for their projects, therefore allowing them to complete the projects in a shorter period (*NST Business, 2021*)

10. Advanced Building Materials

The advancement of materials science technology has led to the growth of new types of materials for the construction industry. Advanced building materials offer superior engineering properties over conventional traditional materials because advanced building materials are developed with extensive research. New legislation and the increasing need towards sustainability, green technology with minimising carbon release to the atmosphere fuels the development of new construction materials. Innovative synthetic materials are being developed, they are lighter, stronger and more environmentally friendly than traditional materials. For example, it is known that cement cracks due to its poor tensile strength when exposed to elements over time could impose structural problems by allowing water to get into the crack and begin to weaken the strength of the concrete. There is a new technology called self-healing concrete that fixes its cracks autonomously by adding additive and water-activated bacteria. There are also advanced building materials which incorporate traditional

materials like straw, mud and waste products into modern construction materials as an effort to reduce carbon footprint.

Below are examples of new materials that could change construction industry for the betterment of society (*BigRentz Inc, 2018*):

a. Self-healing concrete, a concrete with water-activated bacteria that produces calcite to heal cracks.

b. 3D graphene, a lightweight 3D-printed carbon porous foam, can be used for vehicles and construction of skyscrapers.

c. Aerographite, an atom-made material that grows stronger when compressed, can be used for aviation and aerospace application.

d. Laminated timber, a prefabricated timber with higher water resistance and strength over traditional wood, can be used for construction of skyscrapers.

e. Modular bamboo, a low-cost material that can be extended into different shapes and structures. Potentially be used for earthquake resistant buildings and steel bars reinforcement.

f. Translucent wood, a better insulation color-stripped wood with high strength and biodegradability. Can be used for window glass replacement and aesthetic features.

g. Light-generating concrete, a non-flammable concrete embedded with minuscule glass balls to reflect light. Can be used in signage, underground lighting, safety marking.

h. Microbial cellulose, a mixture of bacteria, yeast and microorganism able to form layered structures. Can be used for signage and facades.

i. Aluminum foam, lightweight gas-filled pores with high strength-to-weight ratio can be used for cladding and decorative materials.

j. Nanocrystal, a crystalline nanoparticle that allows light to pass through while blocking heat. Allows controls of the amount of light that pass through windows.

k. Wool brick, fused with wool and seaweed polymer and offers 37% more strength than earth brick.

l. Pollution-absorbing brick, double layered insulated brick able to filter 30% of fine pollutants and 100% of coarse pollutants.

m. Hydroceramics, a self-cooling membrane made of ceramic, fabric, and hydrogels that can absorb up to 400 times its volume in water. Potentially cools building temperature.

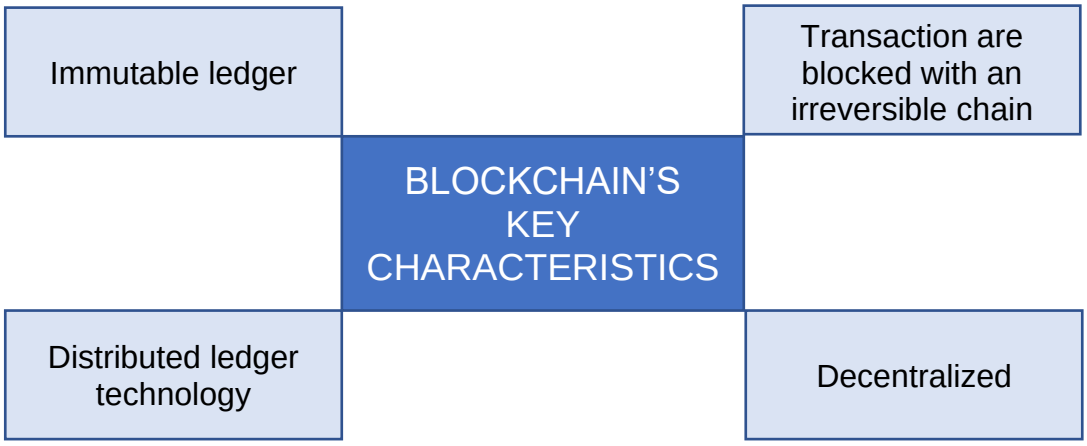
n. Biochar, a waste product material with high insulation qualities produced when tree debris is burned into pyrolysis kilns. Provide better buildings' thermal regulation.

o. Bioreactors, an Algae-infused building panel that can undergo synthesis to create energy.

p. Power generating solar cells, pushes non-visible wavelengths of light to solar cells embedded at the edges, building components that are potential to generate energy.

11. Blockchain

Blockchain is a distributed ledger technology (DLT) that stores various types of data. Encrypted blocks of digital data are stored and linked together to form a chain. Each block contains a record of exactly when it was created and any changes made are recorded, producing a complete timeline history. Blockchain data cannot be corrupted, lost or changed. Digital ledgers in blockchain are shared by simply distributed to members who have permissioned access to the network instead of copied or transferred. The shared digital ledger is decentralized, instead of being maintained, managed and stored in one specific location. Decentralization allows real-time access across multiple users at different locations. All modifications or changes made to the data are recorded in real-time, creating a completely transparent and accountable transaction. Essentially, it creates a chronological immutable single source of truth for the data.



When used together with BIM, blockchain can create a single source of truth for all aspects of a construction project to deliver transparency and trust (*Hazlegreaves, S., 2022*). Among the benefits of blockchain to the construction industry are predictive asset maintenance, smart contracts that stay on track, proactive third-party oversight, accelerated payment processing, instantaneous collaboration and streamlined supply chains (*Stannard, L., 2021*).

The government has started using blockchain technology during the Covid-19 pandemic, The Ministry of Science, Technology and Innovation (MOSTI) introduced public health vaccination infrastructure that can be deployed during emergency pandemic situations. Vaccine Management System (VMS) is a system developed by MOSTI via its agency Mimos Bhd using the hyper ledger blockchain platform to enable the pharmacist, medical and respective officers to track and trace the vaccine supply chain from the manufacturers until its recipients which in this case is the patients, using blockchain technology (*Ahmad, A., 2022*).

12. Artificial Intelligence

Artificial intelligence (AI) is defined as the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. The term is frequently applied to the project of developing systems endowed with the intellectual processes characteristic of humans, such as the ability to reason, discover meaning, generalize, or learn from past experience (*Copeland, B.J, n.d*.). Machine learning is a field of AI that uses a statistical technique to give computer systems the ability to learn from data. AI is a powerful technology that can increase efficiency in the construction industry, ranging from the production of building materials, design, planning, project management and during the building phase. AI can be applied to construction in many ways, which brings benefits to the industry in the automated planning process by shortening the construction process, increasing accuracy and minimizing errors in construction process, automated machine functionality, risk mitigation, could solve skilful labour shortage, cost savings and construction site assessment.

MOSTI's on-campus 5G Experience Centre, namely MRANTI, which is in the midst of developing the first artificial intelligence (AI) park in Malaysia, a designated 300-acre (121.4-hectare) plot which will serve as the platform for the development of AI solutions, where there is also a drone tech centre of excellence named Area 57, a five-acre (2.02-hectare) dedicated land bank for flying, testing, research and development activities. Meanwhile, through the partnership of Mimos, Maxis and Huawei Malaysia, the AI Innovation Hub, a facility equipped with 5G network infrastructure and AI instruments, has been established to accelerate the creation of industrial use-cases enabled by 5G, AI and other advanced technologies in the country (*Ahmad, A., 2022*).

SITES PREPARATION DIGITAL ROADMAP

To recap, disruptive technologies can be adopted in 11 key activities in site preparation stages for construction projects, extracted from Jabatan Kerja Raya JKR's Standard Specification for Building Works, latest edition 2020.

1. Documentation management
2. Site investigation
3. Relocation of existing utilities and services
4. Demolition of existing structures
5. Site clearing
6. Site excavations and earthworks
7. Material Procurement
8. Assets management
9. Workforce management
10. Environmental monitoring
11. Site surveillance system

DOCUMENTATION MANAGEMENT

The first step in preparing a construction site is ensuring contract documents are in place in order to achieve efficiency in project management. The contract documents shall consist of:

1. PWD form of contract (for contract based on specification and drawing or for contract based on quantities) and addendum to the conditions of contract.
2. Form of tender.
3. Letter of acceptance.
4. Special provisions to the conditions as listed in the PWD form of contract.
5. Contract drawings.
6. Specifications and addendums.
7. Summary of tender and schedule of rates (for contract based on specifications and drawings).
8. Bills of quantities B.Q. (for contracts based on quantities).
9. Any other relevant documents included therein.

Getting the correct documentation in place is important so that the workforce can be productive and most importantly to ensure the records are in place when needed to comply with regulatory bodies, local authorities and best practise. These documents will help in obtaining approvals necessary to move the project forward with local permitting authorities, regulatory bodies, such as JKR, DOSH and CIDB.

Other related documents which are equally important and needed to be updated, reported to JKR on regular basis and to be made available on site at all time are:

1. Construction plan
2. Work method statement
3. Contractor's organisation chart

4. Schedules
5. Quality assurance plan (QAP); applicable for project value more than RM10 million.
6. Progress photographs
7. Sufficient notice to local authorities, utility providers, regulatory bodies
8. Erosion and sedimentation control plan (ESCP)
9. Safety and Health plan (S-Plan)
10. Construction Waste Management Plan (CWMP)
11. Environmental Protection Works
12. Sub-Contractors As-built Drawings

These documents are usually in hardcopies and stored in site's office or softcopies in desktop or hard drives. However, physical documents are prone to get damaged, misplaced or get altered. The desktop or hard disk can get corrupted, potentially missing valuable information. Site preparation sometimes requires a printed form to be filled by site supervisor, vendors or suppliers. The information collected from this form can be manually recorded on the desktop but it is time consuming and takes resources. Clerk needs to perform data entry and report formatting, time is needed before the team can discuss and make important decisions based on data recorded. This current method of managing documentation is outdated and needs to be digitally upgraded.

Most of the construction companies, especially SMEs, still use a manual method of managing a project particularly at construction site, with paperwork, printed form, checklist, logs and punch card managing workforce, logistics, inventory, vendors and suppliers. Management still uses email for communication and file sharing. It is tedious especially when it involves huge file size and needs to be shared to several groups of people, some with full inbox, and sometimes email gets bounced. Be that as it may, the method is cheap and people tend to work around its weaknesses because of minimal cost incurred.

Construction documents need to be digitalised first before the construction industry starts embarking on digital transformation. All documentations need to be done online and stored in cloud storage where authorised personnel can access the documents regardless of where they are. On-site discussion can be made easier, team players just need to access to the cloud on smartphones or tablets to view the drawing without needing to carry hardcopies, all points of discussion can be recorded real-time. Management team can also participate in the discussion from a distance away.

Digital documents can be preformatted to simplify data entry process so that site personnel just need to fill in data that are needed only. For universal access, it is important that this type of digital document format can be accessed and read by multiple devices.

Email is a good basic digital tool for sharing information and reporting. Email can be accessed using desktop or mobile devices. Productivity increases when the right information is shared with the right person in the fastest time. However, too many emails can cause confusions and are sometimes overlooked when the inbox becomes saturated with unread messages. Messaging mobile applications, another basic digital tool, can also be used for sharing information. However, their weakness is the same

as email, there will be confusion and important information could be overlooked when there is too much information pouring in.

A document management system (DMS) is an automated software solution where it is used to organise, capture and digitise documents. It can also be used for the approval process and completing tasks. DMS offers both an on-site storage system and cloud-based solution where all data is stored securely in clouds. DMS manages both electronics documents and digitised documents. DMS can help a company organise and manage their digital documents and digitise existing hard copies records. It also allows staff to view or edit documents based on their roles in the company. DMS is suitable for SMEs construction because the solution is relatively affordable. DMS comes with built-in search engines which allows users to look for the intended file fast, and security level is high where only authorized persons can access certain files. DMS has the capability of storing metadata, a set of data that describes and gives information about other (*Merriam-webster, n.d*.) data for example size of document, who stores it and when the document is stored.

There are companies in Malaysia offering document management systems such PointStar Malaysia, a cloud service company in Malaysia that offers document management systems. Ricoh Malaysia offers options of DMS such as DocuWare, Laserfische Avante, Laserfiche Rio and Open Bee. There are a few more companies which are Scanext Malaysia, Toshibatec, Documation Sdn Bhd, Globodox, Rapidcloud, Datamation Group, KBS Malaysia, PaperSOF and many more.

Building Information Management (BIM), a powerful design tool, cum project management system can be used as a document management system, for example Autodesk BIM 360 document management, a much more integrated comprehensive system. Digital forms that are recorded on site can be added to the BIM system via a mobile app where BIM will integrate the information with a 3D model. Autodesk BIM 360 is a single platform for streamlining document management across the project lifecycle. Autodesk BIM 360 allows users to organize, distribute, and share files on a single, connected document management platform, ensuring all team members have access to the information needed (*Autodesk, 2022*). BIM document management streamlines the construction document management process. Documents, drawings and models are collaborated in a single database where all team members have access to the latest revision simultaneously. Autodesk BIM 360 provides access to construction drawings and documents anywhere with instant update across any device, auto syncs to mobile devices, the software maintains document control ensuring access to the most updated information, it also allows mark-up drawings, documents and models with ease enabling collaboration between teams. BIM 360 standardized document approval by allowing users to facilitate, control and automate the review and distribution of project drawings, models and other documents before publishing and sharing it with the team. (*Autodesk, 2020*)

Proficient Software Solution, a Malaysian start-up company has come out with innovative project management for construction industry called Proficient, created and developed in Malaysia, Proficient is a mobile project management software and web dashboard that incorporates the construction project management workflow which may help mitigate construction delays and cost overruns. Proficient was first set up to address the project management gap in the Malaysian construction industry. Proficient

focus on both documentation and operation, with none of the software in the market capable of combining both. Proficient is equipped with AI chatbots and natural language processing (NLP) in their software *(Ravimalar, R., 2022).* Natural Language Processing (NLP) is a field of artificial intelligence (AI) that enables computers to analyse and understand human language, both written and spoken (*Frankenfield, J., 2021*). Proficient software is armed with a high security level, the system is designed by means if anyone tried to temper the original document, multiple versions of a document would be created. Each time the data or network is violated, the information hacked would be useless to the hacker as each layer of the network is highly encrypted. The software is also transparent so that it mitigates the risk of potential fraud or corruption. Everyone using the platform can be monitored and rated, from stakeholders to clients, enabling transparency and accountability. Proficient also plans to adopt blockchain technology to further strengthen the application. Proficient also plans to implement predictive analytics to foresee team performance and the kind of people to work with based on their productivity score given by the application. Going forward, Proficient plans to use augmented reality (AR) and virtual reality (VR) in project management *(Ravimalar, R., 2022).*

SITE INVESTIGATION

Before a new construction project begins on a certain location, that site must first be investigated to ensure that the structure is being constructed on the right location. The most important step before construction commences is a site investigation. The site investigation is designed to analyse the subsurface conditions on the site. Information related to soil, rock properties and hydrologic conditions will allow designers and engineers to determine if the site can support the type of structure that they want to build. If the soil is found weak, engineers will find ways to strengthen it. The main objective of site investigation is to make sure structures that are going to be constructed will be safe to be accommodated.

Site investigation or ground investigation or also known as geotechnical investigation, defined as a soil boring and sampling process together with associated laboratory testing required to establish the sub-surface profiles and relative strengths of the strata encountered at depth likely to have an influence on the design of a building project. Also called subsurface investigation (*McGraw-Hill Dictionary of Architecture and Construction, 2003*). Strata describes several layers of a column of soil or stacked up layers of sedimentary bed rocks.

Geotechnical investigation is conducted by geotechnical engineers intrusively to obtain data on surface, subsurface and rock conditions of the development site as part of the construction site preparation requirement. Also included are soil sampling and laboratory analysis. Geotechnical investigation is important for every construction site before the process of building planning and drafting begins. The data obtained is essential to engineers and designers to design structures, earth retaining systems, building material selection, construction techniques and foundation requirements for the construction of any new infrastructures.

The design of a structure which is economical and safe to construct, durable and has low maintenance costs, depends on in-depth understanding of the nature of the ground. By knowing the characteristics of sub-surface soils, rocks strata, and their properties and behaviour under various influences and constraints during the construction and lifetime of the structure, a safe structure can be built.

Site investigation involves determining the profile of the natural soil deposits at the site, taking the soil samples and determining the engineering properties of the soil. In-situ testing is also required. In general, ground investigation is carried out to determine as accurately as the technology permits on:

1. The nature and order of occurrence of soil and rock strata
2. The physical properties of soil and rock underneath the site
3. The groundwater table level and its variation at the site
4. To identify the presence of methane and other gases
5. To determine the grading amount needed for proper drainage to push water away from the structure.
6. The mechanical properties, such as strength, bearing capacity, compressibility of different layers of soil and rock strata.
7. To estimate the probable and maximum differential settlements
8. To predict the earth pressure against retaining walls and abutments.
9. To determine suitable soil improvement techniques
10. To forecast problems occurring in foundations and their solutions.

For any ground investigation of a construction site is typically performed in several stages. Generally, geotechnical investigation is carried out in stages as below:

1. Desk study
   The study and review of existing information relating to the site including drawings, geological maps, paper records, photographs, historical data that will guide the remainder of the site investigation. Included in desk study is site reconnaissance or walkover survey. Reconnaissance is a visual investigation on the site, it collects information about topographical and geological features of the site. Some observations that can be look at during walkover survey are:

   a. Presence of drainage ditches and dumping yards
   b. Location of ground water table
   c. Existence of spring and swamps and similar features
   d. Flood level marks on bridges, adjacent structures and buildings
   e. Presence of vegetation and nature of the soil
   f. Historical records of landslides, floods, shrinkage cracks of that area
   g. Study of aerial photographs, blueprints of existing buildings and geological maps
   h. Observation of deep cuts to know about the stratification of soils
   i. Observation of settlement cracks of present structures.

   Generally, the desk study and reconnaissance are aimed at the feasibility study of the ground where infrastructure is going to be built. If the desk study shows that the site is feasible for the structure, then preliminary investigation should follow.

Site reconnaissance can adopt the use of UAV such as drone equipped with sensors and 3D scanning laser, LiDAR to capture aerial images of the site from different angles and then feed to dashboard or computer in real-time, where geotechnical engineer can immediately analyse data obtained at blazing speed. The aerial images are tagged with coordinates so engineers are able to pinpoint exact location of the elements with high accuracy. Photogrammetry software combines images of the same object on the ground, taken from multiple angles to produce detailed 2D and 3D model or elevation model of the site. Elevation model will provide a detailed 3D image that will give engineer clear picture on the overall geographical condition of the site. This model can be used to locate presence of vegetation, swamps, spring or river, slopes and existing structure with precision where the locations are inaccessible by foot. Drones are special because it can be integrated with other digital tools for specific applications. Drones can fly at low altitude thus able to produce high resolution images. It is cheaper and can produce faster result compare with aircraft or satellite, and do not affected by presence of cloud. Data taken from drone is stored in cloud, thus other team can analyse the images remotely.

2. Preliminary Investigation
   The next phase of the site investigation is preliminary investigation. The main objective of this investigation is to obtain an estimate of sub-soil conditions at low cost. Preliminary investigation is usually being employed by small projects, light structures, highways and airfields.

   In preliminary investigation, a soil sample is collected from experimental borings and shallow test pits and tested in the laboratory. Such tests are unconfined compressive strength tests, moisture content tests and density. Simple on-site tests are also conducted which are sounding tests, penetration tests and geophysical tests to get the relative density of soils and strength properties.

   The data collected are sufficient enough for engineers and designers to design and build light structures. These are some information that can be gathered during preliminary investigation of the site:

   a. An estimate values of soil's compressive strength
   b. The groundwater table position
   c. Composition of the soil
   d. The depth and extent of soil strata
   e. The overall depth of hard stratum from ground level
   f. Engineering properties of the soil by obtaining a disturbed soil sample

   The disturbed soil samples are soil natural structures that get disturbed during the soil sampling process usually by drilling or boring of the soil before obtaining soil samples.

3. Detailed Investigation
   Detailed investigation involves numerous comprehensive tests and very costly thus should be used for major engineering works, complex building and design plans, heavy structures such as high-rise buildings, bridges and dams where the risks are

substantial. This phase consists of making several test borings at the site to collect disturbed and undisturbed soil samples from various depths for visual observation, later a variety of on-site tests such as vane shear test and plate load test are used. Laboratory tests that are necessary such as permeability test, compressive strength test on undistracted soil samples to identify exact soil properties.

There are several methods used for studying soil profiles. Different methods are listed below:

1. Direct Method: Open excavation
   Open excavation or trial pits are the cheapest method of soil exploration in shallow deposits, since it does not require any specialised equipment and suitable for all types of soils. Pits are excavated at the site, exposing the sub-soil thoroughly. Soil samples can be collected at various strata. The main advantage of trial pits is that the soil can be inspected in its natural condition and disturbed or undisturbed samples can be collected at ease. For deeper and below water level excavation, especially in previous soil, lateral support, retaining wall and ground water pumping are necessary.

2. Semi Direct: Borings
   Soil borings are the most common method of soil exploration in the site. Suitable for deep and below water level exploration. A bore hole is made to collect both disturbed as well as undisturbed samples depending upon the method of boring. There are a few types of boring as listed below:

   a. Auger boring
   b. Auger and Shell
   c. Wash boring
   d. Rotary drilling
   e. Percussion drilling

3. Indirect Method: Subsurface soundings
   Subsurface soundings are measuring the resistance of soil with the depth using a penetrometer under static or dynamic loading. The penetrometer may consist of a sampling spoon, a cone or other shaped tool. The commonly used tests are standard penetration test and cone penetration test. These tests are useful for general exploration of erratic soil profiles.

4. Indirect Method: Geophysical methods
   Geophysical methods are used to evaluate a site behaviour in a seismic condition. Geophysical involves detection of significant differences in the physical properties of geological formation. Seismic refraction methods and electrical resistivity methods are commonly used.

Generally, soil investigation involves in-situ testing, sampling and laboratory tests. In-situ tests are fast, cheap and can test large volumes of soil thus data is more representative. Laboratory tests are well defined under controlled boundary conditions, but only on a smaller volume of soil. Laboratory tests can be carried out to determine a variety of parameters such as moisture content, soil shear strength, compressibility, volumetric weight, Atterberg limits and chemical composition of the

soil samples. Both in-situ and laboratory have their own objective, both are important and needed.

1. In-situ tests
    a. Standard penetration test (SPT)
    b. To be performed in boreholes to estimate consistency, relative density and strength deformation parameters of soils.
    c. Cone penetration test (CPT)
    d. CPT is effective in evaluating site characterization. Suitable for assessing subsurface stratigraphy associated with soft materials, discontinuous lenses, organic soil, potentially liquefiable materials
    e. Vane shear test (VST)
    f. VST provides an indication of in-situ undrained shear strength
    g. Plate load test
    h. The plate load test is performed to determine the ultimate bearing capacity of the soil and the probable settlement under a given load.

2. Laboratory tests
    a. Index property test
       To determine soil classification. Examples are moisture content, unit weight specific gravity, Atterberg limits, particle size distribution
    b. Engineering properties tests
       To determine the strength and deformation parameters. Tests included unconfined compression strength. consolidation test, consolidated undrained triaxial compression test
    c. Rock strength properties tests
       Consist of point load test and uniaxial compression strength test
    d. Chemical analysis of groundwater
       To determine the aggressiveness of groundwater to concrete and steel structure. Parameters to check are pH value, sulphate content and chloride content test.

Site investigation is very important for any development or construction projects. It provides vital information about the soil and will help to determine whether soil treatment is needed. Treating the soil will reduce risk of complications once the construction process begins thus avoiding unnecessary maintenance cost for weak foundations in the long run. Site investigation also improves the safety of the site, if no investigation is conducted prior, unaware of the characteristics of the soil, a new structure could be built on soil that is weak and not able to support the structures thus exposing workers with various hazards like landslides and sinkholes.

In addition, site investigation may reduce the possibility of structure damage, designers and engineers will have ample data to build a strong foundation that can withstand natural elements and pressures. Site investigation will definitely help to identify suitable materials to be used in the construction process. The costs for site investigation are not cheap, especially for detailed investigation where in-depth numerous tests are conducted, nevertheless the benefits of conducting site investigation far outweighs the costs and risks that may occur without it.

Site investigation must be done right to avoid potential damage on the building or structure that is going to build on that particular location. A case study if Miri Industrial

Training Institute in 2018, where the building components experiencing defects due to land settlement. Cracks were found on non-structural elements such as brickwork, sagging on concrete drains and breaking on ceiling finishes. The problem might be due to land movement and unstable soil condition There were many rectification works that have been done but the land settlement process was still active, damages will get worse, incurring unnecessary hefty repairing cost and safety issues (*Muhamad Tahir, R., 2019*). The issue could have been avoided if site investigation was done right and the issue could have been detected earlier so engineers could find a way to strengthen the soil.

Geotechnical uses a few types of mechanical equipment to extract sub-surface soil samples and then subject the samples with in-situ tests and laboratory testing. The processes are all manual and time consuming. However, these testing generates large amounts of data and results that need to be stored and analysed by the geotechnical team. All the data collected at the site manually and digitally from sensor technologies and lab test results need to be properly managed and stored at one specific location where all teams will have access to. Digital tool cloud computing is the best solution in storing and linking data sources so that different people are able to work with the same information, real-time and remotely without the need to be present at one location together. Data taken on-site can be recorded using a cloud-based mobile app which automatically stores data recorded in the cloud. Cloud-based systems enabled team members to work with the most current data and lab results, all stored at the same single source of truth one without needing the use of email or external storage devices such as pendrive or hard disk for data sharing. However, some standardisation on workflow and report format are needed in order for cloud technology to work effectively. There are many cloud computing providers available with plenty of packages to choose from such as Microsoft Azure, AWS Cloud computing, Huawei Cloud, Google Cloud, AMD Data Center, IBM, Alibaba Cloud, Oracle Cloud, Dropbox, Amazon Elastic Compute Cloud, Cisco and many more.

RELOCATION OF EXISTING UTILITIES AND SERVICES

Nowadays, sites especially in urban areas are highly occupied with utility lines such as water pipelines, electric cables, telecommunication cables, sewers, gas pipelines. It is important to have an underground utility map before commencing on construction projects to avoid damaging any existing underground utility lines and may cause harm to the workforce and public. Utility map allows the site to be planned around existing utility lines without damaging it. Before any construction begins, the contractor needs to acquire a subsurface utility map. Information retrieved from it will give the contractor clear indication on where subsurface utility lines are located.

Utility mapping uses ground penetrating radar (GPR), Electromagnetic locators (EML) to detect utility lines subsurfaces of a construction site. The radar will show the positioning and identification of buried pipes and cables underneath the ground. Utility map is typically paired with a topographical survey to provide a comprehensive detailed map of all that is hidden underground. A utility map will inform engineers on

where utility lines are exactly buried, thus avoiding any unforeseen mishaps, safety issues, additional cost and potential delay in the project completion.

In Malaysia, a centralised underground utility database is maintained by the Department of Survey and Mapping Malaysia (JUPEM) in close cooperation with utility agencies. The data is made available to relevant parties involved in construction activities to minimise the risk associated. A guideline called Standard Guideline for Underground Utility Mapping was established in 2006. This standard guideline is intended to be used by those involved in various capacities in underground utility mapping. Beside this, there are a few local companies that provide underground utilities detection and mapping service that people in construction can hire to map the site prior to excavation and earthwork begins.

JKR itself also specified that prior to excavation, a site inspection is needed to identify the presence of underground cables, water or other service pipes at or in the vicinity of such excavation. If found any, work will have to stop immediately and notify the appropriate local authority and utility service provider.

In a nutshell, underground utility mapping provides construction sites with many benefits such as, it helps designers and engineers to improve design and constructability. It is able to prevent utility outages, minimize schedule delay and budget and most importantly, mapping reduces unknown and safety risks to the workforce and other people nearby, especially in urban areas.

Electromagnetic locators (EML) is a two-axial (2D) locators can be combined with signal generator to detect conductive pipes and cables, while ground penetrating radar (GPR), a three-axial (3D) able to detect both metallic and non-metallic objects and ability to capture continuous digital scans. However, GPR required skilled trained personnel to interpret the scans (*Geo Week News, 2017*).

GPR and EML are now being integrated with BIM to geolocate underground utility networks and hidden construction, by building a 3D subsurface mapping system that mated with surface mapping. With the integration between two technologies, BIM is able to produce comprehensive 3D models that detail both surface and subsurface. A fully integrated, multi-disciplinary BIM software reduces cost and increases efficiencies in underground mapping and better subsurface visualisation (*Narain, A., 2019)*. BIM enables surface and subsurface modeling to be integrated as a single project that provides overall detailed 3D with accurate location of subsurface utility network where it helps engineers to identify clash detection (*Narain, A., 2019)*.

Augmented Reality (AR) is also now used in subsurface mapping. The vGIS AR, a mapping tool that integrates three technologies namely Augmented Reality, Geographic Information System (GIS) and Microsoft Hololens to see subsurface utility infrastructure. The geospatial data is converted into Augmented Reality displays that allow engineers to visualise subsurface infrastructure, helping them to make decisions and plan for site excavation activities (*Narain, A., 2019)*.

DEMOLITION OF EXISTING STRUCTURES

Demolition of buildings is the process of dismantling or destroying a structure after its life of serviceability by pre-planned and controlled method (*Rahman, F.U., 2016*). Demolition is also part of site preparation activities to make way for new construction on the site where the old structure is located.

As per JKR's Standard Specification for Building Works, latest edition 2020, In preparing site for construction projects, all fences, buildings, structures and encumbrances of any character within the limits of the works have to be demolished except designated to remain. Small to medium structures can be demolished by bulldozer and hydraulic excavator. These two are the preferred machines when it comes to the removal of structures, slabs, concrete footers and debris due to cost efficiency. However, major structures, those which cannot practically be cleared by the above said machine, requires the use of pneumatic tools, explosives or other specialized equipment. Materials to be salvaged must be carefully removed and properly stored.

In general, there are four steps in demolition process:

1. Surveying
   Surveying involves the study of different characteristics of the building, structure and surroundings. Surveying looks at materials used in the construction, previous use of the building, hazardous materials, drainage conditions, problems with pollution, erosion and flooding, traffic condition, adjacent buildings, shared utilities and facilities, impact of demolition such as noise, dust, vibration on adjacent areas. Surveying also will study the construction method of the structure to be demolished, condition of basements and the building itself. Digital tools like 3D laser scanning can be useful in helping demolition teams to come out with demolition plans for demolishing large structures such as buildings. 3D laser scanning also allows historic buildings to be rebuilt in virtual reality before being demolished.

2. Removal of hazardous materials
   The building must be inspected by authorised personnel for hazardous materials such as asbestos minerals, radioactive substances, flammable materials, chemical contamination and must be removed before demolition begins.

3. Demolition plan
   A detailed plan on how demolition will be executed, number of personnel involved, equipment that will be used, location of the building, distance from adjacent buildings, health and safety plan and waste management plan.

4. Safety measures
   All personnel involved in the demolition plan will be briefed on potential hazards such as flammable materials, exposure to noise, dust and flying objects. Full PPE is mandatory for all workforce involved. Fire and emergency plans are prepared. Permit from local authority must be obtained first prior to demolition.

PPE equipped with IoT and sensors are useful to protect demolition teams from hazardous gases inside old buildings. Wearable sensors are able to detect hazardous gases such as ammonia, methane, formaldehyde and especially carbon monoxide which is colourless, odourless and tasteless gas which is toxic to humans and impossible to be detected by human senses.

Generally, there are two types of demolition methods used for buildings and structures.

1. Non-explosive demolition

   The most cost effective and widely used method where demolition is done with some equipment and machinery without the use of explosives. Typical equipment and machinery are listed below:

   a. Sledge hammer
      Handheld tool used to demolish single column, small wall

   b. Excavators and bulldozers
      Heavy machinery used to demolish small buildings, also used for excavation of soil and loading debris and residuals from demolished buildings to the truck.

   c. Wrecking balls
      Cranes with wrecking balls are used to demolish tall buildings. The steel ball is pulled and released towards the building. The steel ball with displacement force strikes the building as it demolishes.

   d. High reach excavators
      High reach excavators are used in the demolition of tall buildings where using explosions is not possible.

Site preparation activities such as demolition of existing structures, site clearing and site excavations and earthworks generally share the same heavy equipment except for some instances where demolition uses wrecking balls and explosives, subject to the type, condition and location of the building. The digital technology adoption into these universal heavy equipment will be highlighted in Site Excavation and Earthworks Section.

However, specifically for demolition, there are now semi-autonomous remote controlled demolition robots available in the market. Demolition robots are now used in the construction industry to demolish buildings or structures, or parts of the structure where it is too labour intensive, time consuming to be performed by humans. Demolition robots also are used where there is no space or not feasible for excavators to go in for example, demolishing sections of concrete wall at the upper floor. The robot looks like a mini excavator but without cabs, they are equipped with arm tools such as breakers, drills or crushers. Demolition robots are small enough to fit into elevators, doorways or even staircases. so it is ideal to demolish buildings by segment. Demolition robots still require human intervention, in which the user controls the robot’s action remotely. Demolition is a dangerous job, thus automating demolition is to ensure utmost safety on workers while increasing productivity. Even tough demolition robots are not cheap, they are cost effective in the long term. Here are

examples of demolition robots that are available in the market, Husqvarna DXR remote demolition robots, Demorobots 2.0 remote control demolition robots, and Brokk demolition machines.

2. Explosive demolition

   Explosive demolition, often called Implosion method, is demolition by explosives. Usually targeted on the foundations of the building. When the foundations are weakened, the structure will collapse. Implosion method is not meant for buildings in towns and cities but more of remote buildings for example large factories and power stations. Implosion requires explosives to be fixed on the building's main support, columns, beams and slab. There are two types of implosion.

   a. Falling like a tree
      The building falls like a tree sideways, either way to the right or left depending on the sufficient area around it. Cables are tied to the building to control the direction of the fall.

   b. Falling into its footprint
      Explosives are placed into the floor below the middle part in levels, it contains a series of blasts where the building implodes in series layer by layer and heavy load falls onto the lower-level collapsing on its footprint as the building detonates.

SITE CLEARING, GRUBBING AND STRIPPING TOPSOIL

Clearing, grubbing and stripping topsoil are important phases in any construction projects. The site where any structure or building to be constructed must first be cleared before commencing any structural build. Regardless whether the land is raw and overgrown with trees, old structures or its remains, site clearing is part of site preparation that is critical to the success of the construction project,

Clearing, grubbing and removing topsoil are not a simple task to execute. There is an extensive list of heavy machinery necessary to perform all of the activities involved such as bulldozers, scrapers, dump trucks and compactors.

As stated in JKR's Standard Specification for Building Works, latest edition 2020, site clearing consists of clearing, grubbing and stripping topsoil in the area within the limits of works as shown on the drawings. Clearing may consist of cutting and taking down, removal and disposal of everything above ground level, including objects such as walls, fences, drains and other obstructions.

The materials to be cleared are, but not limited to trees, bushes, stumps, roots, down logs, rotten wood, brushwood, undergrowth, long grasses, crops, loose vegetable matter, rubbish and structure. All materials which are still useful will be kept for recycling or repurpose. Nevertheless, some trees, vegetation, structures or parts of structures and other things which are designated in the contract to remain, to be

protected as satisfied under landscaping and turfing criteria. Clearing also covers levelling of obsolete dikes, terraces and ditches. Unwanted material must be removed from the site and disposed of properly.

All depressions made below the ground surface including holes and cavities by the removal of stumps, roots must be refilled with materials similar to the adjacent ground. The fill must be compacted to a dry density in layers until no visible track line and to not less than 90% of cohesive material or 95% for cohesion less material of the maximum dry density (MDD) determined in MS1056 Compaction Test (4.5kg-rammer method).

While clearing may remove and dispose unwanted surface materials it also leaves behind underground materials, grubbing is defined as removing and disposing all unwanted vegetative matter from underground such as stumps, roots, buried logs, other debris, underground parts of structures and other obstructions to a depth of at least 500mm below ground level.

Topsoil must be stripped by removing topsoil to an average depth of at least 100mm below ground level, and its stockpiling for use in the works. Topsoil is the upper layer of a soil profile, typically darker in colour because of higher organic matter. Topsoil occurs naturally as part of biological and environmental processes; it is more fertile than subsoil. Topsoil contains the highest concentration of organic matter, microorganism and plant roots. The soil's strength and bearing capacity depends on its skeletal structures and decreases with the presence of organic matter; it is the main reason why topsoil needs to be removed during site preparation as it may weaken the structure that is built on top of it.

Per JKR requirement, topsoil is to be stockpiled and sufficiently fertile to promote and support the growth of vegetation as part of landscaping. Before stockpiling, topsoil needs to be separated from objectionable materials such as combustible material including timber, all brushwood, stumps, roots, vegetation from clearing, grubbing and stripping topsoil including structure demolition.

All materials generated from site cleaning, grubbing and stripping topsoil shall be removed and disposed of in accordance with Environmental Quality Act 1974 (Act 127) and Solid Waste and Public Cleansing Management Act 2007 (Act 672).

Site preparation activities such as site clearing and site excavations and earthworks generally share the same heavy equipment. The digital technology adoption into these universal heavy equipment will be highlighted in Site Excavation and Earthworks Section.

SITE EXCAVATION AND EARTHWORKS

Excavation is a critical and very important part in site preparation, after being done with site clearing and utility ground mapping, contractors can now move on to excavation and earthworks. Excavation work is defined as the removal of earth, rock or other material in connection with construction or demolition works using tools,

machinery or explosives to form an open face, hole or cavity *(Ismail, H.B., n.d.)*. Earthworks are the processes of moving soil or unformed rock which involves cutting, filling and compaction to reconfigure the topography of a site to achieve design levels (*Construction Site Earthwork Calculation*.,2012). Excavation also includes preparing wall shafts, creating slopes, trenching, backfilling, compaction, forming embankments, tunnelling and underground. It is necessary to prepare construction sites up to the formation levels in accordance with lines, grades, dimensions, shapes and typical cross sections as per the drawing's specifications. Formation level is a final earthwork level after cutting or filling. The purpose of excavation and earthworks is to prepare the soil with the formation level indicated in the drawings. The formation level is required to lay down the foundation for building structures.

Excavation and earthworks follow BS 6031:2009 code of practice for earthworks, guidance on geotechnical aspects of earthworks and on working practices. According to BS 6031:2009, earthworks are structures formed by the excavating, raising or sloping of ground, e.g. embankments, cuttings or remediated natural slopes, earthworks also covers civil engineering process that includes extraction, loading, transport, transformation/improvement, placement and compaction of natural materials (soils, rocks), and/or secondary or recycled materials, in order to obtain stable and durable cuttings, embankments or engineered fills (*BS 6031:2009 Code of practice for earthworks, 2009*).

Excavation and earthworks are used to build foundations for the construction of buildings, houses, highways, bridges and many more. Excavation allows structures to be built on stable ground. The sides of excavations need to be stable, can be done by retaining or supporting material, excavating the soil to slope angle per design drawing.

Scope of earthworks are, site clearing, cutting and excavation, transport and moving, compaction and sloping. Types of excavation works are bulk excavation, underwater rock excavation, dumpling work of support and embankment (*Misnan, S.D.M.S, n.d.)*

The earthworks must be maintained to be kept free from water by establishing temporary water courses, water retaining systems such as ditches, drains and pumping. Contractor must ensure the site's surface is with sufficient gradient at all times by forming cuttings and embankments in order to shed water and prevent water ponding. The contractor must also ensure the stability and settlement of all structures during pumping out water from the excavation area.

Excavation and earthworks activities may impose risk to disturbed soils by erosion typically caused by water. The loss of soil which is carried away by water may cause instability, high repair cost and negative impact on the environment. Erosion and sediment control plans need to be implemented to manage erosion and sediment control effectively. Erosion and sediment control measures includes installing diversion and drainage structures for water to flow, turfing and creepers, which need to be planted immediately after cutting or filling, hydroseeding, adequate protection of stockpiles from erosion, providing sediment filtering and sediment traps to prevent contaminated water from flowing out of the site.

Digital tools also can be adopted in excavation and earthworks, for examples 3D Laser Scanning and Photogrammetry to map the site for engineers to design and plan excavation works. Engineers can use drone equipped with sensors and 3D scanning

laser, LiDAR to capture aerial images of the site from different angles and then feed to computer in real-time. The aerial images are tagged with coordinates so engineers are able to pinpoint the exact location of the site with high accuracy. Photogrammetry software combines images of the same object on the ground, taken from multiple angles to produce detailed 2D and 3D model or elevation model of the site. Elevation model will provide a detailed 3D image that will give engineer clear picture on the overall geographical condition of the site. The 3D model is then integrated to BIM for planning and designing of site layout.

Semi-autonomous equipment also can be used in earthworks. It is known that the automotive industry is developing autonomous vehicles for public use by using a combination of digital technologies such as forward facing cameras and radar systems that collect relevant information for the vehicle's computer to process. Society of Automotive Engineers (SAE International) has categorised six levels of autonomous vehicle, with level 0 indicates no automation at all and level 5 as full autonomy (*Society of Automotive Engineers. 2021*). Advanced Driver-Assistance Systems (ADAS), a driver-assist system which is widely used in modern cars, is considered as level 2, partial automation, where it is still human that monitors the driving environment. Level 3 and above are where the automated system monitors the driving environment (*Synopsys, n.d*.). Audi is said to be ready with their level 3 autonomous car awaiting legal approval. There are no level 4 and 5 available to the public yet, but the development is on-going (*Digwatch, n.d*.).

Heavy equipment that is currently used in construction for site clearing, demolition of existing structures, site excavations and earthwork uses similar heavy equipment such as excavator, backhoe, bulldozer, compactors and tractors. These construction heavy equipment are also experiencing digital disruption just like in the automotive and commercial-vehicle sectors with the introduction of IoT technologies in vehicles, semi-autonomous or even fully autonomous AI vehicles. Example is Volvo concept machine LX03, a fully autonomous, battery-electric wheel loader prototype is the first real-world example of a self-learning wheel loader with the brains to make decisions, perform tasks, and interact with humans (*Volvo CE, 2022*). However, much of these are still at the development stage, there is still much research and experiment to be done to fully automate heavy equipment fleets.

Nevertheless, semi-autonomous technology is now already making its way into the construction industry, Komatsu has developed smart construction solutions to harness technology for accurate data, comprehensive reporting and remote capabilities. Komatsu smart construction solutions consist of Dashboard, combining 3D design data with aerial mapping and intelligent machine data for visualizing the status of the site. A high precision mapping drone with cloud enabled technology. Komatsu smart construction field mobile app automates data collection on the site. Smart construction retrofit can be fitted to conventional excavators for 3D experience and intelligent machine control where 3D design can be directly programmed into the machine (*Komatsu, 2022*),

Caterpillar also offers smart construction applications to be suited or retrofitted to their equipment. Caterpillar's Cat Grade combines automated machine control in their fleet of heavy equipment offering semi-autonomous technologies to their customers. Caterpillars Cat Connect for remote asset monitoring services, Cat Command, a remote control option that contributes to jobsite safety by allowing operators to run

equipment remotely in hazardous applications (*Caterpillar, 2022*). Volvo CE also offers remote technologies in their equipment. Volvo CE with CareTrack allowed machines to be connected and monitored, where customers were able to access all their machines' information through a single platform (*Volvo CE, 2022*).

MATERIAL PROCUREMENT

Procurement in construction is the process of acquiring goods and services from external sources to be used on construction works. Procurement includes finding potential suppliers, negotiating contracts and managing a group of vendors and suppliers. The process must be transparent, competitive, fair to all suppliers and vendors and cost effective in order to eliminate unnecessary spending. Construction procurement processes are complex, where the procurement team deals with hundreds, thousands of materials and services. Data generated from procurement works is enormous and capturing, processing and storing are daunting tasks using traditional procurement, resulting in errors, wastage, and worst non-compliance issues. Digital procurement or e-procurement also called smart procurement is a digital supply chain management that should be able to address these issues. Digital procurement eliminates repeatable tasks, having real-time data on the go, optimising supply chain processes with standard workflow, connecting management team and site office on one platform for fast decision approval, increasing efficiency and reducing operational costs.

Smart procurement uses integrated technologies which consist of collaborating multiple disruptive technologies, examples of smart procurement technologies are smart procurement, robotics technology, intelligent content extraction, blockchain , smart sensor and advanced analytics. Smart procurement with cognitive computing and artificial intelligence, collaborating these two collect, store, organise and analyse all related supplier data. It will also automatically identify the correct vendor and contract data for optimal purchasing while blocking invoice fraud. Advanced robotics technology in procurement called robotics process automation, a software that recognizes, learns patterns and is able to perform rule-based tasks, used to automate repetitive manual tasks, reducing errors and risks. Intelligent content extraction able to ready unstructured documents such as PDF of contract, bills of material and extract critical data such as pricing tables, payment terms. Blockchain in procurement can be utilised as a secure software with no third-party involvement and all the transactions are archived and performed on a secure digital ledger. The blockchain decentralised transfer of control and decision making to a distributed network eliminating possible fraud. Smart sensor able to monitor movement of goods and inventory levels and enable audit tracking. Smart sensors benefit the supply chain by anticipating demand, optimising sourcing and inventory. Advanced analytics systems help the procurement process by consolidating vendors' opportunities resulting in direct cost improvement. It also recognises and provides sensitivity analysis in multiple demand situations (Punzalan, M.G., 2022).

Examples of digital procurement platforms are SAP Ariba, INPERA, Xpedeon, Speedbrick COMPOSE, Conwize, PLANERGY, Agora, ProcurePro and many more.

In 2018, Gamuda Berhad started using digital procurement platform SAP Ariba to source goods and services for their projects. With SAP Ariba, the entire contracting process between client and its suppliers is done online and every step is fully tracked. The system also has robust e-bidding capabilities that allow multiple suppliers to bid in a more transparent manner, promoting fair competition (*Lim W.L., 2018*).

ASSETS MANAGEMENT

Assets management refers to the supervision, tracking, monitoring and maintaining of all assets owned by the construction company particularly on site. An effective assets management system allows contractors to manage the use of assets, monitor their performance, reduce wastage, prevent loss and theft and proper equipment maintenance. Assets management software enables users to access assets performance data in real-time. Collecting and storing assets data able to diligently control the usability of the assets on-site.

A cloud-based asset management system offers mobility to managers and mechanical engineers to access the system remotely. Typically, this software is equipped with IoT enabled devices that can be installed on the assets on site. The IoT devices such as GPS trackers, RFID tags, Bluetooth receivers communicated effortlessly with the system which allows assets data to be retrieved, real-time that will help engineers to understand the asset condition. The advantage of tracking and recording assets life cycle is, it gives better understanding of the asset performance level and engineers able to profile the asset and establish a predictive maintenance and repair schedule. This will minimise the risk of equipment unplanned downtime. In addition, data collected can help to understand the cost involved in actual maintenance as compared to planning, doing this will definitely help in future budget planning.

Asset management software can be integrated with other disruptive technology which is modular construction. Key data such as type of material used, type of equipment, the parameters can be collected and used as a reference for manufacturing of modules of the same standards and quality.

WORKFORCE MANAGEMENT

Managing workforce or labours in site preparation construction projects is important because the main objective for management is to ensure productivity and efficiency of the workforce. Human resources must be carefully managed in order to stay with the project timeline and cost. As technology progresses, time and attendance technology also becomes more innovative and offers automated data collection. Construction workforce management able to track schedule, time tracking including leave request,

time clocks, centralized payroll system that integrates time and employee information into a single system. Workforce management software also keeps track of all the different tasks required. There are many advantages to using workforce management software such as less administrative intervention, reliable information contributes to more accurate payroll, high level of data integrity and keeping past records for data analytics. Overall, there are 6 important areas where workforce management is focussing on; communication, data management, scheduling, people management, forecasting and data analytics.

One example of a workforce management system useful in construction sites is the time tracking app. Time tracking system mobile application is convenient and easy to use since nowadays, almost all working people carry smartphones. Workers will check in and check out on the mobile app. Payroll can be done swiftly, without having to do data entry because all is already captured in the system. However this system will only work if workers carry their smartphone with them.

A time workforce management digital tool is Geofencing Time and Attendance System, a mobile app with GPS enabled. A site perimeter location is tracked and monitored, the worker whereabouts and time are tracked within the parameter. Examples of the mobile apps are Buddy Punch, QuickBooks Time, Hubstaff, ClockShark, allGeo, Connecteam, Clockify, Homebase and TimeCamp. Another time tracking app technology is integrated access control system, an intelligent system that provides workers data in real-time where workers wear ID badge for access.

ENVIRONMENTAL MONITORING

Construction sites generate noise, dust, vibration and may temper the water and air quality of the surrounding area. There are regulations and guidelines set by regulatory bodies on the requirements for contractors to manage these disturbances and pollution, minimising impact to surrounding community and environment. There are also methods and devices to mitigate these pollutants but without proper monitoring of the mitigations, the result might not be as expected, worst, the methods might fail causing damages to the surrounding and the contractor will face costly legislation issues with hefty fines from local regulatory bodies.

Data taken from Department of Statistics Malaysia, Big Data Analytics: National Occupational Accident and Disease Statistics 2021, out of 5289 number of occupational disease cases, 3648 cases was due to occupational noise-related hearing disorders, that is account 69% of all number of occupational disease cases from January 2021 to December 2021 (*Department of Statistics Malaysia, 2022*). The number is very alarming.

As such, it is paramount for construction companies to invest and equip the construction site with adequate monitoring devices because the contingency cost in repairing damage to the environment, surrounding properties and legal action are far more than investing on an active monitoring system.

With the advancement of monitoring systems today, construction companies are able to remotely monitor noise, vibration, dust, air and water in real-time at the site. Contractor can use a remote monitoring platform that can be integrated with a variety of monitoring systems and transducers such as sensors and microphone. The platform is based on AI technology, capable of autonomous monitoring at construction sites. The software is able to integrate with any monitoring system, transducer or transmitter, collecting data from these devices. The data is then stored in the cloud-based management system and can be accessed remotely from a website or mobile app. In addition, this software is capable of identifying noise sources with advanced AI and machine learning algorithms, it is also able to notify users when abnormality is detected. The software is also able to provide data analytics which can be used by contractors to improve pollution level.

Noise, vibration, dust emissions, air quality and water quality and quantity can all be monitored using cloud-based IoT sensors. These sensors are solar powered, or battery powered, self-operated that can perform monitoring, collect measurement data and communicate to users via internet connections. The sensors must be placed at strategic locations to effectively capture data. For example, a water discharge monitor or stream gauge is placed at the main drainage system to monitor the level of water flowing through drainage system, water level sensor that monitor the level of water in catchments, ponds or reservoir, dust monitor that is positioned near to demolition site to ensure dust emission is within tolerable level.

These are environmental monitoring solution providers that offer IoT enabled monitoring system, transducer or transmitter and also remote monitoring platform softwares, Althen Sensors, SiteHive, Acoem, Envirosuite, Specto Technology, Novecom and Adroit.

SITE SURVEILLANCE SYSTEM

Construction sites are a complex and busy system that requires full accountability from each party, especially on large-scale construction projects. Workers performing tasks here and there, multiple movements of heavy equipment everywhere, building materials being delivered, waste materials being removed, subcontractors, vendors and suppliers come and go. Expansive building materials, spare parts, instruments and equipment worth a large sum of money are kept in the site. Above all is safety, this combination is a recipe for disaster if not properly organised and managed.

In Feb 15, 2020 social activist Tan Sri Lee Lam Thye, former Chairman of the National Institute of Occupational Safety and Health (DOSH) told New Straits Times that Malaysia's Fatal Accident Rate (FAR) was not only 10 times worse than that of the United Kingdom but had in fact deteriorated by 20 per cent since the turn of the century, according to a Construction Industry Development Board report. Moreover, it will jeopardise public confidence towards safety in the construction industry. Site safety supervision must also be stepped up. Lee said developers and contractors must also be prepared to use technology to improve occupational safety and health (OSH) compliance. Wireless technology combined with the latest software and gadgets, such

as drones and remote sensing gear can also enable safety managers to monitor workers and machines as well as assess the situation via their laptop or smartphone (*Babulal, V., 2020*).

As such, it is critical for construction companies to invest in surveillance systems or remote site monitoring at the construction site. In addition, Covid-19 pandemic has changed on how people manage their working hours, especially professional and management team that does not have to be present at the site to do their work, site monitoring technology helps professional to observe the progress of work

There are a few ways where construction sites can be monitored, employing UAV or drones to do aerial surveys on a periodic basis, for example weekly routine for tracking development, safety inspection or to locate the whereabouts of expensive equipment, geotagging features of drones make it possible for track and trace tasks. The ability of drones to hover at low altitude make it an ideal tool for non-daily inspection check.

However, drones may not be suitable for continuous surveillance work on the site. The ideal method for continuous site monitoring would be the use of a cloud-based, IoT enabled surveillance solution called rapid deployment camera system with remote connectivity. Rapid deployment system comes with AI video analysis linked with alert function. Rapid deployment camera is armed with video analytic which is able to learn on behaviour recognition, the system will detect actions or movement and will automatically trigger alert should predefined activity is detected. What makes a rapid deployment system ideal for site security are its portability and requires no supporting infrastructures. It is solar powered thus can be deployed at any location within the site.

There are many advantages of using a remote monitoring system on site. The most important one would be the safety of the workers. Installation of surveillance systems is needed to monitor safety of workers so that immediate attention is given whenever mishaps happen. For example, to monitor safety of workers at demolition sites or workers excavating in remote deep pits or workers climbing on scaffolding.

Data taken from Department of Occupational Safety and Health DOSH Malaysia, looking at occupational accident statistics by sector until January 2021 to December 2021, covers only cases that are reported to DOSH and investigated. A total of 6686 workers from the whole industry sectors were recorded involved in occupational accident, where 217 came from construction sector 3.25%, however fatality in construction is high at 37.36% (*International Policy and Research Development Division DOSH Malaysia, 2022*).

Data taken from Department of Statistics Malaysia, Big Data Analytics: National Occupational Accident and Disease Statistics 2021, 21534 workers had occupational injuries, where 301 involved fatal injuries or at 1.43 rate (per 1000 workers). 2297 came from construction, where 73 involved fatal occupational accidents, which is at the rate of 6.3 (per 100,000 workers) (*Department of Statistics Malaysia, 2022*).

Construction site is a dangerous place, even during the site preparation stage. On July 30, 2022, An excavator driver was killed during a landslide at a construction site in Kedah. The remains recovered from beneath piles of rocks. The landslide was believed to have happened when piling work was carried out at the site (*Chan D, 2022*)

From these data, it shows that accidents do happen at all industry sectors including construction. A proactive measure is needed and a remote monitoring system is one of the solutions in reducing accident rate, especially fatal accidents. Construction companies must place safety of the workers as the utmost criteria at construction sites. Inadequate safety precaution can lead to accident on site, for example the main contractor and subcontractor of the Sungai Besi-Ulu Kelang Expressway (SUKE) project have been fined RM180,000 for failing to ensure safety at the highway construction site following an incident in which a concrete slab fell from the elevated highway and crushed a passing vehicle on Sept 19, 2020 (*Bernama, 2020*). In a separate case, two contractors involved in the Sungai Besi-Ulu Klang Elevated Expressway (SUKE) project have been fined a total of RM300,000 for failing to ensure site safety that resulted in a fatal accident on March 22, 2021 (*The Star Online, 2021*).

Theft in construction site do happen, police have arrested six men for stealing construction metal worth RM700,000 at the Refinery and Petrochemical Integrated Development (Rapid), which is part of the Petronas Pengerang Integrated Complex (PIC). They had also offered bribes of between RM150 and RM700 to the security guard each time they conducted their activity, the police have also identified the security guard involved (*EdgeProp, 2020*). Three men and a woman have been held on suspicion of stealing equipment worth RM30,000 from the ECRL sites (*EdgeProp, 2022*).

Remote monitoring may help in theft prevention, it can detect when building materials go missing, or the equipment whereabout. Remote monitoring system also will put transparency so that workers or personnel on site are accountable for the safeguarding of construction's assets. Remote monitoring also may be used to handle disputes, progress monitoring, compliance to regulations, worker's management and assets management.

Examples of rapid deployment systems are Hikvison, Sensorlink, Plan Radar, Wacthman, OTS IoT solutions, Oxblue and Teksys.

The above-mentioned activities within site preparation are areas where digital tools can be adopted, the activities covers almost every segment that need to be taking care of before the construction phase begins to ensure every construction phases run according to the schedule, delay is unfavourable since it will incur unnecessary additional cost to the overall construction project.

PREPARING FOR DIGITAL TRANSFORMATION

The Implementation of the Construction Strategy Plan 4.0 is driven by 4 enablers as below:

Enabler 1: People
Enabler 2: Integrated Technologies
Enabler 3: Governance
Enabler 4: Economy

The four enablers will form the foundation for ascertaining Construction 4.0 transformation is realised, consequently creating a complete eco-system to face the changes. In order for the construction strategy plan to be well progressed, these foundations need to be strengthened first.

ENABLER 1: PEOPLE

Nowadays, Malaysia employment's trend is to look for talents with digital skills sets such as analytical skills, engineering, computer science, software development, programming, structured query language (SQL), lead JavaScript, information technology and cloud computing. These are Malaysia's top 10 in-demand digital skills in 2021 based on LinkedIn Talent Insights platform (*Oi, R., 2022*). Not just in Malaysia, this trend is occurring to almost every part of the world. The industries believe that for them to succeed in digital transformation, they need to strengthen company's foundation first by acquiring digital talents. Digital transformation is advancing, requires organizations to stay competitive and willing to invest on digital infrastructure, to emerge as innovative, tech-leading company in order to lure digital talents.

World Economic Forum (WEF)'s "The Future of Jobs Report 2020" has indicated in their report that in Malaysia, eight of the top ten emerging jobs will require digital tech skills. This includes jobs in data analysts and scientists, Internet of Things (IoT) specialists, digital transformation specialists and cybersecurity specialists. The same study also forecasted that 50% of all employees will need re-skilling by 2025 (Nair, S., 2021)

According to LinkedIn head of Asia, talent and learning solutions, Frank Koo, he told *The Malaysian Reserve* that the workplace has changed dramatically since the pandemic. Many of the available job opportunities today require workers to be equipped with some form of digital skills, as most of the job functions now take place virtually. This demonstrates a pressing need to ensure that workers have avenues to strengthen their skills to stay relevant in the future economy (Azuar A. & Hazim A., 2021).

Higher Education Minister Datuk Seri Dr Noraini Ahmad has said that demand for digital-related positions in the country has increased by 300% in 2021 compared to the previous year, of which 20% were to be filled by new graduates. The figure was the result of a study done by the Malaysian Digital Economy Corporation (MDEC) which involved 56,000 vacancies in the digital field from 19,000 in June 2020. She also added that globally, based on the Future of Jobs Report 2020 report, the employment opportunities in this field is reported to increase by 12% to 97 million jobs by 2025 (*Bernama, 2021*).

However, A Global Skills Report by Coursera in 2021, ranked Malaysia in the 46th spot in global skills, indicating lack of digital skills, way behind the two higher-ranking ASEAN members, Singapore is at 10th and Vietnam at 20th (*Oi, R., 2022*) It shows that the demand for digital talent is uprising but employees in Malaysia still need to do

more to acquire digital skills so that Malaysia can be on par with above mentioned countries in terms of digital skills.

One of Construction 4.0 strategies is to tackle the lack of digital skills among Malaysians to prepare them for tomorrow's workforce. The adoption of technology to the construction process requires future workforce to be equipped and ready with new skills in enabling people to adapt to the changing industry environment.

Enabler 1.1 : Young Generation

Interest towards digital skills and digital literacy need to be part of the education system at an early age and progress up to higher education level so that when they graduate, they already have a strong foundation in digital skills. Higher Education Minister Datuk Seri Dr Noraini Ahmad has said that the Ministry of Higher Education (MOHE) always carried out strategic measures and made various efforts to ensure that local graduates could meet the needs of the industries in the digital field (*Bernama, 2021*).

Recently, leading provider of telecommunications technology and services, Ericsson, announced its collaboration with Universiti Teknologi Malaysia (UTM) and Digital Nasional Berhad (DNB) to educate students on 5G and emerging technologies. It gives the UTM students access to the Ericsson Educate portal for free to complement the university's online-based degrees and micro-credentials programs (*Oi, R., 2022*).

There is no better way to give exposure to the young generation on digital skills than via the education system. Policy makers need to align the national education system with a digital future.

Short Term

- Schools to conduct talk, workshop to student on 4IR, Construction 4.0.
- Use social media as tool to create awareness towards 4IR, Construction 4.0.
- Organise contest for children, teenagers to nurture interest towards digital tools.

Medium Term

- Mandatory digital skills foundation course for graduates in tertiary education.
- Promote learning by information and research, encourage students to utilise digital tools.

Long Term

- Embracing 4IR, Construction 4.0 at early stage by incorporating in primary and secondary school syllabus to produce digital literate generation.
- Transform education institutions by integrating digital tools.

Enabler 1.2 : Society

As digitalisation disrupts almost every aspects in the world today, society is no exception. Digital technologies are now being integrated at every level of society, every activities including economy, working, health, lifestyle are been digitalised to the extent that it has become a norm. Here are how digitalisation can be further embedded into the society.

Short Term

- Create content in social media, TV programs, to create awareness towards 4IR, Construction 4.0.
- Organise talk at community hall on the benefits of digital tools, examples, safeness of communication tower, smart meter.
- Digital tools to be made available for working-age and the elderly.
- Nurture a community of digital tools adopters.

Medium Term

- Provide incentive to public, example extending tax exemption for purchase of IoT, smart home devices.
- Educate community to embrace new construction method, prefabrication, modular.

Long Term

- Cultivate public community mindset on cultural change to embrace new technologies disruption.

Enabler 1.3 : Employee

2,003 Malaysians were polled by PwC Malaysia on their views around technology, jobs and skills in January and February 2021 when the country was placed under a targeted Movement Control Order. Compared to 60% of global respondents, 71% of Malaysians fear that jobs may be at risk because of automation, an increase from 34% the previous year. While only 19% of Malaysian respondents say they had adequate digital skills to perform their jobs, 57% say they have improved their digital skills since the pandemic began compared 40% globally. Among the 57% respondents, 46% had some digital skills and developed them further, while 11% who did not have adequate digital skills were able to acquire them on the job. The report is an important call to action for employees to upskill, and for organisations to rethink how they can support their employees in their upskilling journey and in preparing them for the future of work (*PricewaterhouseCoopers, 2021*).

Here are approaches that employee can take to elevate their digital skills:

Short Term

- Self-enhanced skills and talents in digital technology.
- Open-up for changes on working with digital tools.

- Adopt the right mindset to maximise operational excellence.
- Demonstrate digital leadership.
- Adapt with changes and make full out of it.

Medium Term
- Cultivate analytical thinking.
- Self-develop digital mindset.

Long Term
- To keep abreast and continuously learning on new emerging technologies.

Enabler 1.4 : Employer

The MDEC Digital Talent Survey 2021 published in October last year found 85% of companies recognize the need to reskill their employees. As 48% of companies adopted digital tech platforms for day-to-day operations, up from 19% in 2020, the required skills have also evolved. The survey also found that more emphasis is put on technical skills, such as cloud computing, cybersecurity, data analytics, digital marketing, and software development, instead of digital productivity and remote working skills (*Oi, R., 2022*).

Nurul A'in Abdul Latif, Markets Leader, PwC Malaysia has said as much as technology is a lifeline in keeping people at work and an enabler for business continuity, certain barriers still persist. 78% of Malaysians say that a lack of access to technology has limited their ability to develop skills. This could reflect a shortage of the right technology, or perhaps even indicate that Malaysian companies need to move beyond mere lip service to urgently plug the skills gap through a proper upskilling strategy. 92% say they have been given a chance by their current employers to improve their digital skills outside their normal duties. 87% of Malaysian respondents who agree that it is their responsibility to update their skills instead of relying on their employers to do so. Meanwhile, 88% say they are ready to learn new skills or completely retrain so that they can continue to be employable in the future. Upskilling rests on everyone's shoulders but employers have an added responsibility to tailor their programmes to the needs of their business and employees. A skills assessment may help to identify the crucial skill sets that are lacking (*PricewaterhouseCoopers, 2021*).

Here are what employer can do to boost their presence in the industries by taking short term, medium term and long term approaches towards digitalising their business.
Short Term
- Educating and empowering employees on digital transformation shifts.
- Developing employee's skills by providing training and courses.
- Nurturing collaborative business model.
- Invest on talent with digital tools to add value to the company.
- Acquiring digital tools, open up to new business opportunities.
- Encourage usage of digital IDs example IoT tracking working hours.

Medium Term

- Regular two-way communication with employees on certain changes in organisation towards digitalisation.
- Planning for digital transformation.
- Partnering with other industry players for knowledge and technology transfer.
- Digitalise workplace.
- Embrace innovation through new business strategies and tools.
- Aligning business systems and processes to maximise digital proficiency.

Long Term

- To cultivate working culture and organisational changes towards working with digital tools.
- Evaluate changes that digitalisation brought to the company for process optimisation and further improvement.

ENABLER 2: INTEGRATED TECHNOLOGIES

Technology works better by integrating it with other technology. For example, integrating additive manufacturing with modular construction, integrating IoT, Cloud and Realtime collaboration with BIM. By integration, it will help increase productivity, improve success rates and enjoy benefits throughout the whole life cycle of the project.

Short Term

- Develop disruptive technologies usage in construction practices.
- Promote the use of integrated technologies in construction industry.
- Reform infrastructure to accommodate for implementation of 4IR and construction 4.0.
- Exercising pilot programs to assess on the effectiveness of digital tools with organisation.
- Assess disruptive solutions in advance such requires less investment.
- Digitize payments to all team players.
- Enabling broader connection solutions across construction team.

Medium Term

- Cultivate culture of innovation and growth.
- Enable data exchange with peer companies and construction project teams.
- Extend growth of BIM beyond Architecture, Engineering, Construction (AEC), penetration into low level tasks.

Long Term

- Invest in setting up a big data predictive analytics solution.
- Invest in R&D on home-grown disruptive technologies providers.

ENABLER 3: GOVERNANCE

For the industry to embrace digitalisation, it is imperative to have a strong and supportive governance ready to reshape regulatory frameworks of a country. Changes towards digitalisation need to happen within the governance system in order to adapt with the industry. Improving government's accountability and gaining people's confidence by moving towards collaborative systems and transforming how they interact with business, people and investors.

Malaysia has been implementing various initiatives to help to upskill and reskill its population, including #MyDigitalMaker Movement, eUsahawan, Premier Digital Tech Institute, Digital Skills Training Directory, Let's Learn Digital, and more. For example, #MyDigitalWorkforce Work in Tech (MYWiT) provides training and salary subsidies to encourage employers to hire the unemployed for digital tech and services jobs. Global tech giants, such as Facebook, IBM, Google, Huawei, and Microsoft, are also partnering up with the initiatives to bridge the local skills gap (*Oi, R., 2022*)

MDEC Digital skills training directory is a catalogue of courses that address in-demand digital skills. These learning modules and trainers have been reviewed and endorsed by a panel of digital industry experts to ensure proper guidance is available to Malaysians who are selecting courses that meet the requirements for digital jobs. The courses comprise in-depth training and certification at beginner, intermediate and advanced levels in data sciences, cybersecurity, software development, animation and game development. Refer to MDEC Digital skills training directory for further details https://mdec.my/digitalskillstrainingdirectory/ (*MDEC, n.d.*)

Short Term

- Assess on digital initiative policies created to ensure deliverables within committed timeline.
- Develop awareness programs via various forms of content and media social platforms.
- Addressing inequality in technology reach, focussing on SMEs construction companies.
- Support SMEs by organising programs, giving incentives for adopting new technologies and gives guidance on transforming their business practises.
- Pursuing policies that promote digital economies.
- Organise programs that recognise achievement of local construction players in adopting digitalisation.
- Strengthen national cyber security systems.
- Adjust regulation to suit for a digitalised world by adopting functionally based regulation and applying regulatory consistency throughout the ecosystems.
- To accelerate the implementation of full digitised public services especially those related to the construction industry.

Medium Term

- Support R&D and entrepreneurship in new digital platforms and technologies developed by local talent.
- Established partnering platform with major international construction companies for knowledge and technology transfer.
- Improve pull factors to attract foreign disruptive technologies makers to set up manufacturing facilities for bringing the cost down and to accelerate technology transfer to local players.
- Encourage local finance institutions to ease funding, loan to SMEs in acquiring major disruptive technologies.

Long Term

- Established a national big data centre, blockchain, interconnecting nationwide construction industry.
- Accelerate the development of smart cities, and span it across nationwide.

A recent preliminary survey was conducted by Swinburne University of Technology Sarawak Campus at Malaysia's southern region in July 2022 stakeholder's awareness of the Construction 4.0 Strategic Plan. It shows that though the plan has been launched in 2020, the awareness about it is low among industry players. The preliminary survey found that as high as 70% of the industry players, which are developers (66%), contractors (86%), consultants (57%) are not aware of the existence of the plan (*Foo, D. C. H., & Chai, D. C. S., 2022)* . This indicates that there is lack of communication especially to industry players in rural areas. This probably due to the geographic locations of where the survey took place, communication may not be effectively conveyed in rural areas as compared to urban areas. Government needs to step up in organising more awareness campaigns promoting Construction 4.0 especially in rural areas.

ENABLER 4: ECONOMY

Economy must address opportunities for improvements and leverage efforts to create a business climate that attracts investment. Provide a mechanism to evaluate investments and redirect policies where needed.

Short Term

- Exercise change in organisational capabilities.
- Business processes optimisation, simplifying processes as to prepare for disruptive technologies adoption.
- Creating dedicated economy manufacturing category of new advanced building material.
- Promoting an efficient reallocation of labour and capital across organisation by reducing administrative barriers on start-ups, facilitating job transitions.
- Preparing economy to adapt with new competition challenges.

Medium Term

- Revamping business models tailored with adoption of AI, Cloud & Realtime collaboration.
- Reducing financial constraints hindering digitalisation, by addressing market failures in the financing of young innovative firms.
- Increase competency of the local construction industry through collaboration with international entities.

Long Term

- Full digitalisation integration across all business functions covering marketing, operations, human resources, administration and customer service.
- Business process automation by enabling robotic process automation in business activities.

Michael Graham, Chief Digital Officer, PwC Malaysia has commented that for organisations to be working out their upskilling strategies alone is not enough. This is an agenda in need of a larger mandate through closer collaboration between the government and the private sector. With the recent launch of the Malaysia Digital Economy Blueprint (MyDIGITAL), businesses are in a pivotal position to partner with the government to intensify upskilling initiatives, and track and measure their progress to benefit everyone in society. Beyond addressing the infrastructure needs of the nation for improved broadband access and internet speed, the government and private sector need to consider what are the fears or challenges holding people back from embracing technology. Michael Graham questioned whether organisations nurturing the right culture to promote upskilling among their employees or schools doing their part to promote lifelong learning among students. The pandemic has also given rise to a new breed of employees who are not afraid to pursue new challenges, as part of both their professional and personal development. (*PricewaterhouseCoopers, 2021*).

The importance of technological advances and their beneficial effects to the construction industry is tremendous. Digital tools simplify complex construction operations and make it a safer place to work. Industry needs to take advantage of what disruptive technologies could offer and help the company to boost their expertise and capabilities, empowering their position in the market. Construction companies need to accelerate their effort to start embracing digital technologies to experience its benefits and for them to remain competitive in the market and not to be left behind by their competitors.

DISASTER RECOVERY PLAN

In today's challenging sophisticated business environment, digital transformation is becoming a norm, almost every sector is rushing for digital adoption in their operations, while doing so, company's IT infrastructure that facilitate digital activities also need to be reinforced in order to weather unplanned disruption that may be due to natural disaster such as flood or even earthquake, man-made incidents such as war, act of

terrorism, fire, socio-politics event such as riots, rampage and also security breach and cyberattacks.

Kaspersky data showed that for businesses that experienced a data breach, more than a quarter (28%) admitted they did not have appropriate IT solutions in place. The same percentage conceded that their businesses lack internal IT knowledge and experience. The same research also revealed that more than 22% of SMEs do not have a policy to regulate, or restrict, access to internal infrastructure by a third party (*Business Today Editorial, 2022*). A proper documented process or plan is needed to guide the company in the event of mishaps.

A disaster recovery plan (DRP) is a formal document created by an organisation that contains detailed instruction on how to respond to unplanned incidents such as natural disasters, power outages, cyber-attacks and other disruptive events. The plan contains strategies on minimising the effects of a disaster, so an organisation will continue to operate, or quickly resume key operations (*IBM, n.d*.).

Disaster recovery plan is a defensive measure which contains tools and procedures that organisations will use to recover from major disruption to their information technology infrastructure. It is a written master plan documented processes that details how the business would respond in the event to ensure business continuity. DRP will utilize tools that the company has and follow written procedures where the ultimate objectives are to quickly overcome data disaster, minimise downtime with minimal losses, rapid recovery from disruption and resume critical business functions.

Construction sites are vulnerable to natural elements such as major landslides or erosion that may occur especially during heavy rain. Construction sites may also be subject to unfortunate events or accidents such as sinkholes due to groundwater movement, collapse tunnel, explosion, buried pit and structure collapse due to land settlement. Construction projects also require IT infrastructure setup on-site such as internet, servers to support construction activities where computers, IoT devices, smart equipment are utilised. On-site IT infrastructure is also subjected to cyberthreats, natural disasters such as flood, or even earthquake or man-made incidents. Work could be halted and safety could be compromised if mishaps happen. Apart from safety procedures as per DOSH's requirement such as Safe Work Method Statements (SWMS) in place, companies need to make sure construction sites are also being factored in Disaster Recovery Plan.

Project managers and engineers play a bigger role in disaster recovery plans at construction sites. They need to make sure that their staff keep all records of the construction workforce such as contact details and job functions. This is important because some of the workers at construction sites are subcontractors where the company may not have much details on them. Engineers need to make sure the workforce are properly communicated on the plan, participate in audit and training, and know what to do when disaster strikes. Project engineers also need to facilitate the IT team to provide maintenance, security updates to on-site IT infrastructure.

Of late, earthquake occurrences in Malaysia are getting more frequent. According to Universiti Teknologi Malaysia (UTM) Engineering Seismology and Earthquake Engineering Research group leader Prof Dr Azlan Adnan has said that most of the new government buildings designed after 2017 are ready to withstand earthquakes.

However, older buildings built before that may face the risk of suffering severe damage from earthquakes. In 2015 when the six-magnitude earthquake occurred in Ranau, Sabah, most of the buildings were badly cracked, there were also buildings that were not designed properly, there were broken beams and buildings that could no longer be used. Azlan said his team expected a five-magnitude earthquake to occur in Peninsular Malaysia and because of that, they needed to produce standard operating procedures for building designs that could withstand the effects of the natural disaster. On Feb 25, when tremors from an earthquake in Bukit Tinggi, Sumatra, Indonesia, were felt in the country, a total of 34 building emergency calls were received by the Fire and Rescue Department from around the Klang Valley (*The Star Online, 2022*).

From this news, it shows the importance of companies or organisations to have disaster recovery plans in place because even though Malaysia is not located along tectonic plates where the majority of earthquakes happen, Malaysia do face minor earthquakes, tremors and seismic waves from earthquakes that happened in neighbouring countries. Sometimes, the impact could be devastating.

An effective comprehensive DRP need to have these elements described in the plan:

1. Assemble disaster recovery plan team.
   The first thing that needs to be done is to form a disaster recovery plan team. DRP team is a group of employees focussing on planning, implementing, conducting training, maintaining, auditing and testing of a company's DRP procedures. The team may consist of a manager as head of the recovery team, IT experts, business experts, and groups of experts from multi-disciplinary that are crucial to the company, such as engineering, finance, procurement and human resources.

2. Established multiple communication method
   Companies set up multiple communication ways to reach their employees in the event of a natural disaster or security breach so that any information or update pertaining to the event can be clearly communicated to the employee.

3. Asset management
   DRP teams need to create an inventory of all critical hardware, software, network components and business databases within the organisation.

4. Risk assessment
   It is important to identify potential threats that might be targeting the company, its risk level and solutions for mitigation if under attack.

5. Plan for business continuity
   In the event of threat, it is important to make sure the business can continue to operate during and after threat is contained, minimising financial and reputational loss.

6. Set clear objective
   Two types of objective must be set in DRP, recovery time objective (RTO) and recovery point objective (RPO). Recovery time objective estimates how long will it take for the data to be recovered and business resumes back to normal. Recovery

point objective is a measure of how much data may be lost during recovery. This can be predetermined by controlling data backups frequency.

7. Established roles and responsibilities in DRP
   DRP must clearly state roles and responsibilities for those involved in the event of cyberthreat or other disaster. DRP will be much more effective when everyone involved knows exactly what to do when a disaster strikes.

8. Remote data backup
   It is imperative to have remote data backup, should the primary data storage solution hit with a disaster, it will be much faster to restore the data. The backup could be stored at third party remote servers of cloud-based backup service provided by a third party. Some businesses offer disaster recovery-as-a-service (DRaaS) to help companies create and manage their DRP. There are IT companies that offer such service, for example IBM Malaysia, Aegis, NSD, SYS IT (M) Sdn. Bhd, Veeam Exabytes, RapidCloud, Shinjiru, Progenet Innovations, TM One Azure Stack and many more.

9. Determine critical data
   Usually, companies will keep a large amount of data and some data might not be critical. These data need to be sorted, the company needs to determine which are critical for back-ups, doing this saves storage space and processing expenses and cost in maintaining it.

10. Plan testing
    The disaster recovery plan needs to be tested to ensure the plan works as planned. Multiple tests covering various disasters must be carried out to make sure the plan works in any condition. The outcome of the tests needs to be analysed and the plan can be adjusted accordingly. The plan needs to be periodically tested on a regular basis since the company is always dynamic, there will be changes in organisation chart and equipment. Carrying multiple tests can help the company find ways to improve DRP in the long run which in turn will make the company able to withstand disaster and quickly recover from it.

Covid-19 pandemic has driven employees to work from home. The pandemic has taught industry that even working from home will not affect productivity or the quality of work. Post-pandemic, more companies support hybrid working models, where employees combine remote work and office time. However, hybrid working models may be subjected to security breach, cyber-attack on unprotected network infrastructure. As such, is it important for companies to equip remote access to the company network infrastructure with security provisions to protect it from hacking, malwares, bloatware attack, unauthorised access which may jeopardise company IT infrastructures, and worst, security breach that might halt the operation of the company.

Each employee needs to understand the importance of DRP and be trained on their roles in the disaster recovery plan, especially the DRP team. Periodic audit of the plan is required to ensure all the information such as employee details are still relevant. Simulation drills are equally important so that employees will know exactly what to do in the actual event.

Investing in the development of a disaster recovery plan is crucial to ensure the survival of the company and its resilience when disaster strikes or against any cyber-attack. Nevertheless, investing in prevention is equally important. Therefore, businesses need to make sure to equip their IT system with firewalls, multiple authentications, regular updates and upgrades on latest security patches and control users to prevent unauthorised access of important data.

Digital tools potentially be used in site preparation is categorised into 3 level of adoption which are Basic, Intermediate and Advanced. The digital tools which fall under each level are tabulated below:

LEVEL	TOOLS	CLASSIFICATION
Basic Getting ready for digital economy	• Project Management Software (PMS) • Building Information Modeling (BIM) • Computer Aided Design (CAD)	Simulation & Modeling
Intermediate Growing in the digital economy	• Building Information Modeling (BIM) • Prefabrication & Modularization Construction • Cloud and Realtime Collaboration • Augmented Reality & Virtual Reality • Advanced Building Materials • Internet of Things (IoT) • 3D Scanning & Photogrammetry • 3D printing, additive manufacturing • Smart sensor	Digitalisation, Virtualisation & Monitoring
Advanced Leaping forward in the digital economy	• Building Information Modeling (BIM) • Artificial Intelligence (AI) • B2B blockchain • Big Data & Predictive Analysis	Smart Construction

DISRUPTIVE TECHNOLOGIES IN SHAPING DISASTER RESILIENT CONSTRUCTION

The use of disruptive technologies may help the construction industry to build buildings or structures such as bridges, dams that are resilient to natural disaster and man-made incidents. The advancement of today's technologies are so remarkable, opening up to new wonders in technological advancement in construction. For example, IoT devices and Smart Sensors connected to clouds are able to detect unusual patterns of soil vibration or movement, which gives early notification to engineers so that investigation can be carried out promptly. A 3D laser scanning LiDAR that can detect cracked ground that may be due to earth movement, 3D ground penetrating radar (GPR) that is used for subsurface investigation, able to detect subsurface objects, voids, cracks, ground water and changes in soil strata. These data will help

geotechnical engineers to understand the condition of construction ground whether it sits on active ground or unstable ground due to water movement, thus preventing disaster from happening.

Emerging technologies are changing how building is being built, the use of prefabrication and modular construction are getting norm worldwide due to its advantages in terms of parameters control and cost. Prefabricated and modular construction can be tailored and designed so that it can withstand stresses from natural disaster, and should the building be damaged by the disaster, the parts can be easily fabricated and the building can be restored or rebuilt faster at much lower cost. Innovation of advanced building materials with superior properties also help engineers in designing structures with exceptional resilience to disaster. For examples, 3D graphene, a 3D-printed carbon that is 5% of steel density but up to 200 times of strength, Laminated timber, a prefabricated timber with higher water resistance and strength over traditional wood suitable for flood prone areas and wool brick, fused with wool and seaweed polymer with higher strength than earth brick.

Semi-automated machines or AI automated machines can be used at dangerous areas such as tunnels where in the event of disaster, fatality can be avoided. 3D printing or additive manufacturing able to print building elements that are damaged by the disaster enable buildings to be repaired faster. Artificial Intelligence and Big data analytics on weather history are able to construct weather patterns on construction sites which will help the design team to understand weather conditions thus being able to design buildings that are able to withstand rough weather.

Building Information Modeling (BIM), the ultimate digital tool for the construction industry, is so powerful that it can help engineers designing and constructing buildings and structures that can hold out against mother nature and man-made disasters. BIM is an exceptional collaborative process that allows the project team to plan, design and construct a structure or building in a 3D model, containing all of the information required on building the structure from inside out. BIM allows engineers to play with type of materials, building designs, building layout including mechanical and electrical fittings, to get the most ideal combination for the building to be resilient with natural disasters.

The beauty of BIM is that it can be collaborated with other software or disruptive technologies. For example, integration of BIM and Finite Element Analysis (FEA) a computerized method for predicting how a product reacts to real-world forces, vibration, heat transfer, fluid flow, and other physical effects (*Autodesk, n.d.*). FEA integrated with BIM enables engineers to run simulations of the models to reflect what will happen to the actual structures in the real world. FEA is able to simulate natural disasters such as flood, fire incidents, earthquake to see its impact on building and materials reaction when subjected under stress. All of this finding can be shared to the rest of the team with ease. When all of the building information such as 3D model, design parameters, bill of materials, all are in one place. The BIM model helps engineers and contractors to rebuild or repair buildings that are damaged back to the original design faster.

BIM can be used to help companies to create Disaster Recovery Plan (DRP). Based on a simulation conducted on a 3D model, mechanical engineers will be able to devise a fire evacuation plan that will be used in the event of an emergency such as building

under fire. BIM will also show the exact location of the air ducting system throughout the building so that the fire bridge is able to control fire from spreading. What makes BIM so useful is that the 3D model containing all the important information can be shared to emergency response teams such as fireman, paramedic and police, helping them to plan for search and rescue, navigating route in 3D model identifying nearest safety exit during post-disaster. What is more, it can be done in real-time while in the rescue operation, where a 3D model can be viewed on mobile or tablets saving valuable time, thus potentially saving more life. After all, in search and rescue, time is the essence.

Disruptive technologies are a true marvel in the modern world today. It helps not just the construction industry but other industries as well in disaster management. BIM is also useful to emergency response teams and it also helps the community in getting back on their feet by giving access to building 3D models and information for municipal and contractors to repair or rebuild buildings that are damaged due to disaster strike.

GET STARTED TODAY

Digital transformation is usually initiated by the company leader because it is an extensive undertaking. It will take up resources, require proper planning and investment in terms of acquiring the technologies itself, elevating IT infrastructures and empowering employees with digital skills.

Digital transformation covers any initiative to use technology to improve operations and activities within the construction industry, it is a big undertaking for a company. However, the benefits of digital transformation to the organisation are evident. The use of digital tools may improve efficiency and reduce operating cost in the long run, thus companies can utilize their resources to other value added activities. Digital transformation also brings potential to open doors to new business opportunities. However, transforming the way an organisation operates is not an easy task, proper planning is needed to ensure successful digital transformation.

In a broader perspective, digital transformation has to begin with top down direction. Leaders need to take initiative to go on with the transformation, taking steps towards digitalisation. Companies may jump start with experimenter or ground breaker digital projects that may not take up much funding for them to gain traction, ensure its success, then win top management buy-in to move forward.

Here are steps that an organisation may need to look at, in embarking to digital transformation:

1. Perform assessment on current situation
   Firstly, a company needs to make an assessment on the digital level of where their company is at.

   a. Identify activities or areas within the company that need improvement or where digital tools can be adopted.
   b. Identify the type of digital tools that can be adopted based on activities or areas that require improvement.
   c. Gauge on resources readiness and identify skills needed.
   d. Assessing current data management of the organisation, whether an upgrade on IT infrastructure is required to handle large volumes of data from the usage of digital tools.
   e. Get a finance team to assess the company's capability in funding the transformation, how much is needed and how much the company is willing to spend and invest on the transformation. Allocate a budget for it.

2. Digital transformation roadmap
   Create a digital transformation roadmap that is suited to the company. Come out with short-term goals, medium-term and long-term goals. Outline set of strategies that will guide the company resources through the transformation process in achieving the goals.

3. Obtaining the right skill sets

Digital transformation involves the use of new technologies that require new skills and expertise, thus the workforce needs to have a certain set of digital skills. Invest on new talents to boost company technical readiness for the transformation.

4. Prepare every level in organisation for transformation
   Regular communication to employees is required before the transformation begins, this is to prepare employees to make themselves ready to embrace changes. Additional soft skills training or motivational seminars will help employees with the upcoming changes.

5. Launching the roadmap
   Once all the preparation is ready and challenges have been taken care off, it is time to launch on the transformation. Perform assessment and evaluate on the effectiveness of the transformation at certain intervals that is set earlier on in the roadmap, make necessary changes accordingly if required. It is important for the organisation to be dynamic, ready to look for new technologies or opportunities even during the transformation because digital tools are advancing rapidly every single day, and the same goes to customer's expectations.

GRANT AND FUNDING SUPPORT

One of the biggest challenges that an organisation may face, before even beginning with the digital transformation is lack of funding, budget constraints. Fortunately, The Government of Malaysia has allotted funding in the form of incentives, grants, workshop and training to businesses of all sizes, in assisting businesses to move towards digitalisation to continue accelerating in Digital Economy via government's agencies such as Malaysia Digital Economy Corporation (MDEC), Malaysian Investment Development Authority (MIDA), Malaysian Technology Development Corporation (MTDC) and The Malaysian Communications and Multimedia Commission (MCMC).

Businesses of all sizes are open to apply for different grants from Malaysia Digital Economy Corporation (MDEC) that are currently made available for different industry verticals. These grants are initiatives by the government to provide support to businesses that need to remain sustainable or expand their operations.

1. Smart Automation Grant (SAG)
   SAG is a matching grant for services companies to automate their business processes and move towards digitalisation. The amount of matching grant is up to 50% of the total project cost or maximum RM200,000.

2. Global Technology Grant (GTG)
   GTG is to nurture global champions, driving investments and catalysing digital innovation. The grant will be used solely for the purpose of technology innovation, development and commercialisation of innovative commercial-driven products or services. There are two types of grants, Technology Company and Technology Accelerator.

a. Technology Company
   GTG targets local scale-up technology companies who are ready to go into their first global or expand their existing global market presence via technology innovation and commercialisation of market-driven product or service. Eligible to local owned and foreign owned companies. Local owners will get grants up to 50% of total project cost or up to RM2 Million whichever is lower.

b. Technology Accelerator
   GTG also targets foreign technologies companies to set up Centres of Excellence to conduct high value technology innovation/R&D activities leading to the development and commercialisation of market driven, innovative product or service for the global market as well as contribute to ecosystem development. The grant is up to 30% of total project cost or up to 2 Million whichever is lower.

3. 4th IR Catalyst Grant (4ICG)
   4ICG is designed to catalyse the use and development of IR4.0 technology into key business verticals as outlined in the National 4IR Policy. The grant will be used solely for the purpose of co-creation, problem-solving and commercialisation of 4IR solutions. Eligible to local companies with grant up to 50% of total project cost or up to RM2 Million whichever is lower. Whereas for foreign owned companies will get up to 30% of total project cost or up to 2 Million whichever is lower.

4. MyDigitalWorkforce Work in Tech (MYWiT) incentives employers to hire Malaysians for digital tech and services jobs via salary and training subsidies. The incentive is funded by the Government of Malaysia to encourage employers to provide job opportunities to unemployed citizens. This initiative offers a 40% salary subsidy for 6 months and training incentives for in-house or external or third-party training.

5. MDEC also provides training in supporting People's development; an Enabler 1 in Construction 4.0 Plan. Digital Skills Training Directory is a catalogue of courses and online training providers to guide Malaysians in selecting courses that meet career needs for digital economy jobs.

Malaysian Investment Development Authority (MIDA), a government's principal investment promotion agency for the development of the manufacturing and services sectors in Malaysia listed Industry4WRD Intervention Fund, a financial support facility for Malaysian SMEs in the manufacturing and related services sectors to embrace Industry 4.0. This fund is eligible for all SMEs which have completed the government-funded Industry4WRD Readiness Assessment (RA) programme. MITI has appointed MIDA as the Implementing Agency for the Industry4WRD Intervention Fund. The fund is up to a maximum of RM500,000.

There are also funding facilities available from Malaysian Technology Development Corporation (MTDC).

1. Business Start-up Fund (BSF) is established to fund early stage technology-based companies. The Fund incorporates elements of loan and equity, offering companies flexible funding via Convertible Promissory Notes (CPN) and/or Preference Shares. Funding worth a maximum of up to RM5.0 million or 90% of the total project cost, whichever is lower.

2. Business Growth Fund (BGF), a funding program that focuses on growing the company not only on its production output and reach, but also on internal preparedness towards professionalism, corporate governance, and all the necessary tools to escalate the company to the next level. Funding worth a maximum of up to RM10.0 million.

3. National Technology and Innovation Sandbox (NTIS) is a national initiative which serves as a safe place to allow innovators to test their products, services, business models and delivery mechanisms in a live environment with relaxations on all or specific processes and/or regulatory requirements. In support of the NTIS programme, MTDC offers the NTIS Fund which will finance relevant activities under the programme. The fund is by categories, which may go up to RM4 million.

The Digital society Research Grant (DSRG) by The Malaysian Communications and Multimedia Commission (MCMC). DSRG builds the research evidence base necessary to promote and improve the understanding of the human and social factors, which affects and contributes to the adoption and usage of digital technologies and services. In so doing, DSRG funded research works provide inputs in ensuring that the advancements in communications infrastructure and services contribute to the inclusion and participation of all segments of the population in the realisation of a Digitally Connected and Informed Society (Digital Society).

SUMMARY

Relatively, digital technology adoption in the construction industry in Malaysia is growing, albeit at a slower pace compared with other industries such as manufacturing, finance, retail and commerce. Nonetheless, the trend is prevalent worldwide, the construction industry is rather slow in adopting digital technologies, most likely due to its complexity, diverse and fragmented. However, Covid-19 pandemic is an eye opener, during the pandemic, construction industry has took a beating, facing with labour shortage and increase in material cost which took them almost to a grinding halt, only then the industry started to utilise the use of digital technologies to make way through the pandemic and started to gain momentum since then. Similarly in Malaysia, receptiveness to technological adoption within the construction industry is improving.

Construction 4.0 Strategic Plan has been formulated to guide the Malaysian construction industry to embrace digital transformation to increase productivity by reducing the dependence on low-skilled labour and to adopt smart construction philosophy to become more resilient in the increasingly competitive market. Site preparation for construction digital roadmap is specifically drafted to guide the construction industry to harness digital technologies on site preparation activities.

The construction industry is now entering a new territory, a digital era. The time is now for the construction company in Malaysia to adapt and adopt digital solutions in their organisation and operation so as not to be left behind in competing for construction projects. The company must first come out with its own digital transformation roadmap that defines plans and strategies with a realistic timeline to integrate digital tools in the organisation. Know where the company’s level of adoption is at first, start investing in digital tools realistically with the company's financial strength. Focus on four enablers namely people, integrated technology, governance and economy, which has been identified in Construction 4.0 Strategic Plan. The roadmap needs to be accompanied with a disaster recovery plan to safeguard the company's digital infrastructure against natural disasters or cyber-attacks.

Lack of funding is often the biggest gating that hinders companies from growing with the transformation especially for SMEs. It is understandable, because digital transformation is not only about investing in digital tools itself, resources need to be prepared and trained, IT infrastructure needs to be upgraded to facilitate the use of digital tools. No matter how good the roadmap is, without enough funding, the plan may not work well. Companies need to source for funding from financial institutions or apply for incentives, grants and soft-skills training through government agencies.

Digital transformation will enhance customer satisfaction, bring new opportunities for the better, opening up new possibilities in the new digital era. Digital transformation for construction needs to start now or elevate for those that has started. The transformation is not expected to occur overnight, it is a one step process at a time, one technology adoption at a time.

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GLOSSARY

Advanced building materials	Development of new materials for the industry by integrating new technologies and processes to create a better product.
Advanced manufacturing processes	Use of innovative technologies to create existing products and the creation of new products. Advanced manufacturing can include production activities that depend on information, automation, computation, software, sensing, and networking.
Artificial intelligence	Allowance for machines to imitate the human cognitive functions to enable machines to conduct tasks that is usually performed by humans via a set algorithm.
Augmented reality	An interaction between human and computer which would enable an individual to distinguish both virtual and real-world object(s).
Autonomous construction	Automatic assembly method of construction tasks by applying robot that is controlled using computer process and mechanisation.
Big data	Efficiently handle large amounts of projects data by efficiently storing, managing and processing using a commodity server.
Blockchain	Distributed ledger of database in which information, records of transactions, internet protocol and others can be maintained across a network of computers.
Building information modelling (BIM)	A central repository which requires integration of fragmented disciplines of architecture, engineering and construction, and to optimise the lifecycle performance of buildings.
Cloud and Realtime collaboration / cloud computing	Internet centric to provide free flow of information within the construction professionals and offering a huge amount of storage resources.
Construction 4.0	Process to implement modern technology in order to encourage the digitisation of the construction industry and its supply chain.
Cyber security	Measures taken to protect a computer or computer system (as on the Internet) against unauthorized access or attack
Data analytics	The process of collecting, organising large data sets to discover different patterns and other useful information.
Distributed ledger	A novel and fast-evolving approach to recording and sharing data across multiple data stores (or ledgers). This technology allows for transactions and data to be recorded, shared, and synchronized across a distributed network of different network participants.
Document management system	An automated software solution where it is use to organise, capture and digitise documents
E-submission	Economic operators to respond to calls for tenders by preparing their tenders electronically in a structured and secured way and submitting their tenders electronically.

Human-machine interfaces	User interface or dashboard that connects a person to a machine, system, or device. The term can technically be applied to any screen that allows a user to interact with a device.
Industrial revolution	The development or changes in the way of goods or services being produced and work being organised.
Information and communication (ICT)	Synergy between computers and communication devices and forms an important part of the modern world.
Information technology	Technology which uses computers to gather, process, store, protect, and transfer information.
Intelligent products	A product that has part or all of the following five characteristics: Possesses a unique identity, capable of communicating effectively with its environment, can retain or store data about itself, deploys a language to display its features, production requirements etc. and capable of participating in or making decisions relevant to its own destiny.
Internet of Things (IoT)	Is a system that enables in detecting the surrounding environmental conditions which sense by objects and devices and have an unique identifiers (UIDs) or ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.
Laser scanning	A method of high-accuracy mapping or reality capture that uses laser beams to quickly capture complete detail of the entire building construction project - much like a camera taking a 360-degree photo, but with an accurate position for every pixel.
Machine learning	A field of computer science that studies algorithms and techniques for automating solutions to complex problems that are hard to program using automating solutions to complex problems that are hard to program using conventional programming methods.
Machine-to-machine communications	Information and communications technologies (ICT) able to measure, deliver, digest and react upon information in an autonomous fashion, i.e., with no or really minimum human interaction during deployment, configuration, operation and maintenance phases.
Mixed reality	Merge real and virtual worlds to create a new context of interaction where both physical and digital objects co-exist and interact consistently in real life.
Mobile information	Systems that rely on wireless communications and support mobile applications that typically run on wireless devices such as smartphones and mobile phones.
Modelling and simulation	A process of driving a model of a system with suitable inputs and observing the corresponding outputs.
Natural Language Processing	The application of computational techniques to the analysis and synthesis of natural language and speech
Prefabrication and modular	A completed manufacturing process for volumetric units of

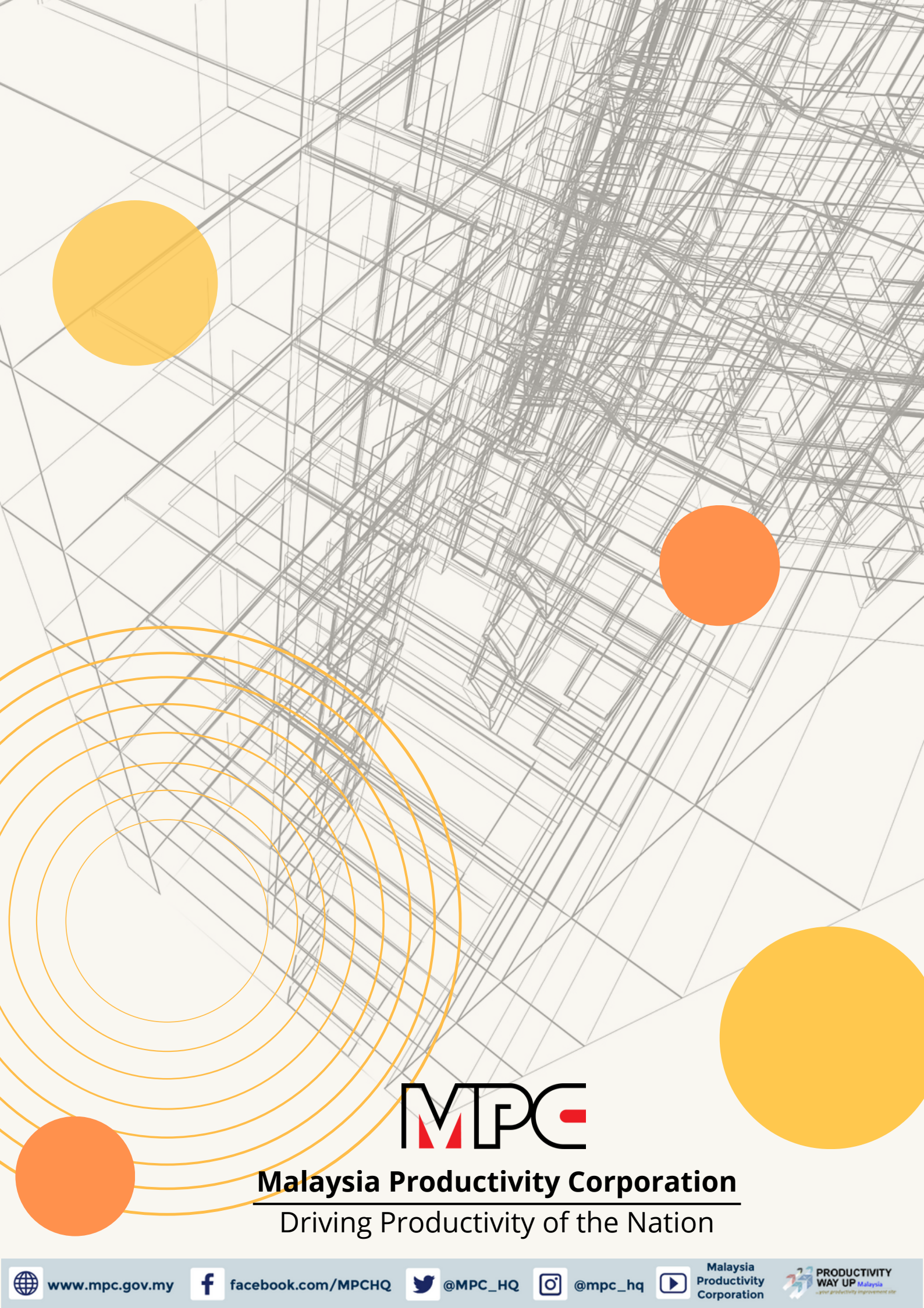
construction	building construction systems that generally made/ assembled in factory to form as a component prior to final installation on site.
Radio-frequency identification	A remote identification system using radio waves of different frequencies.
Rapid Deployment Cameras	An all in one security system designed for rapid installation, portability and visibility at temporary or remote sites
Robotics	Mechanical or electrical engineering coupled with computer science used to design, construct, operate, and apply robots. It also includes the computer systems for their control, sensory feedback, and information processing. Where a robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks.
Self-assembly	A process in which a disordered system of pre-existing components forms an organized structure or pattern as a consequence of specific, local interactions among the components themselves, without external direction.
Self-healing materials	A material that is capable of repairing itself back to the original state.
Smart construction	Smart construction is building design, construction and operation that through collaborative partnerships will fully utilise digital technologies and industrialised manufacturing techniques to improve productivity, minimise whole life cost, improve sustainability and maximise user benefits.
Smart glasses	Wearable computer glasses that add information alongside or to what the wearer sees.
Smart helmets	A new type of human machine interface that connects in between people, data and machines and able to redefining the future of work by empowering workers with the latest in augmented reality and Internet of Things technologies.
Smart manufacturing	A technology-driven approach that utilises Internet-connected machinery to monitor the production process.
Smart sensors	A sensor that provides functions beyond those necessary for generating a correct representation of a sensed or controlled quantity.
Virtual reality	A simulated experience that can be similar to or completely different from the real world a simulated experience that can be similar to or completely different from the real world.
Wireless Monitoring & Connected Equipment / Unmanned Aerial Vehicle (UAV) / Drones/ Autonomous Vehicles/ Autonomous Plants	Is an intelligent autonomous systems that able to operate complex task in a dynamic and uncertain environment using wireless communication support, monitoring targets of interest, serving a wireless sensor network, and collaborating with ground robots.
3D printing	A process to create or recreate a physical object that modelled in digital version by depositing layers of materials.

3d scanning and photogrammetry	Data acquisition as point cloud data and mapping tool with the ability to interpolate a photograph to become 3D models for changes monitoring.

ABBREVIATIONS

3DCP	3D Construction Printing
4ICG	4th IR Catalyst Grant
4IR	The Fourth Industrial Revolution
ADAS	Advanced Driver-Assistance System
AEC	Architecture, Engineering and Construction
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
AR	Augmented Reality
B.Q.	Bills of Quantities
BGF	Business Growth Fund
BIM	Building Information Modeling
BSF	Business Start-up Fund
CAD	Computer Aided Design
CMMS	Computerised Maintenance Management System
CPN	Convertible Promissory Notes
CPT	Cone Penetration Test
CWMP	Construction Waste Management Plan
DMS	Document Management System
DNB	Digital Nasional Berhad
DOSH	Department of Occupational Safety and Health
DRP	Disaster Recovery Plan
DSRG	The Digital society Research Grant
ECRP	East Coast Rail Link
ECS	Elastic Computer Service
EML	Electromagnetic Locator
ESCP	Erosion and Sedimentation Control Plan
FMT	Free Malaysia Today
GDP	Gross Domestic Product
GIS	Geographic Information System
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GTG	Global Tech Grant
GWh	Gigawatt hour
HVAC	Heating, Ventilation and Air Conditioning
IBS	Industrialised Building System
IoT	Internet of Things
IPP	Independent Power Resources
IR4.0	Industrial Revolution 4.0
IT	Information Technology
IWK	Indah Water Konsortium
IWRM	Integrated Water Resources Management
JKR	Jabatan Kerja Raya
JUPEM	Department of Survey and Mapping
KVMRT	Klang Valley Mass Rapid Transit
LiDAR	Light Detection and Ranging
M2M	Machine to Machine
MBAM	Master Builders Association Malaysia
MCMC	The Malaysian Communications and Multimedia Commission
MDD	Maximum Dry Density
MDEC	Malaysia Digital Economy Corporation
MIDA	Malaysian Investment Development Authority
ML	Machine Learning

MLD	Million Litre per Day
MOHE	Ministry of Higher Education
MOSTI	Ministry of Science, Technology and Innovation
MRCT	Mass Rapid Transit Corporation
MRO	Maintenance, Repair and Overhaul
MTDC	Malaysian Technology Development Corporation
MW	Megawatt
MYWiT	MyDigitalWorkForce Work In Tech
NCP	National Construction Policy
NFCP	National Fiberisation and Connectivity Plan
NLP	Natural Language Processing
NTIS	National Technology and Innovation Sandbox
NWRC	The National Water Resources Council
PAAB	Pengurusan Aset Air Berhad
PMS	Project Management Software
PNB	Permodalan National Berhad
PPE	Personal Protective Equipment
PV	Photovoltaic
PwC	PricewaterhouseCoopers
QAP	Quality Assurance Plan
R&D	Research and Development
REHDA	Real Estates and Housing Developers Association
RFID	Radio-Frequency Identification
RMM	Remote Monitoring and Maintenance
ROI	Return of Investment
ROW	Right of Way
RPO	Recovering Point Objective
RTO	Recovering Time Objective
S-Plan	Safety and Health Plan
SAG	Smart Automation Grant
SESB	Sabah Electricity Sdn Bhd
SME	Small and Medium Size Enterprise
SPAN	National Water Service Commission
SPT	Standard Penetration Test
SQL	Structured Query Language
STP	Sewage Treatment Plant
TNB	Tenaga Nasional Berhad
UAV	Unmanned Aerial Vehicles
UBBL	Uniform Building By-Law 1984
UTM	Universiti Teknologi Malaysia
VMS	Vaccine Management System
VR	Virtual Reality
VST	Vane Shear Test
WEF	World Economic Forum



Malaysia Productivity Corporation

Driving Productivity of the Nation