HOUSING DESIGN

DIGITAL ROADMAP

MALAYSIA PRODUCTIVITY CORPORATION

DIGITAL ROADMAP FOR HOUSING DESIGNS

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Architecture, Engineering and Construction	AEC
Artificial Intelligence	AI
Augmented Reality and Virtual Reality	AR VR
Building Information Modelling	BIM
Common Data Environment	CDE
Computer Aided Design	CAD
Distributed Ledger Technology	DLT
Geographic Information System	GIS
Internet of Thing	IoT
Micro, Small and Medium Enterprise	MSME

FOREWORD

YB Dato' Seri Mohamed Azmin Ali
Senior Minister,
Ministry of International Trade and Industry (MITI)

"Digitalisation drives productivity. It enhances connectivity and transactions among businesses, peers, and customers beyond geographical borders. The development of the Housing Design Digital Roadmap by Construction & Built Environment Productivity Nexus (COBEPN) is an apt move to modernize the tourism industry and propel it to the high-yield market segments.

Digitalization beyond borders enables the tourism industry players to reach bigger and broader audiences to promote and market tourism products and services. There is an urgent need to innovate and update Malaysia's construction to match the changing consumer expectations. Health, safety, and security become significant novel elements in the construction business. Technology and digitalization can facilitate the growth of tourism in the new era.

Congratulations to Malaysia Productivity Corporation (MPC) and CPN for publishing this document. I hope to see similar references tackling the diverse aspects of the construction industry"

FOREWORD

YB Dato' Sri Mustapa bin Mohamed
Minister in the Prime Minister's Department (Economy)

"During the duration of the Twelfth Malaysia Plan, the priority is on rebuilding the economy and repositioning Malaysia on a stronger foundation for sustainability and resilience. The pandemic in the past two years severely affected Malaysia's construction industry. 2022 began with a positive note as SOPs were relaxed and Malaysia entered the endemic phase. The stakeholders in the industry have the monumental task of reinvigorating Malaysia's construction industry and bringing its productivity to positive growth.

At the core of rebuilding Malaysia's construction industry is the adoption of digital technology. The Strategic Plan under Construction 4.0 implementation will be fueled by four enablers, namely; people integrated technologies, economy, and governance. The four enablers must work in synchronicity in developing a future-ready workforce from the grassroots and give rise to home-grown technologies. Most importantly, the existing legal framework surrounding construction must be strengthened and reviewed to encourage the adoption of new emerging technologies.

I urge the industry players to leverage the guidance in this digital roadmap to transform the construction business. Restoring the dynamism of Malaysia's businesses requires the digitalization of the economy. As one of the main contributors to the country's economy, the construction industry is no exception".

FOREWORD

YB Dato' Sri Haji Fadillah bin Haji Yusof
Senior Minister of Infrastructure, Ministry of Works

Housing Design Digital Roadmap is a roadmap for the Malaysian Construction Industry to embrace the Fourth Industrial Revolution (IR 4.0) in ways that would transform its productivity and competitiveness.

Through the Strategic Plan, we envision being the leading country in the implementation of IR 4.0 for the Construction industry in the Southeast Asia Region. This can be achieved by transforming the Malaysian construction industry towards embracing smart construction.

Housing Design Digital Roadmap transformation will certainly not happen overnight. The industry players must convince and the necessary investments must be made by both the private and the public sectors toward technology adoption. As a nation, we must strive to be at the forefront of technological advancement or we risk being left behind.

I urge all construction industry stakeholders to play an active role and collaborate with the industry players towards ensuring the achievement of all Construction 4.0 objectives and goals, thus creating a tremendous positive impact on the construction industry in Malaysia".

CHAPTER 1

OVERVIEW OF MALAYSIAN CONSTRUCTION INDUSTRY

The construction industry is one of the crucial sectors that contribute to the development of gross domestic product (GDP). The landscape of the whole industry, including the Malaysian construction industry, has changed dramatically due to the construction sector's rapid development. The dynamic nature and interrelated with the other sectors have led the construction sector to keep plays an important role in the Malaysian economy. This industry is crucial for providing the socioeconomic infrastructure to increase industrial production and growth as well as basic amenities like housing and commercial space, parks, playgrounds, and stadiums, health care facilities, ports, airports, dams, power generating and supplying stations, communication utilities, as well as other basic infrastructure required for the country's growth and improvement of societal living standards.

Presently, the performance of construction sector has given a positive impact to the success of other economy. It can be characterised as a type of economic engine for economies in both developed and developing countries. The development of the country is significantly dependent on the income and higher standard of living that the building industry contributes to. Furthermore, it helps the economy create a significant amount of employment. As early after gaining the Malaysia independence, the Government had realised the importance of construction industry to the economy and started to boost up its implementation. Although construction sector contribution is smaller than the other sectors such as services, manufacturing and agriculture, however the construction project are able to attract the foreign investors and become one of the key economic sectors of the Malaysian economy (Khan et al., 2014). However, rapid development of Malaysian construction industry has impacted the productivity not only in Malaysia, but the whole construction sector around the world. In Malaysia, the Movement Control Order (MCO) that has been enforced by the Government due to Covid-19 pandemic cause the construction sectors to stop and not operated at full capacity and capability.

A report by Department of Statistics Malaysia (2022a) stated that the value of construction work done in the second quarter of 2022 progressed to improve at 6.1% with RM 29.9 billion compared to the first quarter of 2022 with RM 29.5 billion. Non-residential buildings recorded the positive growth from 4.2% to 18.1% comparing to the first quarter and second quarter respectively. However, by looking into the highest growth from four main activities in construction sector, residential buildings recorded a positive growth increment from -11.9% in first quarter of 2022 to 7.9% in the second quarter of 2022. As the Government has already moved into endemic phase from the pandemic of Covid-19 phase, it has caused the growth of most sectors in Malaysia especially in construction industry.

Furthermore, the reports also highlighted that the civil engineering activities continued to become one of the main activities that contributed to the work done at 36.6% share followed by non-residential buildings (31.4%). Both public and private sectors contributed almost same share to the growth of Malaysia construction industry. 41.9% share at RM 12.5 billion from the public sectors while the remaining 58.1% share of the private sectors has been recorded up until second quarter of 2022. Selangor, the Federal Territory and Sarawak is among the top three highest contributor for construction sector in quarter two 2022. The detail of the growth is shown in Figure 1. **Error! Reference source not found.**.

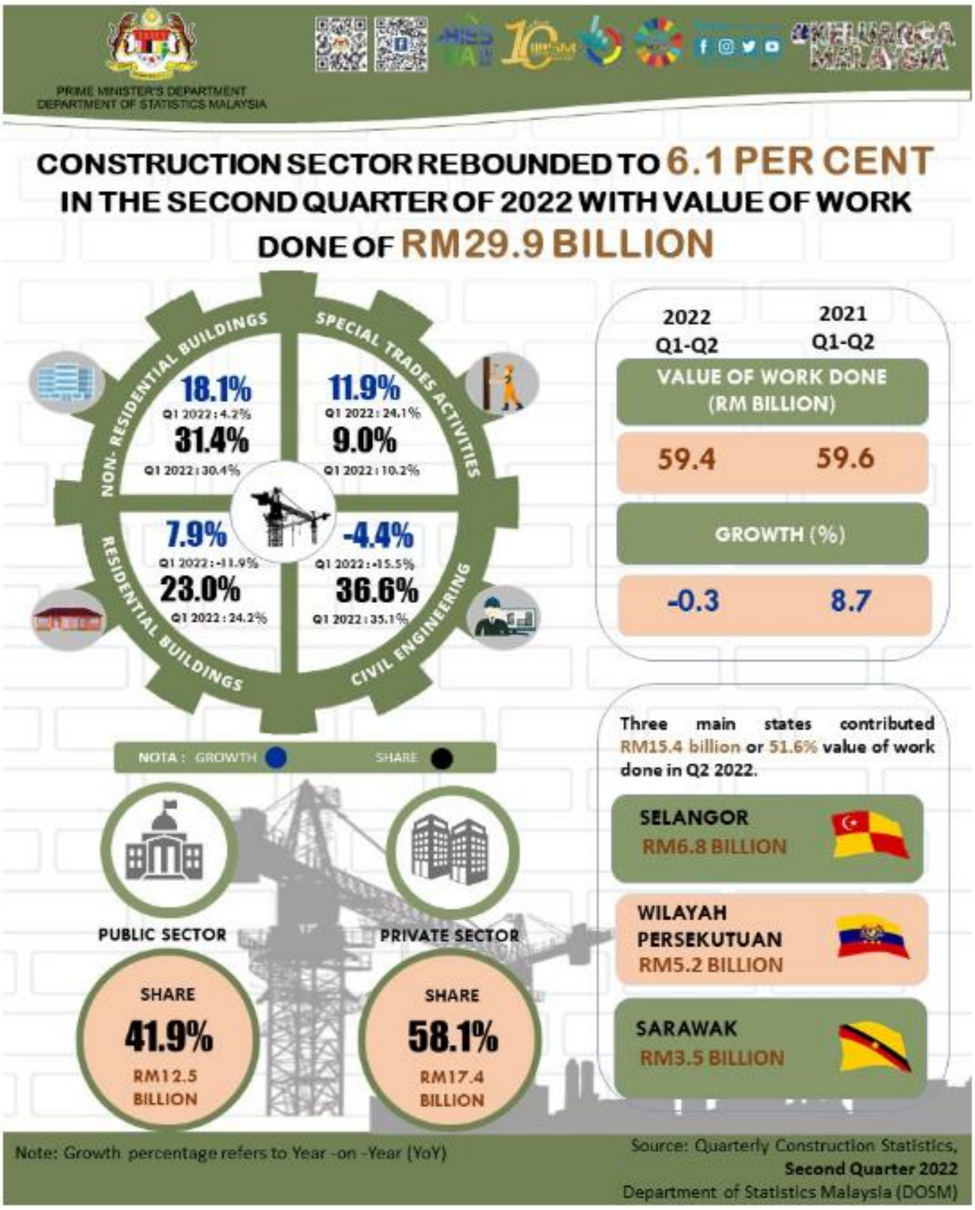


Figure 1. The growth of construction work done in the Second Quarter 2022

However, the digital tsunami waves that impact globally has changed the landscape of construction industry. The bloom of Fourth Industrial Revolution has hit most of the sectors whereby the construction industry has undergone digital transformations known as Construction 4.0. Through the digital transformation, all level of stakeholders is affected, especially the Micro, Small and Medium Enterprises (MSMEs) where they need to catch up with the digital transformation at a high pace to ensure competitiveness and capabilities to deliver the work done. This is where the digital transformations will not be beneficial to those who are still implementing the traditional working environment but for those who applied it in their working environment, surely it will affect the productivity and quality of works.

CHAPTER 2

TRENDS IMPACTING CONSTRUCTION INDUSTRY

2.1 Building Information Modelling (BIM)

New digital technologies in visualisations have evolved from freehand drawing, drafting equipment, and computer-aided design (CAD) into a new horizon of construction industry, called as Building Information Modelling (BIM). BIM is a process that incorporates digital representations of buildings in 3D models to facilitate better collaboration among all stakeholders on a project. This can lead to better design and construction of buildings. Changes to the BIM model occur in real time, so any changes or updates to the model are instantly communicated to all team members when they access the model. Everyone is working with the most up-to-date information at all times. Because the schedule can be simulated, a visual representation of the construction process allows team members to plan out each phase of construction (Jones, 2020).

To keep updated with productivity and innovation with the latest digital transformation, people and organisations will need to embrace digitalization. The global adoption of BIM has pushed most country to adapt to the changes that the global construction sector is undergoing. World Economic Forum (2018) highlighted the value of BIM as the industry's cornerstone through the use of a variety of technologies, including prefabrication, automated machinery, and mobile apps. BIM adoption requires a collaborative and integrated platform as well as commitment from key industry stakeholders throughout the whole construction lifecycle. More over 30% of all projects are implemented using BIM globally, according to a report by (McGraw Hill (2014), albeit the percentage varies by location.

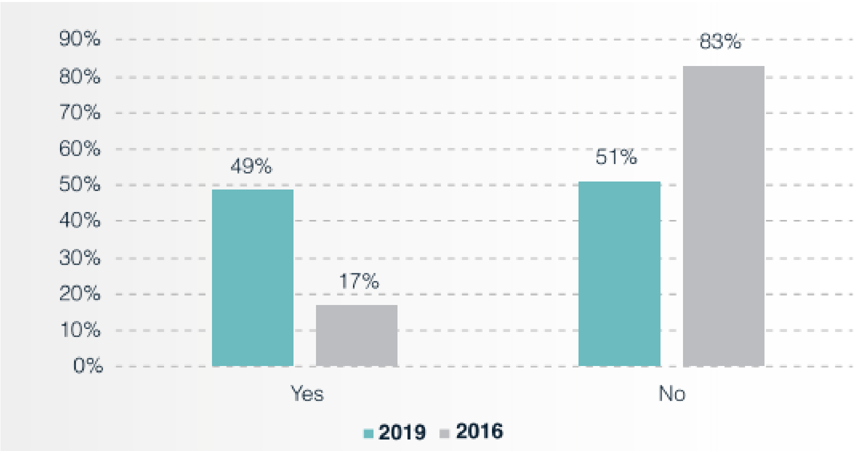


Figure 2. BIM adoption in Malaysian construction industry (CIDB, 2019)

The adoption of BIM in Malaysian construction industry rose at high percentage. According to Malaysian BIM Report 2019, the BIM adopters in Malaysia increase more than half from the previous research back in 2016 with 49% (2019) and 17% (2016) (Figure 2). The rise in BIM adoption could impact the digital transformations that currently happened in 2022 where the digital environment especially in housing construction will further being evaluated and monitored.

The housing business encountered the issue of speed, quality, and efficiency, thus finding solution to create more high-quality homes at affordable prices is of utmost importance. Through digital working, offshore construction, and lean site assembly, a strong, sustainable, viable, integrated building process can offer a substitute for traditional construction approaches. BIM technology will be advantageous to all stakeholders in achieving the technology's full potential after endeavors to build housing through digitalization.

BIM technology enables the players in the housing building industry to address significant concerns such budget overrun, QC issues, and project delays. The entire building documentation process is increasingly likely to be impacted by the BIM, moving away from traditional architectural drawings and toward a digital model.

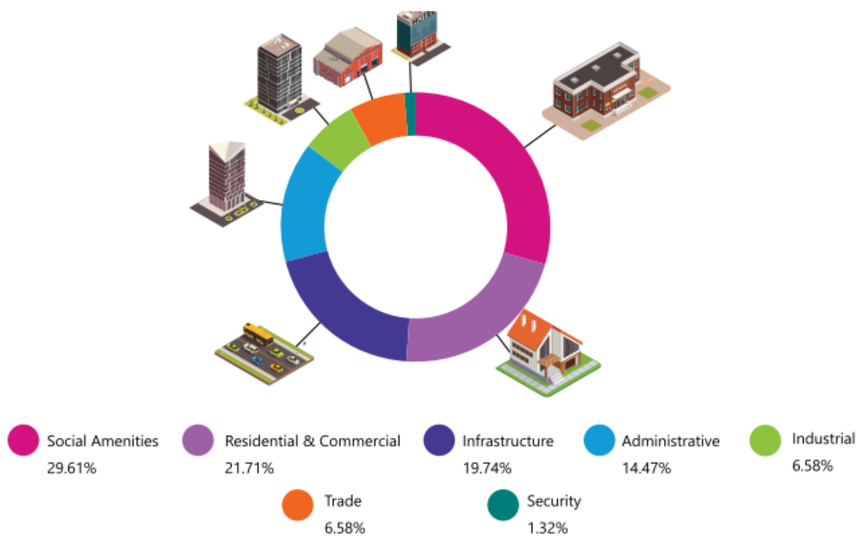


Figure 3. Residential and commercial BIM adoption rate in 2022

Through the research conducted by CIDB (2022), residential and commercial projected the second highest of BIM adoption among 517 construction projects in Malaysia worth RM 50 million and above. Through this digitalisation, it will further impact the whole construction industry to ensure the implementation of BIM in future will increase drastically to every level of stakeholder. The big question is, how far BIM will be implemented in other area of construction?

2.2 Cloud Computing

Construction housing companies are seeking new ways to drive down infrastructure and operational costs. As such, the industry is not buoyant for the massive IT infrastructure, which requires expert human resources and training to manage. Therefore, cloud computing technologies have given construction enterprises, particularly MSMEs, the chance to access leading edge computer infrastructure and applications that might otherwise be very expensive to buy. This will certainly lead to a decrease in the overall project delivery cost, offering construction businesses a strategic and competitive advantage. The cloud computing technology increases construction agility by removing ownership and operational costs and only paying for actual consumption (Bello et al., 2021).

Data and information are generated over the life cycle of a project, that various modelling simulations are necessary for the experts to turn the owner's conceptual building plan into a workable design. The adoption of advanced technologies like IoT, augmented reality, and 5D BIM continuously creates huge amounts of data. On a normal computer, an aerial image of a location that would take up space on a cloud storage will use hundreds of GBs. Due to the huge volume of data and the capability of hardware infrastructure, on-site storage of construction data has always been a challenge. Furthermore, on-site data storing would require physical access with the availability of unlimited cloud data storage. Hence, the full utilisation of cloud storage will open up the opportunity and potential for construction industry to go for digitalization (Bello et al., 2021).

A variety of computing services, including storage, databases, networking, servers, software, and analytics, can be handled over the "cloud" (the internet) using cloud technologies which enables the construction experts' access to more quicker and adaptable resources and tools. In fact, the project team members such as architects and engineers can engage on the BIM model with the assistance of cloud computing even all of them are in different locations. Indirectly, it will improve the time consumption as well as productivity to check and verify the construction drawing and model.

Table 1. Cloud Service Type and function

Cloud Provider	Cloud Service	Service Model	Service Function
Amazon	EC2	IaaS	Server
Amazon	S3	IaaS	Storage
Google	GAE	SaaS	Development Environment
Microsoft Corp	Windows Azure	IaaS	Storage
Microsoft Corp	Office 365	SaaS	Office Suite
Salesforce	Salesforce Service Cloud	SaaS	Customer Relationship Management

CDC Software APTEAN	Pivotal CRM	SaaS	Business Customer Relationship
eBid Systems	ProcoreWare	SaaS	Procurement System
Procore	Procore Construction Project Management Software	SaaS	Project Management System
e-Builder	e-Builder	SaaS	Construction Management Software
Oracle	Aconex	SaaS	Project Management System
Amazon	AWS EMR	SaaS	Hadoop Framework

Table *1* shows different type of cloud service and function. It seems that different cloud provider provides different function for own purpose. With construction projects featured with high fragmentation, and different teams having little or no synchronization, it is expected that the cloud-based collaboration solutions, addressing the gap efficiently.

With several project participants and teams widely dispersed, it is evident that the project complexity increases, and the key to success are effective project team collaboration (Georgiou, 2022).

2.3 Artificial Intelligence (AI) & Machine Learning

Data is increasingly being used by the construction industry to improve decision-making, productivity, workplace safety, and risk management. Businesses can utilise the huge data that have been gathered over the years to forecast future project outcomes and gain a competitive advantage when estimating and bidding on construction projects by using artificial intelligence (AI) and machine learning technologies.

AI can enhance the productivity of worker by reducing the time wasted in construction site for example, retrieve tools, materials, and equipment to deliver certain tasks. Throughout the day, the employees are tracked and monitored using wearables or smartphones.

Materials and equipment with installed sensors keep track of how everything else moves around the construction site. When sufficient data is gathered, AI will analyze how workers move around and interact with the site to identify ways to re-organise the positioning of tools and supplies to improve worker accessibility and decrease downtime (Jones, 2020).

The conceptualization, design, and planning phases are essential to the success of a construction projects. Any project must be completed on schedule, with high quality, and within the allotted budget. In normal situation, Designers, engineers, and architects will spend hours of discussion to work out on the housing design. The process of producing alternatives design and examining the building's architectural statics and other parameters takes a lot of time (e.g. compliance with building regulations, does the building fulfil all functional requirements, and so on).

Here, the role of AI will be useful where it can create the generative design that might provide few alternative model or design to the stakeholders. An AI-based system that has access to a database of various building plans that have already been constructed is able to create design alternatives using the information it learns from the database's designs. The generative design programme allows designers and engineers to easily enter design objectives together with criteria like required space, performance, materials, financial restrictions, and many more. Hence, the software will examine all potential variations of a solution, utilising artificial intelligence to produce design options that satisfy all previously defined parameters. The software then gains knowledge about alternative design options with each iteration, improving as a tool with each new project.

This is a significant advance over the previous scripting because it allows for the consideration of many more factors and permutations. It will left the designer or engineer to choose their most desirable design or model from the available options. Designing with generative design enables user to quickly develop the most effective designs depending on any parameters provided, allowing for quicker, better-quality, and more affordable planning and design. Generic design can potentially boost creativity in addition to these improvements. First, it makes the most feasible to find methods for building curves and shapes that previously were simply a fantasy of architects. Second, generative design occasionally offers engineering and design solutions that designers and engineers could not have otherwise thought of.

Designers and engineers in the AEC (architecture, engineering, construction) sector are now begin to apply generative design. According to recent research and polls, almost one-third of engineers and architects are currently at least experimenting with generative design. Due to its benefits, it is fair to believe that the AEC sector will continue to adopt generative design. Challenges and delays in the design stage, which are particularly common in major projects, can cause delays in construction projects. One factor is the necessity to avoid conflicts with utilities, which is important for initiatives to build urban infrastructure in particular.

Engineer teams used to spend weeks comparing blueprints with the utilities surrounding the construction site. This method involves a lot of time- and money-consuming reworks and reevaluations. AI can make this procedure much simpler. In a short time, artificial neural networks can detect collisions without the assistance of technical teams. This will be beneficial to those who are poor in design and construction engineers. AI can identify possible utility conflicts as well as resolve them and adjust the drawing or model as necessary (Schober, 2022).

Every stage of a project's lifespan, including design, construction, post construction, and facility management, has the potential to be benefited by the application of AI in the construction industry. It might even help organization business models grow. AI helps the construction industry as a whole address some of its most challenging issues, including safety concerns, labour shortages, and cost and schedule overruns. There are several uses for AI and machine learning in the construction sector. Information requests, unresolved issues, and change orders are common in the industry. This ocean of data can be examined by machine learning in a knowledgeable assistant-like manner. The critical concerns that demand project managers' attention are then disclosed. AI is already applied in many different ways. Its benefits include everything from straightforward spam email filtering to intricate safety monitoring (Rao, 2022).

Table 2. Various AI Application for construction (Rao, 2022)

Advantage of AI	How AI Provide Benefits in Construction
Prevent cost overruns	Despite having the best project teams, the majority of mega projects run over their budget. On projects, artificial neural networks are used to forecast cost overruns depending on variables including project size, contract type, and project managers' level of expertise. Predictive models use past data, such as identified start and finish dates, to create realistic project schedules in the future. AI enables personnel to remotely access hands on training materials that

	quickly improve their abilities and knowledge. As a result, it takes less time to integrate new resources into projects. Delivery of the project is accelerated as a result.
Improved building design through generative design	Building information modelling is a 3D model-based technique that provides architects, engineers, and construction workers with information they can utilise to effectively plan, design, build, and manage infrastructure and structures. The architecture, engineering, mechanical, electrical, and plumbing (MEP) plans, including the order of the respective teams' activities, must be considered in the 3D models during planning and designing a project's construction. There is needs to ensure that the various models from the various sub-teams do not conflict with one another. To discover and resolve conflicts between the various models produced by the different teams, the industry leverages machine learning in the form of AI-powered generative design. This reduces the need for rework. There is software that explores every possible variation of a solution and generates design alternatives using machine learning algorithms. The generative design software develops 3D models suited for the constraints when the user enters their requirements into the model. Iteratively creating models, it learns from every single model and start to quantify the best solution after all.
Enhanced risk mitigation	Each construction project involves some level of risk, which can take many different forms, including quality, safety, time, and cost risk. The more subcontractors working on various trades simultaneously on worksite, the bigger the project, the greater the risk. General

	contractors can now monitor and prioritise risk on the job site using AI and machine learning solutions, allowing the project team to concentrate their limited time and resources on the biggest risk issues. Issues are automatically given a priority using AI. To reduce risk, project manager can engage closely with high-risk teams by rating subcontractors depending on their level of risk.
Improve project planning	One organisation specialising in construction intelligence launched in 2017 with the idea that the use of robotics and artificial intelligence will be the solution to the problem of building projects running late and over budget. A deep neural network is used by the corporation to classify how far along various sub-projects are after autonomous robots scan construction sites in 3D. The management team can intervene if things start to go awry to deal with minor concerns before they turn into more serious ones. Future algorithms will adopt "reinforcement learning," an AI method. By making poor decisions, this method enables algorithms to learn. Based on previous projects, it can evaluate an unlimited number of combinations and options. Since it optimises the optimal path and corrects itself over time, it assists with project planning.
Productive worksites	Organizations have begun to offer self-driving machine to carry out repetitive tasks—like pouring concrete, laying bricks, welding, and demolition—more effectively than their human counterparts. With the aid of a human programmer, autonomous or semi-autonomous bulldozers may precisely prepare a job site through excavation and prep work. This minimises

	time required to finish the task and frees up human personnel for the actual construction labour. Project managers can also track the development of a worksite through real time. To evaluate employee productivity and compliance to protocols, the implementation of facial recognition software, on-site cameras, and other comparable technologies are highly dependent.
Increase construction safety	OSHA recorded construction workers deaths' rate are five times higher than other laborers. Falls, being struck by an object, electrocution, and being caught in between or between objects were the major causes of fatalities in the private construction sector (apart from fatalities resulting from traffic accidents). A Boston company has developed an algorithm that examines images from its worksites, looks for safety risks like employees who aren't wearing protective gear, and compares the images with its accident reports.
Tackle issue of labor shortages	Due to labour shortages and a need to increase the low productivity of the sector, construction companies are urge to invest in AI dan data science. The after effect of these might increase efficiency up to 50% with real-time data analysis, according to a 2017 McKinsey report. AI and machine learning are being used by construction companies to improve labour and equipment distribution planning. Project managers can instantly determine which construction sites will have enough personnel and equipment to complete the project on schedule. There might be a possibility to identify which projects that might be lagging behind where more labour need to be deployed.

Off-site construction	The implementation of off-site construction enables the construction of housing will be completed faster due to productivity increment and efficiency. However, the implementation of autonomous robots in off-site factories enable the building components to be assembled off-site at factories which next pieced together by human workers on-site. The core structure such as wall, column and slab can be completed assembly-line style by autonomous machinery more efficiently. This will leave the detail work such as mechanical, electrical and plumbing (MEP) services to be completed by human. However, the installation of MEP also can be done through automation at advanced digital factory.
AI and big data in construction	AI systems are exposed to an infinite quantity of data to learn from and improve daily at a time when large amounts of data are being created every day. Every construction site becomes a potential source of data for AI. A pool of information has been created from the data produced by photos and videos taken with mobile devices, drone footage, security sensors, building information modelling (BIM), and other sources. At a time when a massive amount of data is being created every day, AI systems are exposed to an endless amount of data to learn from and improve every day. Every job site becomes a potential data source for AI. Data generated from images captured from mobile devices, drone videos, security sensors, building information modeling (BIM), and others have become a pool of information. This offers the chance for clients and professionals in the construction sector to evaluate and benefitted from the data insights

	generated with the use of AI and machine learning systems.
AI for post-construction	Building managers can apply AI even after the housing construction is complete. The operation and performance of a building, bridge, road, or anything in the built environment can be gathered using sensors, drones, and other wireless technologies, which then are analysed by advanced analytics and AI-powered algorithms. As a result, AI can be used to identify problems before it become worst as well as analysing predictive and preventive maintenance. AI also helps to ensure the utmost security and safety of the construction workers especially issue regarding post-construction.

2.4 3D Scanning and Photogrammetry

High-definition photography, 3-D laser scanning, geographic information systems, and other new methods can enhance precision and speed of the housing development. Usually, the general contractors will hire specialised surveying companies to carry out laser scanning services but, in some cases, most of them will carry out in-house surveying by renting or purchasing their own laser scanner and software. The scale of the project, the type of data that must be defined, and the speed of the survey completion and frequency of survey will affect the choice of the best tools and devices for the work. One of the most accurate 3D laser scanners, terrestrial 3D laser scanners can deliver high level of accuracy as well as capturing very dense point clouds. These digital images of the space in three dimensions were created using a vast number of data points, such as X, Y, and Z coordinates, colour values, and reflectance values. One of the interesting parts of these 3D scanners is that I can collaborate and integrate with BIM software. The BIM software may import such point cloud data. Unmanned aerial systems (drones) can be used to collect high-resolution photos of the topography and the exteriors of buildings, including difficult-to-reach areas like roofs (Cousins, 2018).

3D laser scanning is a method of collecting extremely fine and correct information about a construction area using laser rays. A laser beam assesses the structure's numerous dimensions, including the length, width, and height of the construction elements, and also their connections to each other. The point cloud image created by the 3D laser scanner precisely copies the scanned objects. Based on the type of the 3D scanner, it could be used up to a distance of many meters. The information obtained can subsequently be utilized to construct 2D CAD drawings or 3D Revit BIM models using Building Information Modeling (BIM) and Computer-Aided Drawing (CAD) tools.

3D laser scanning has many benefits in the field of construction. We can acquire data quickly using 3D laser scanning. Drones are mostly used to scan point clouds and convert them to BIM. Slam scanners are frequently employed with this unmanned aerial system. Easy-to-deploy pedestal for mapping and surveying with drones from the air. Drones, on the other hand, have been outlawed in many countries for security reasons. The drone, on the other hand, provides us with vital 3D laser scans for the BIM process (Solvotek, 2021).

2.5 Internet of Thing (IoT)

Internet of Things (IoT) is a powerful tool which can be applied throughout the whole construction life-cycle to transform the industries into automation and digitalisation. Construction is one of the sectors that is ready for change, and IoT technology has enormous promise for improving productivity, operational efficiency, and safety on the job site. A company manager doesn't need to extend the contracts of the workforce before the project is finished since the Internet of Things ensures prompt delivery of fresh resources and equipment, allowing the entire team to use its time effectively

IoT tools support site managers in tracking daily costs and assessing the resource-efficiency of building projects by tracking resources and assets. By assuring prompt supply of fresh resources and equipment, the Internet of Things lowers project expenses.

IoT makes it possible for assets to be connected and big data analytics to be performed while giving project teams access to real time results and information. IoT is a network of physical items that are equipped with electronics, software, sensors, actuators, and network connectivity which allow it to gather and exchange data via online. Future opportunities include setting up monitors at the start of the construction project to evaluate output (energy, utilities, labour, etc.) will improve the interactions between the supply chain and the worksite.

In housing construction, IoT helps to minimize the workload of the project team, for example the civil engineer, architect, site engineer and others which enables them to monitor the progress of work done through the tablet or applications. IoT can also be used to build predictive maintenance plans. Construction machinery that has sensors installed can immediately issue an alert if any unusual patterns are found. The sensors can warn the employees to take immediate actions in order to prevent crucial downtime.

2.6 Augmented & Virtual Reality

The implementation of augmented reality (AR) and virtual reality is one of the most recent and cutting-edge improvements to the building industry (VR). Building information modelling (BIM) has made it possible for construction businesses to visually take buyers inside their future building before actual work ever starts. Augmented reality can be used for multiple reasons at different stages of your project. Construction organisations normally apply augmented reality (AR) to plan and adapt projects, automate measurements, provide onsite project information, improve team cooperation, and carry out safety training.

The production of 3D models on a 2D blueprint is achieved by implementing AR. Construction companies can create interactive models of projects to show clients by using specialised 3D modelling software. It indicates that clients are involved in the process from the beginning.

Virtual reality (VR) has the potential to have a significant impact on the construction industry in two areas: safety training and equipment operator training. Workers could experience situations like working at heights or in limited areas with VR in a secure and controlled setting. This is to ensure the workers will feel a real situation and condition as working in the real world. Apart from that, VR simulators have been used to train the other professional such as pilot and surgeons. Hence, it is important to apply the same concept to train the professional in construction sector such as operating crane and welding work for housing construction.

Another technology that significantly raises safety on the job place is augmented reality (AR). There are several ways that AR may be used on the workplace, including making it easier to create a more thorough safety plan and educating workers on heavy machinery using real equipment on real sites with augmented risks (Jones, 2020). To ensure collaboration between consultants, designers and construction teams, AR can be used to display BIM data through next generation visual interface which can be proof of basis with the clients.

2.7 Blockchain

Reliability, traceability, disintermediation, recording of changes, and data ownership are few of the constraints that the usage of blockchain technology has the potential to eliminate. These constraints have recently served to inhibit the development of the BIM model. Therefore, it is possible to emphasise the following three advantages of combining BIM and Blockchain.

First, the integration between the BIM model and the distributed database containing all the process information helps to ensure the creation of a single, trustworthy register, creates a collaborative environment among all user, and characterises transparently each user's responsibilities and duties, minimizing or eliminating the occurrence of any misunderstandings and successive conflicts between the stakeholders. Second, the distributed database's ability to keep and track the information intellectual property entered by each process user enables the development of a collaborative environment. Last but not least, the two advantages shown above are mostly related to the design phase whereby the implementation of Smart Contracts connected with the development of the BIM model is equally pertinent throughout the building phase. The simultaneous progress between the BIM model and implementation of smart contract make it easy to automate every stage of delivery.

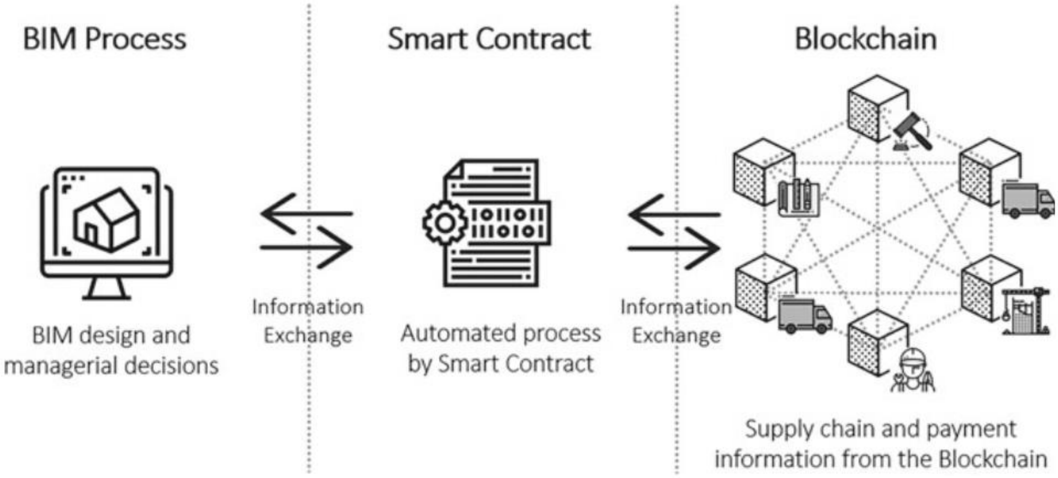


Figure 4. Integration of BIM and Blockchain during Design stage (Daniotti et al., 2020)

2.8 Drones

On construction sites, drones are used in a wide range of ways. Every day, potential hazards can be immediately identified and construction site checks can be conducted using drones. In order to make sure everyone is working safely, it can be used to monitor employees throughout the day. Drones are being utilised to take images of the construction site as it is being built to build as-built models, which will keep every stakeholders updated on the construction site condition.

In addition, drones are deployed to perform risky tasks such as inspections of bridges and buildings. Although this won't completely eliminate the need for workers, it will require the user to undergo training on how to use the technology to complete these tasks (Jones, 2020). To perform survey works for a construction site, it will normally takes about weeks and in osme cases, months. However, due to digital transformations that currently happened today, the survey task can be completed in a matter of minutes. The benefits carry by the use of drones will enhance more construction organisation to adopt new technology which will save more cost and time as well as accuracy and precision of the drones.

Table 3. The drone benefits throughout the construction lifecycle (Wingtra, 2021)

Drone Benefit Throughout Construction Life-cycle	How Drone Change the Construction Landscape
Bidding and pre-planning	A topographic survey of the site is necessary prior to the start of construction projects in order to gain a thorough understanding of the environment in which the project will take place. Drone-generated DTMs and

	DSMs of a site can display potential drainage sites, changes in elevation, and other elements that can assist to choose the ideal areas for construction, digging, or storing supplies.
Planning and design	The same photos that were captured by drones can subsequently be used in the planning phase to provide the foundation for the work of other professionals including architects, local government officials, and engineers. To gain a clear idea of how a new building would seem next to an existing one, it is possible to overlay buildings into their surroundings using drone orthophotos and 3D models. It can evaluate both the functional and aesthetic effects of the new project on the neighbourhood. Cast shadow analysis and visualisation are also possible with 3D models. To improve already-existing data, accurate data can be extracted and imported into CAD or GIS software, such as measurements of curbs or manholes.
Execution	While it already offers multiple advantages in the planning phase, the greatest value of drone use might come when projects enter the construction phase. **Earthworks** It can produce a point cloud from drone images which has thousands of points with each carrying geospatial (X, Y, Z) and colour information. The accurate volume measurements data can then be gathered using photogrammetry software, and a cut/fill analysis can be performed. Earthwork contractors are paid based on how much cut and fill work that has been done. Therefore, it's important to measure earth movement accurately. The payments' margin of error is decreased by using very accurate drone data. **As-Built versus As-Design** The ability to overlay the CAD on the orthophoto is one of the most obvious benefits of accurate site visualisation. This will allow the as built plan suit together with the actual progress on site after overlaying has been done. Site managers can thus spot discrepancies between actual progress and that which was expected and manage projects accordingly. **Site Progress Monitoring**

	Site managers must supervise finished work during the building phase in order to authorize subsequent work. Faster rate of checking and validation will ensure shorter time taken for the overall construction process. The project milestones can be used as reference to control and authorize the tasks more faster, hence save the time taken and meet the deadlines for the project completion. **Communication Tool** In some cases, there are several stakeholders who always keen to know the progress for their housing project everyday. So, they need to travel from one construction site to another construction site to update the progress or probably hire a professional aircraft to capture the aerial images of the site. However, the impact of this method will result to poor updates of aerial images which might be outdated for the next days or following weeks. However, the visual data from routine drone inspections helps with operational planning that is performed on demand which might be daily, weekly or monthly. Furthermore, it aids in identifying safe and risky locations and defines how urgent work should be carried out. In fact, clients can receive visual reports that keep them updated on the status of the project's timeline and financial constraints. **Handover** The contractors and the client will take over management of the project after it is finished whereby both will be benefitted from detailed documentation. To be more specific, clients can carefully review the documentation before approving the handover, and contractors can demonstrate that the work was completed in accordance with specifications by providing detailed information of those who are responsible for each work and task.

CHAPTER 3

CONSTRUCTION GO DIGITAL

Initially, traditional housing construction lifecycle will work in silos and less collaboration and integration with the other stakeholders. In fact, the work done also need further rework and changes especially during the design stage. In some cases, the implementation of BIM model being done after the bidding process has already success which will incur additional cost and time to re-model the 3D model. However, in modern practices of housing construction, it will involve digitalization with collaboration and integration throughout the whole construction lifecycle starting from beginning-end process.

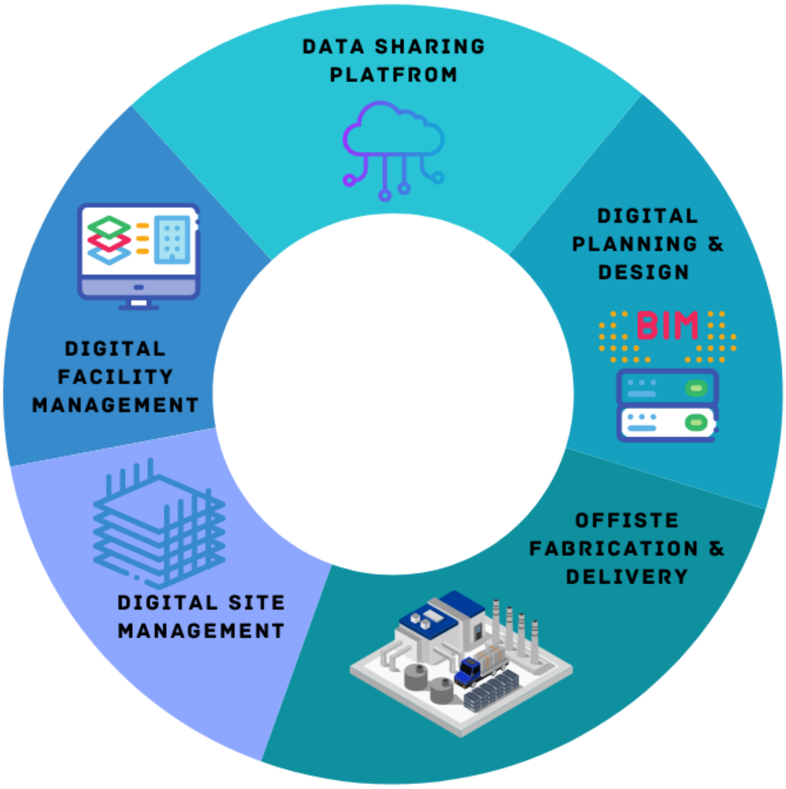


Figure 5. Construction Go Digital Lifecycle Integration

Figure 5 represent digital approach across the whole construction life-cycle process which need to be applied by every stakeholder involved. Through the process, a common database or data sharing platform need to be setup as early as possible to collaborate everyone in a collaborative network. Every single change and amendment will be notified by others through real-time collaboration. This is crucial to prevent from missing data and duplication among the stakeholders.

Table 4. Construction Go Digital Lifecycle Approach

Stage	Approach
Data Sharing Platform	• The "core" of construction digitalization is composed of Common Spatial Data Infrastructure (CSDI) and Common Data Environment (CDE), which are integrated with BIM and GIS
Digital Planning & Design	• Establish public geospatial data from the government data to assist the site planning, engineering, and environmental analysis. Additonally, the 3D spatial and BIM data from the industry will be used to establish 3D digital map. • Digital and on paper submission of 2D and 3D plan/model which are created from BIM models will facilitate the submission process to the authorities.
Offsite Fabrication & Delivery	• Utilise digitalization to accomplish just-in-time delivery by moving onsite processes to a controlled offsite environment.
Digital Site Management	• Systems for planning, monitoring, and managing site records that utilise IoT devices, sensors, and actuators that are seamlessly networked.
Digital Facility Management	• Use of digital technologies and integration with Building Management Systems for better asset and facility management and to achieve sustainability

Digital environment is a must for every stakeholder to work on collaborative and integrated working environment. It will involve the role of every stakeholder to suit among others starting from the foundation; data sharing platform. Establishment of data sharing platform by using the shared cloud or server. The data sharing platform will assist the stakeholders to keep up with any changes on the housing model everywhere and anytime without need to organise physical meeting.

Moreover, the digital planning and design will involve the production of geospatial data from the existing and available data for the specific purposes; site planning, engineering analysis and environmental analysis. Hence, it will ease the purpose to develop 3D digital map which can ease the visualisation purposes. In addition, the submission of housing design could be conducted via online platform to the authorities rather than submission throughout the traditional way which will reduce cost for 2D plan printing and save time.

Digital construction is specifically purposed to enhance the offsite construction rather than wet construction method at site. By enhancing the offsite construction, eventually it will affect the quality of housing components such as slab and wall components because it is produced in controlled environment. Furthermore, the implementation of digital site monitoring by using the IoT devices will help and boost the monitoring and site evaluation to be more productive and efficient. Interconnectivity between IoT devices will boost seamless monitoring and project update. Last but not least, the digital facility management with the integration of Building Management Systems can assist assest and facility management of the buildings, hence enables end-to-end predictive maintenance of the buildings. To know in detail of integrated design process and conventional design process of digital construction, the details are shown in Table 5.

Table 5. Comparison between IDP and the conventional design process (Rogiez, n.d.)

Integrated Design Process (IDP)	**Conventional Design Process**
Inclusion of all stakeholders from the beginning	Involves only the members of the expanded team when necessary
Time and energy invested quickly and massively at the beginning of the project	Less time, energy and collaboration in the first steps
Decision-making influenced by a large team	Majority of decisions made by a limited number of stakeholders
Iterative process	Linear process
Comprehensive and systematic thinking	Systems often isolated (silos)
Geared to complete optimization	Optimization dictated by the constraints
Increased search for synergies	Reduced search for synergies
Analysis of costs over the life cycle	Emphasis on the initial costs
Ongoing process after occupancy	Ends with delivery of construction

The construction go lifecycle as shown in Figure 5 and Figure 6 shows how digital approach being implemented throughout the whole construction, starting from pre planning until facilities management process. Before starting the project, it is crucial for the project manager to set-up the data sharing platform which enables to facilitate the integration of BIM and common data environment (CDE) for housing construction. Why it is important to setup this data sharing platform first? Integrated project management allows all the stakeholders to exchange the information of the housing model through the CDE. Any changes and amendment that being made by the stakeholders can be notified by others at anytime and anywhere. Here, transfer of information is being made at high rate without the needs for physical meetings with the project teams. It can be seen that a big difference on how this cloud computing affect the workstyle environment of the construction stakeholders.

Planning and design stage is one of the main important stages that affect the productivity of the projects. BIM is an integrated platform where it helps all the stakeholders to view the housing model in 3-dimensional perspectives even the house not being built yet. Through BIM, it will assist the engineer to detect any clash and conflict between the architectural, structural and mechanical and electrical BIM model. The role of BIM manager and coordinator to manage and solve the conflicts will reduce the cost and time consumption during the construction stages and reduce the rework being done. Moreover, the BIM also helps to facilitate the submission to the clients through digital platform and ease the automatic checking and approval of plan.

Offsite prefabrication can improve the quality of the housing components because most of the components are being manufactured under controlled environment. The production of housing components at factory can reduce and minimise the work done during the construction stages. Digital site planning through the BIM platform enables the monitoring of the construction progress for examples, the use of drones. Last but not least, digital facility management allows the as-built drawing of the housing design to be stored in digital model. Soon, it will help for any renovation works and predictive maintenance in future.

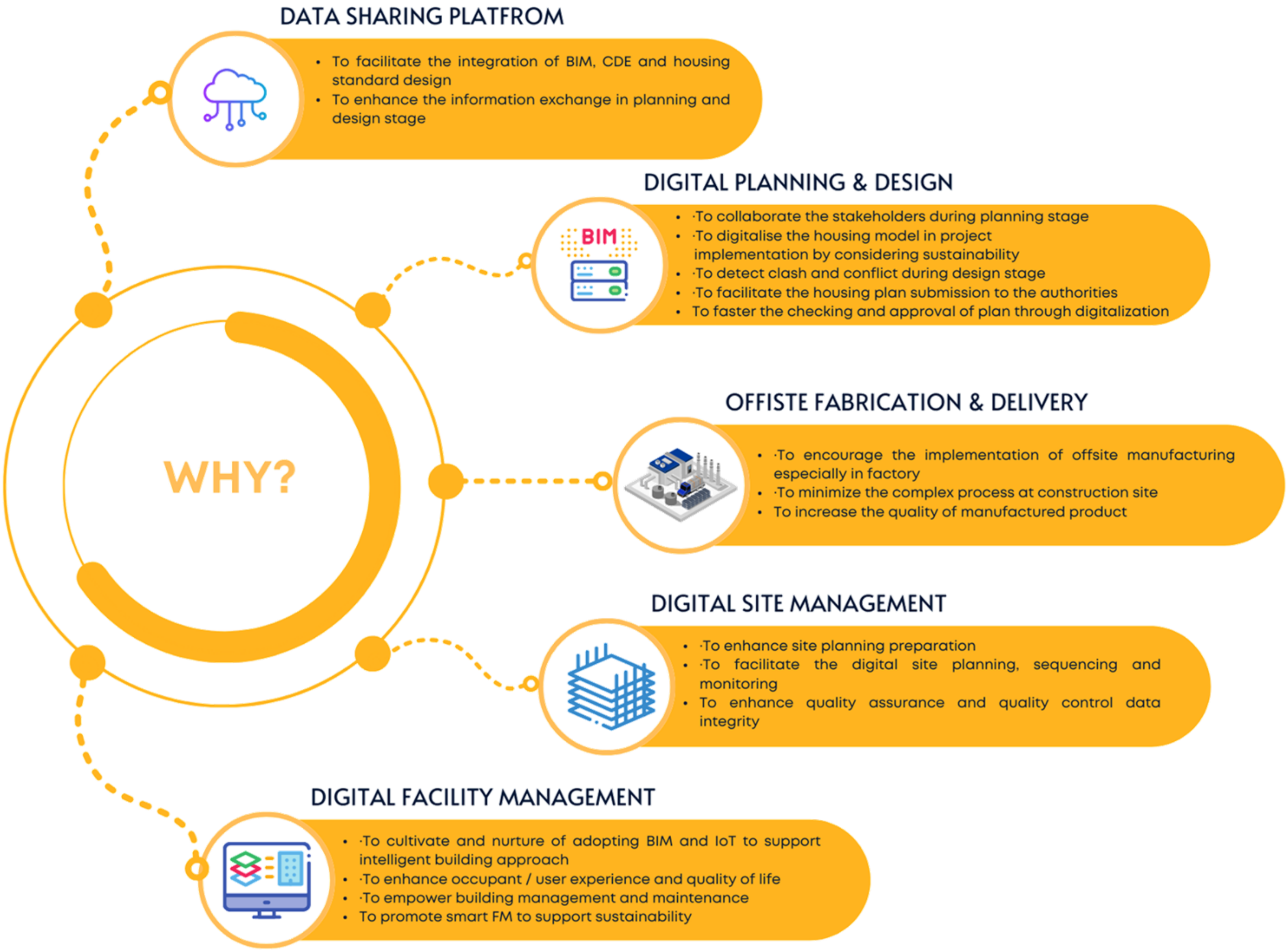


Figure 6. The benefit of integrated construction lifecycle approach

CHAPTER 4

DIGITAL ROADMAP

CONSTRUCTION GO DIGITAL

SHORT TERM

Timeframe: < 3 years

- BUILDING INFORMATION MODELLING (BIM)
- INTERNET OF THING (IoT)
- AUGMENTED REALITY / VIRTUAL REALITY
- MODULAR / PREFABRICATION
- CLOUD COMPUTING
- 3D SCANNING & PHOTOGRAMMETRY
- SMART SAFETY HELMET
- DRONES
- ROBOTICS & AUTONOMOUS

MEDIUM TERM

Timeframe: < 5 years

- BIG DATA ANALYTICS
- 3D PRINTIING
- ADDITIVE MATERIALS / SELF HEALING
- EXOSKELETON
- SELF-CHECKING BIM MODEL

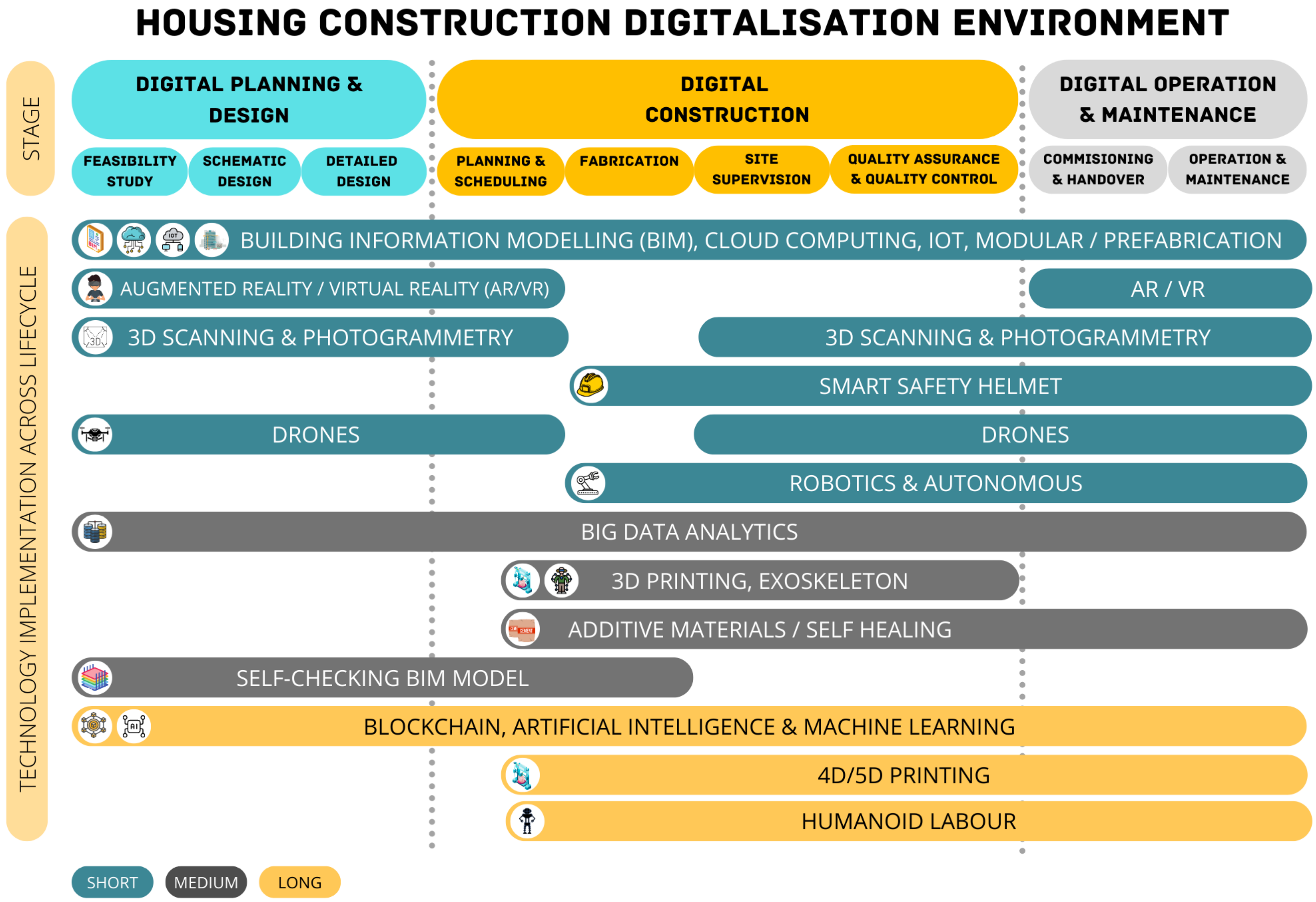
LONG TERM

Timeframe: > 7 years

- BLOCKCHAIN
- 4D/5D PRINTING
- ARTIFICIAL INTELLIGENCE & MACHINE LEARNING
- HUMANOID LABOUR

The Implementation of Emerging Technologies Throughout Construction Project Lifecycle

4.1 Construction Digitalisation Environment



DIGITAL PLANNING & DESIGN

Three basic construction planning and design lifecycle process are explained in detailed.

FEASIBILITY STUDY & PLANNING

- Geotechnical study
- Statutory requirement
- Environmental Impact Assessment (EIA)
- Traffic Impact Assessment
- Value Engineering
- Visual impact analysis
- Sustainability evaluation
- Drawing / Model production
- Underground utilities study

SCHEMATIC DESIGN

- Preliminary design for housing project
- Design review
- Design authoring and verification
- Spatial coordination
- Carbon assessment tool
- 3D construction coordination
- Site, facility energy, civil and MEP analysis
- Building code checking & validation
- GFA calculation
- Air ventilation assessment
- Architectural & foundation design
- Structural analysis

DETAILED DESIGN

- BIM use for tendering
- Cost Estimation
- Quantity take-off
- Cash flow forecasting

4.2 Collaborative Construction Process

Building Information Modelling form a core foundation for collaboration and integration of construction players starting from the design, construction and up to post-construction. The adoption of BIM can be integrated with the other digital tools such as artificial intelligence, augmented reality and virtual reality, cloud computing and others. Figure *7* depicts how the AI in the construction industry brought benefits to the housing construction projects.

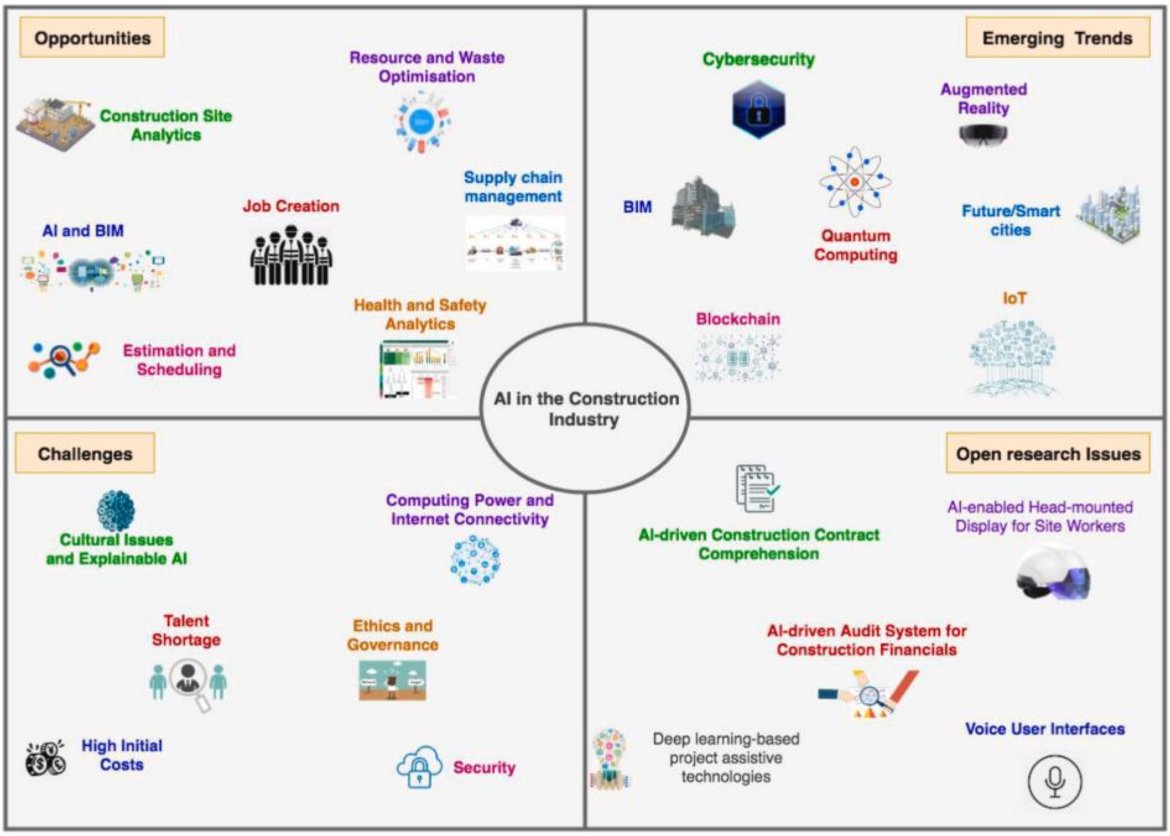


Figure 7. Emerging trends of AI in construction industry (Abioye et al., 2021)

4.2.1 Building Information Modelling - Geographic Information System

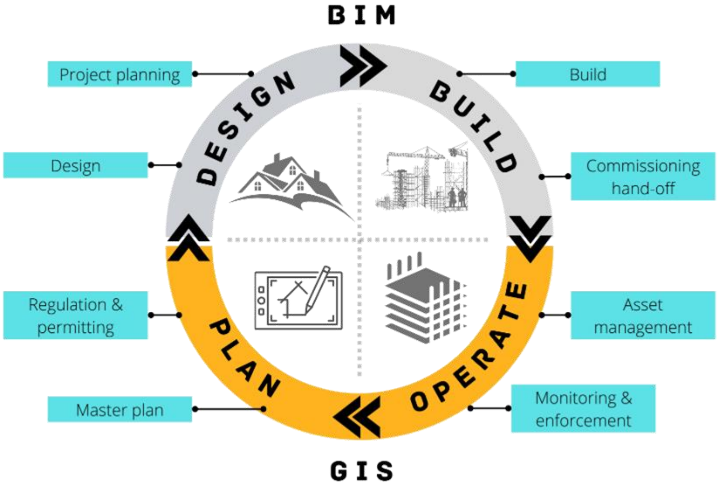


Figure 8. Integration of BIM and GIS for design, construction and post-construction (Andrews, 2018)

How will the integration of BIM and GIS will improve the whole construction project? Let's take a look at Figure *8*. The whole ecosystem of BIM and GIS integration involve design and build as the main element in BIM while planning and operation are covered under GIS. GIS is a platform which provides information regarding the built environmental assets as well as other significant elements such as geography, social economy, demography and environment. The system utilises maps to gather, produce, integrate, analyse, manage and visualize geographical data of the Earth. Hence, it facilitates to choose the most effectives preference of facility management and maintenance of those assets.

Site selection, energy design, traffic design, structural design, interior acoustic design, climatic assessment, design authorization, and performance evaluation were part of the Planning & Design (P&D) phase of a building's operations that implemented BIM and GIS. In terms of site selection, the BIM models can be imported into geospatial environment which will help the engineers to evaluate the profile and area of the plan obtained from BIM models with those of the site blocks in the map of GIS in order to determine whether a site location is suitable for the planned construction.

To obtain BIM and GIS data from open databases, a middleware is needed to create the 3D model of the construction site with the integration of BIM models, site maps, land registration maps, land planning data and satellite images from GIS which will allow the engineers to conduct preliminary estimation of the gross floor area. Through this method, it can improve the productivity and time especially during the design stage of the housing construction. In terms of energy design of the housing, the interoperability between BIM and GIS was applied to link the energy related features and indicators to multiple levels of space including single spaces, functional area, building and district. The early consideration of energy efficiency design will impose optimisation of energy-efficiency performance as early as design stage rather than considering it during the construction stages.

According to Liu et al. (2017), there are three hypothesis of BIM-GIS integration whereas it involves the design, construction and post-construction stages. By implementing BIM-GIS during the P&D stages, it can offer the stakeholders with comprehensive and varieties of information and data of the construction project. Eventually, it will help the stakeholders to perform early scheduling, cost and sustainability evaluation in 3D virtual environment. For complex housing design, BIM-GIS integration allow the designer to conduct building design with the most efficient design regarding the space utilisation.

During construction stage, BIM and GIS could be useful to provide information for building information to create dynamic site layout and optimisation of element distributions. It is crucial to ensure the safety aspect of construction site during the construction stages by using 4D/nD BIM visualisation of construction components, thus helps to prevent or minimise the risk of accidents. In terms of financial, integration of BIM and GIS can help to control the project cost where all the cash flow and financial statement can be monitored through BIM and prediction of future scenario cost by GIS.

Last but not least, operation and maintenance stages are the longest stage of any construction activities. Under these three hypotheses of design, construction and post construction, integration of BIM and GIS can cope the following situation such as simulation, management, prevention, and response to emergencies and disasters, preservation of cultural heritage, operation of large-scale projects and ecological assessment.

4.2.2 Building Information Modelling – Artificial Intelligence

Artificial intelligence is the ability of a machine to learn in a manner comparable to that of a human, to assimilate new information, and to utilise this information to create its own intelligence system is known as artificial intelligence. Although there are many other branches to the interdisciplinary field of artificial intelligence, machine learning has the most present impact. The computer will get better at interpreting and generating insights as it is exposed to more data. This is crucial in the construction industry because most of the procedures are depend heavily on human talent. Ai allows to streamline these processes and reduce cost, time and risk enhancing project output quality.

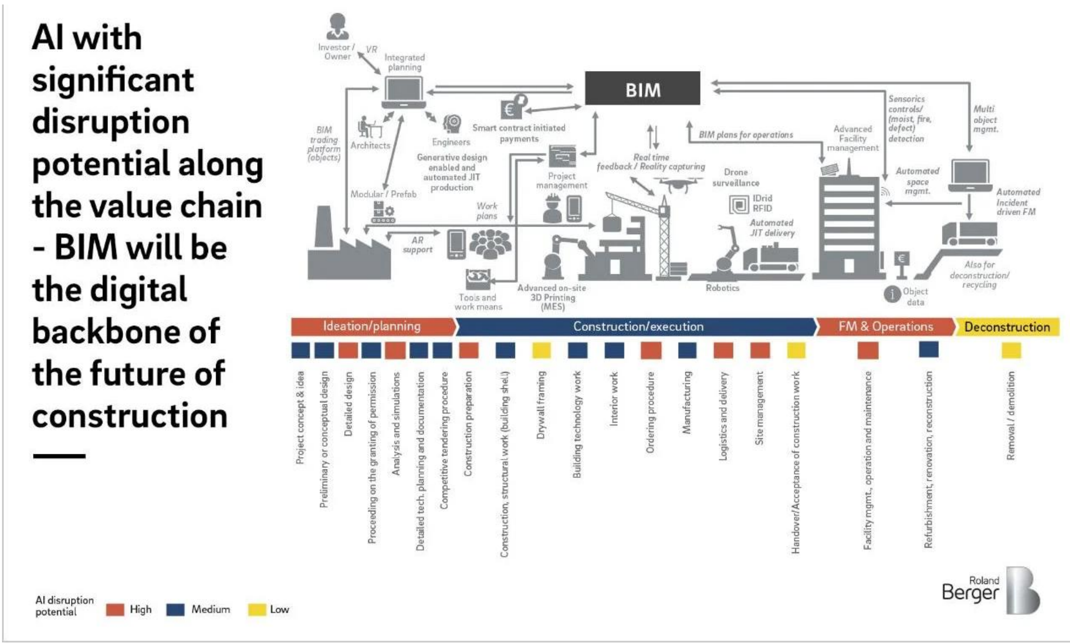


Figure 9. The integration of AI and BIM to be applied in housing design

Artificial intelligence is already being used by BIM software providers to increase the effectiveness and potential of their programmes. Machine learning is a technique that is used by BIM software to analyse data, identify trends, and utilise this information to automatically decide how to automate and enhance the model creation process. AI can explore the potential of each element of a construction project and identify the best solution efficiently than a human mind using the massive quantities of information collected by BIM software. This not only expedites procedures but also lowers the possibility of human error, which can increase site safety (Prompt Consulting, 2020).

Artificial Intelligence, a machine's potential to operate in a human-like manner has contributed to the core strength of BIM. Their features for example, AI-assisted BIM has grown its popularity to support BIM infrastructure. The features of AI is able to assimilate knowledge, evaluate real time data, and propose new approaches to problem based on its newly acquired wisdom. In addition, machine learning is an AI technology that enables the system to learn from itself and act in accordance with these new insights.

Artificial intelligence is crucial to BIM since it aids in identifying potential future issues. Artificial intelligence assists to the development of a long-term perspective and the capacity to look into the future since infrastructure development projects are on a vast scale and errors can be extremely costly. A BIM software may gather and use a variety of data, and AI can help make data driven decisions, analyse it to make forecasts, and build models to help with future work. BIM software's data is used by AI to assess resource-efficient solutions, discover prospects, and even develop execution strategies that reduce the risk of failure.

BIM uses artificial intelligence to assist lower the risks driven on by human mistake. Since infrastructure projects are risky in and of itself, it aids in preventing serious harm to life and property. Artificial intelligence has only recently begun to be incorporated into BIM, and the future development of this potent duo is expected to grow further in future. It brings cohesion and integration to the workforce across teams on an infrastructure project, which has helped enhance efficiency in construction projects.

BIM has assisted in improving all-around safety and reducing risks related to construction projects. Risk reduction is essential in the accident-prone construction sector. Artificial intelligence recognises risky areas and alerts users. This helps with the development of emergency plans, evacuation procedures, and the identification of potential dangers like heights and falls. More effective building design is made feasible with artificial intelligence. It can produce precise models and floor plans after being provided a dataset of "rules” without affecting any execution, all plans can be smoothly connected with one another. In reality, these integrated plans help in the analysis of issues that may arise as a result of another project.

Finally, BIM systems with AI technologies allow users to track a project's progress pretty much instantly through virtual platform. This implies that all other aspects are immediately updated when the system receives a single update, saving the time and effort required to inform or change each component separately. In terms of infrastructure development, this helps to boost project productivity, decrease time and money expenditures, and reduce risks and accidents (The Geospatial, 2020).

4.2.3 Building Information Modelling – Blockchain – Internet of Things

A form of Distributed Ledger Technology (DLT) known as the blockchain allows for the verification and digitization of all business processes. It is a decentralised network where notrusted authority is required to keep up the appropriate parties' verification. Instead, the cryptographic block can be linked after its validity is established, and every transaction is visible to the connected blocks, allowing prefabricated housing construction (PHC) owners to easily monitor the progress of construction projects and verify the information that has been recorded. A case study of C. Z. Li et al. (2021) revealed how PHC construction are consists of four main stages of construction, namely as design, production, logistics and assembly stage which each of the stages will provide primary data sources. During these four steps, smart connected products (SCPs) primarily gather data from stakeholders (information upload), prefabricated components (PCs) (status monitor), and materials (consumption reading), after which the relevant data is encrypted and uploaded. As opposed to centralized architectures, various monitoring and decision schemes based on blockchains should be more scalable than conventional ones. After data collection process complete, each of stakeholders will upload the encrypted data, thus secure data transmissions are conducted in the blockchains. The details of the data processing are shown in Figure 10.

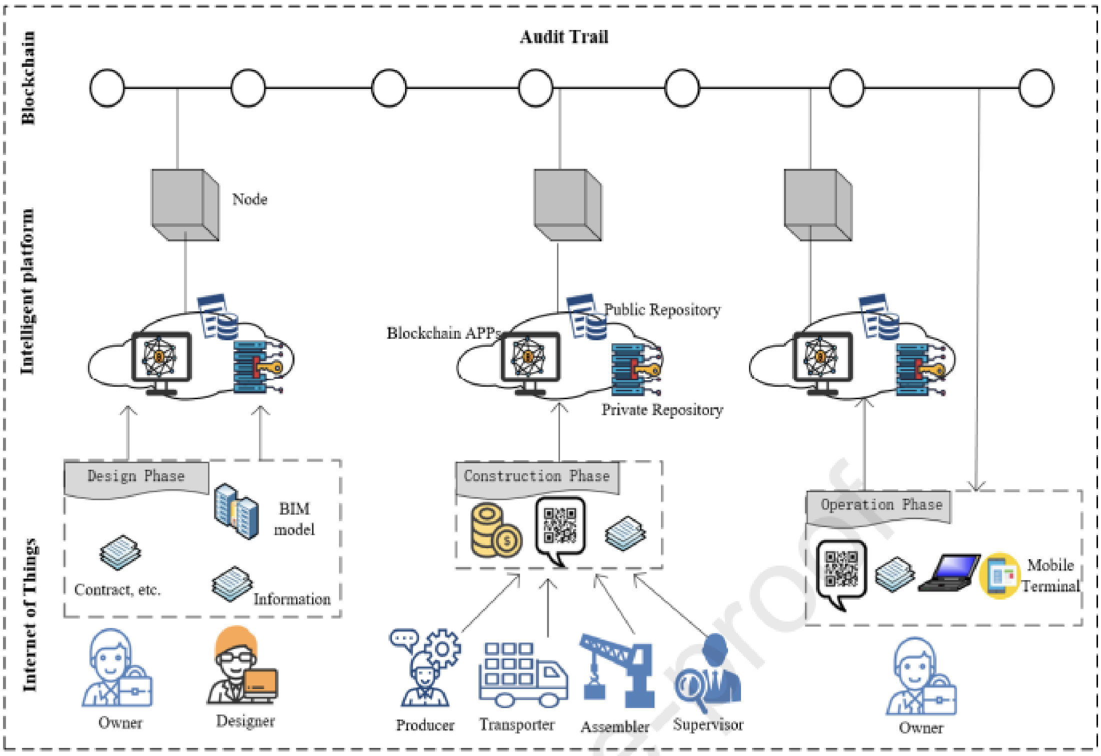


Figure 10. Integration of BIM, IoT and Blockchain for housing construction

An emerging concept named as the Internet of Things (IoT) can improve BIM by providing it real-time data to connect physical resources with virtual BIM components. The fundamental paradigm for creating digital twin applications is integrating IoT data with BIM in real-time to increase construction productivity (X. Li et al., 2022).

4.2.4 Building Information Modelling – Augmented Reality / Virtual Reality

This is one of the crucial approaches to visualise how the house concept will be after project completion. The BIM model, Data Transformation, and AR platform made up the three main parts of the strategy for combining BIM and AR as depicted in Figure 11. The BIM Model supported geometric and non-geometric building information, such as door and window locations, and their manufacturers and maintenance information. So how is it works? The BIM model will act to sent and receive BIM information to and from Data Transformation. Next, the Data Transformation will analyse the information and facilitated communication between the other two platform; BIM model and AR platform. As the AR platform connected to the Data Transformation, it can allow the individuals to visualise and verify the BIM model in real-time. These three key elements—BIM Model, Data Transformation, and AR Platform—worked in harmony by integrating their various functions and objectives into a cohesive system for architectural visualisation.

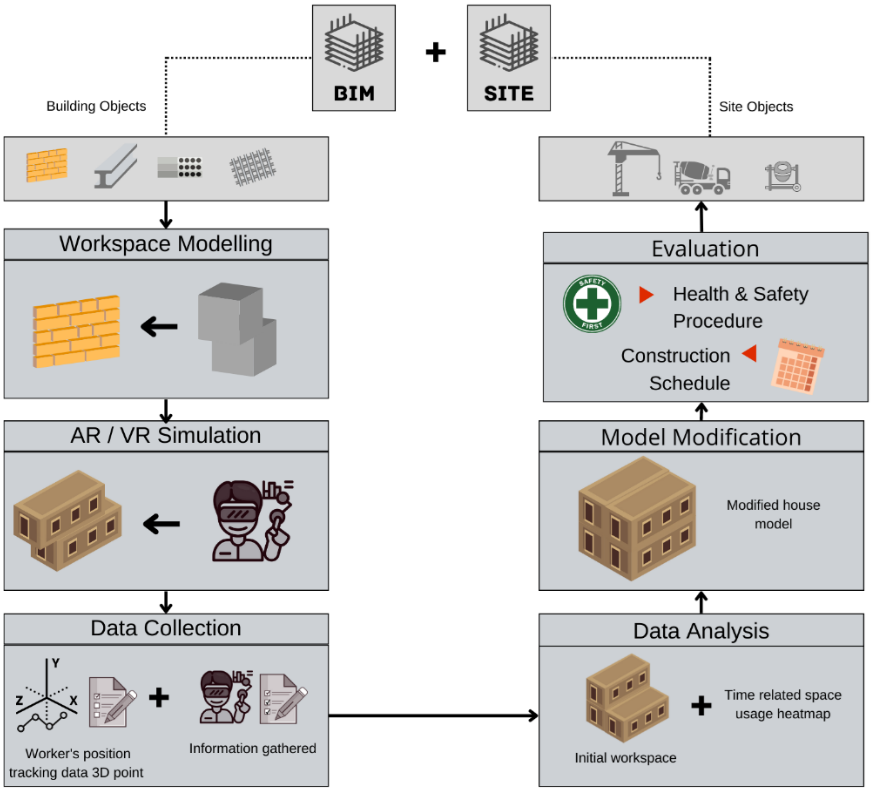


Figure 11. Integration of BIM and AR/VR for housing construction (X. Li et al., 2022)

As shown in Figure 11, the building objects has been modelled in BIM platform where it can be visualise in AR/VR simulation. Then, the data collection in the AR/VR platform will be gathered and analyse where the user can see if there is any clash or mislocation of building components. The BIM model will serve as to provide geometric and non-geometric information, so it can be visualise in 3-Dimensional; X, Y and Z point. Based on a 2D design drawing, each BIM model was developed and important information, including design specifications, marketing data, maintenance information, and requirements, comprising owner demand, marketing trend, and customer need were integrated and collaborated in a single platform.

Integrating the BIM model and AR/VR platform is not easy as overlaying the model. Both are consisting of difference in form of data formats and methods used to store the information. Before being visualise in AR/VR platform, the data and information form the BIM model need to be converted and processed. In particular modelling software, the data were converted and processed into formats that supported AR. Modeling and scripts were used in this procedure to construct the contents and interactions, hence the 3D geometry, wireframe and properties of the 3D BIM model can be visualise properly (Wang et al., 2014).

4.2.5 Building Information Modelling – Cloud Computing

Cloud computing is one of the best emerging technologies that can be implemented throughout the whole construction stages. This technology provides sharing of information from one cloud in a collaborative and integrated environment which increase the user-friendliness and interoperability between the users. The underlying technology that underpinned the field of cloud computing is virtualization. It separated physical computing devices into a variation of virtual worlds, enabling each of them to carry out duties successfully and effectively. BIM and cloud computing integration not only improve the traditional BIM process, but it also minimise the possibility of human error.

Every project member will have limitless access to the information stored on the cloud while using cloud-based BIM. In contrast to the previous iteration in Figure 12, where the BIM manager was the only participant, this information exchange procedure will no longer be dependent on a single party. For an integrated cloud-based BIM as shown in Figure 13, all user will have the ability to easily integrate renderings into a single BIM model in the cloud and execute a variety of tasks in real-time, including design evaluation and information exchange. In summary, the entire project team may seamlessly view, comment on, and coordinate all of their works under a single BIM model (Jiancheng et al., 2021).

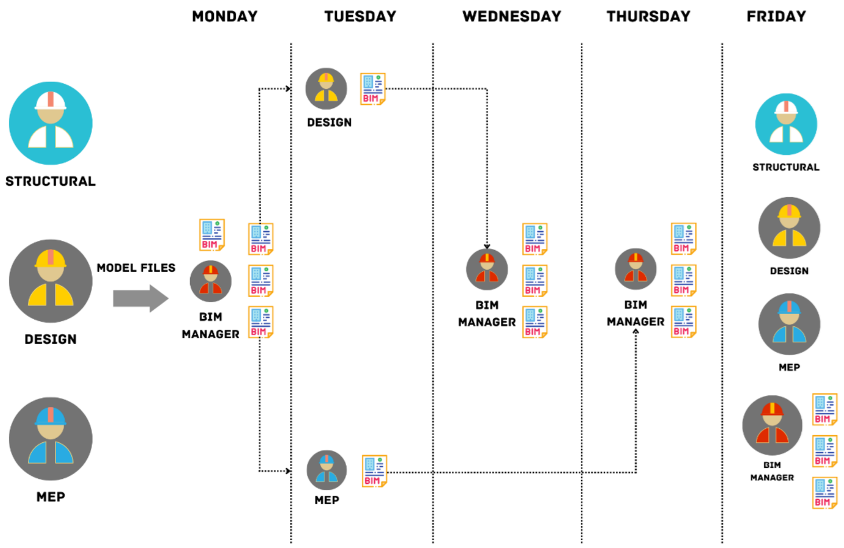


Figure 12. Conventional working environment using BIM and cloud

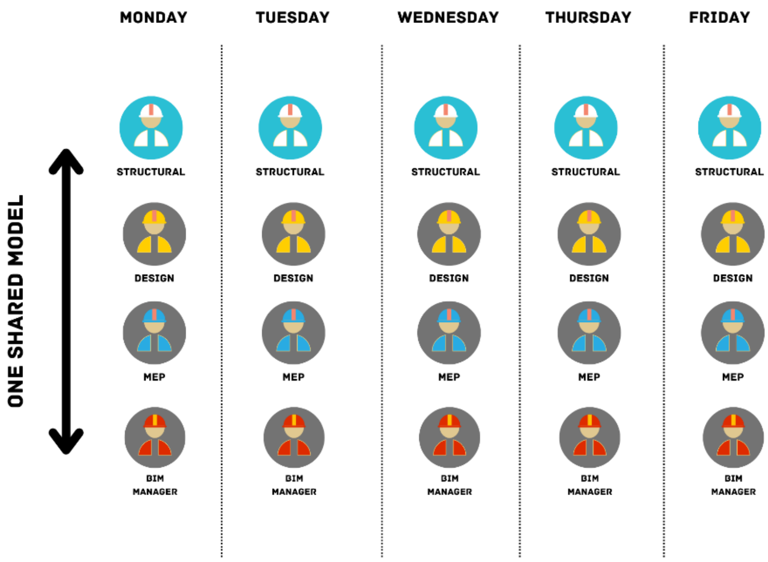


Figure 13. New approach of BIM and cloud usage among industry players

CHAPTER 5

DIGITAL SKILLS NEEDED

5.1 Creativity

Creativity can be defined as tendency to create or recognise ideas, alternatives, or possibilities that may be useful in solving issues, interacting with others, and entertaining ourselves and others. To fully capture the advantages of all the new things for the future—new goods, ways of working, and technologies, the individuals need to be creative to ensure that they are not left behind the digital world pace. As the digitalisation rate keep increasing at high pace, the future workplace will demand new ways of thinking and they need the human creativity tu survive and suit with the current demands and needs. The future skills will need to embrace the technology transformations where combination of digital and creativity skill will be beneficial to everyone.

Construction industry in a robust industry where it needs the industry players to cope with the advancements. Adaptability to new technology such as BIM and cloud computing will increase the value of worker's in the workplace. Such the skills should be taught as early in primary education which will provide early insights and exposure to the students. Hence, most of them will be familiar with the technologies which will lead to more digitise and creative community in future.

5.2 Changing Mindset

The digitalisation itself will not occur without having mindset changing from the users. Changing mindset commonly regarded as more crucial than the technology implementation itself. Most of the time, the necessary technology exists, but the users are not prepared to adapt. Transformation from traditional construction industry to modern mindset of construction industry for sure will incur some cost to suit with the current systems and digital equipment. This is one of the main challenges that have been faced by the industry players, especially Micro, Small and Medium Enterprises (MSMEs) where they need a high cost and monetary to rent or buy the digital equipment and machineries.

However, in certain situation, the adoption of technology in housing construction are not required millions of Ringgit Malaysia. Adoption of cloud computing for example only incurred thousands of Ringgit Malaysia for the subscription. Throughout the project, the implementation of cloud computing can enhance and reduce the coordination and integration issue among the stakeholders, hence increase the efficiency and productivity of the job.

5.3 Capacity and Capability Building

The development of capacity and capability of industry players are a must in the era of digitalisation and rapid global economic changes. How is the development of talent will induce the transformation of construction industry? A comprehensive approach by strengthening the Technical and Vocational Education and Training (TVET) in secondary school will assist in raising the awareness and interest of talent towards digitalisation especially in construction industry. When there is a demand for the a high-skill talent in construction industry, the supply side will be ready at any time due to early exposure of technology transformations in the market.

Moreover, re-skilling and upskilling for the professional industry players who are already in the industry is a must to ensure they are not left behind the transformations. The digital advancements in construction will force the working environment to become more collaborative through wireless networking with the other stakeholders. For example, the adoption of BIM during the design stage of construction. In traditional method, it will involve the development of drawing plan in 2-dimensional and any amendment or changes will be resulting to weeks and months before any confirmation of drawing plan being made.

However, in digital environments, any changes of 3-dimensional model can be seen and knew by every stakeholder involved through cloud computing. Consequently, this can reduce the cost and time for development of housing where the benefits of technology adoption being reaped fully by the users.

5.4 Analytical thinking

A person with critical thinking abilities can provide creative suggestions and ideas, use logic and reasoning to solve complex problems, and analyze viewpoints. To engage in critical thinking, one must first examine the informational flow coming from diverse sources. Strong analytical thinkers will collect the advantages and disadvantages of a situation, think critically about the best course of action, and depend on logic rather than emotion when making decisions after careful observation.

Upon the implementation of digital technology in construction, strong analytics thinking is needed to navigate the human-machine integration. Without having high analytical thinking, the machine cannot perform the job well because it will require the input from the human being. For example, the big data analytics for construction foresights.

In predicting the future of construction economy trends, the data is a very important element to be considered. Although the system is intelligent and advanced, but how the data being analysed and connected will result to the applicability of data. As the data is very crucial to the industry, it can be evaluated and analysed through foresighting method to see for the potential trends and emerging technologies that will help to boost the construction industry.

In the workplace of the future, human decision-making will become increasingly complex. Even while computers and data can digest information and provide insights that humans are unable to obtain, a human must ultimately make the decision while understanding the wider consequences of that decision on other company sectors, personnel, and the effect on economy.

5.5 Data Protection & Cyber Security

The advancement of technology in construction industry has created a new raising issue, data protection and cyber security. In the era of Construction 4.0, the use of BIM is highly demanded for design and construction stages. Most of the allowable stakeholders will have an access to the BIM model anywhere and at any time. Since the increasing number of users who can viewed the BIM model, it can lead to the weak links of security. Data breaches through BIM model will result to leakage of housing crucial information which can be considered as private and confidential (P&C). It will affect the project performance, and sometimes might be misused for personal purposes.

However, there is a security protocol called as two-factor authentication (2FA) and multi-factor authentication (MFA) where the protocol identifies the users through unique and specific user codes. Without having the specific codes, the external user will not having an access to breach the cyber security protocols. It is important for the future talent to alert and having awareness on the data protection.

Another way to prevent from data security breaches is through the application of blockchain. Adoption of blockchain will improve the security by decentralising the data that might be have high possibility to be hacked. By separating the assets into separate blocks, any potential hackers would have to breach each block one at a time rather than being able to bypass the CDE's security procedures and access all the assets.

5.6 Leadership skills

Common traits in leadership, for instance inspired the other workers and workers centre approach might increase the performance and motivation of the project teams. But in the era of Industry 4.0, the transformation in working environment urge the leaders to become agile and resilient in any conditions and scenario. Leader must be able to adapt with the rapid changes that might happen every month and year in order to cater for the emerging technologies. Innovative and creativity in solving the raise issue in the project needs to be enhanced through leadership skills. But first, the understanding of how the technology work is vital to overcome any resistance and obstacles in implementing the technologies.

Moreover, as the technology changes too rapid, the leader must know how the foresight method in implementing technology being adopted well. A good leader must know to predict through the future and their current level to suit with the demands. For example, the use of drone in earthwork and project progress. It is important for the leaders to know how the drone can ease the earthwork and estimation of cut and fill work that need to be done as well as monitoring the project progress.

5.7 Technology skills

The advancement of technology in Fourth Industrial Revolution (IR 4.0) are drive by emerging technologies such as BIM, artificial intelligence, blockchain, big data analytics and 3D printing. The future talent must be equipped well with at least the most basic skill in technology such as using the cloud computing for the daily works up to implementation of blockchain in working environment. All of these implementations will require from basic training up to advanced skills to reap the benefits of the technology.

Moreover, the preparation to equip the future talent with the technology skills in digital construction will impact on the cost and productivity of the construction industry as a whole. By looking through the foresight, it is sure that the construction data plays a vital role in projecting the future trends, cost and efficiency of construction project. The application of big data analytics can help the industry players to know what is the current and future demands of construction. In this scenario, it can be seen that how the productivity of BIM helps to reduce the time taken for 3D model design. In fact, it also can show how the clash detection that was usually raise during construction can be solved at earlier stage, as early as planning stage.

CHAPTER 6

GET STARTED NOW

GET STARTED NOW

START

SELF-ASSESSMENT

- Scorecard Assessment
- Strength & weakness of organisation
- Identify expertise
- Priorities most important to least

DEVELOP STRATEGY

- Develop implementation plan
- Strengthen integrated platform
- Collaboration with experts
- Reskill and upskill of worker

IMPLEMENTATION

- Enforce integrated platform
- Continuous training & development
- Performance evaluation
- Data collection
- Roadmap/plan review

SUSTAINABILITY

- Risk assessment
- Enhancement of training and module
- Roadmap/plan review

Re-assess the plan if not successful (back to develop strategy)

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