ROAD TOWARDS PRODUCTIVITY EXCELLENCE:

PRODUCTIVITY OF BUILDING CONSTRUCTION USING INDUSTRIALISED BUILDING SYSTEM (IBS)

CIDB TECHNICAL PUBLICATION NO: 209

CIDB MALAYSIA

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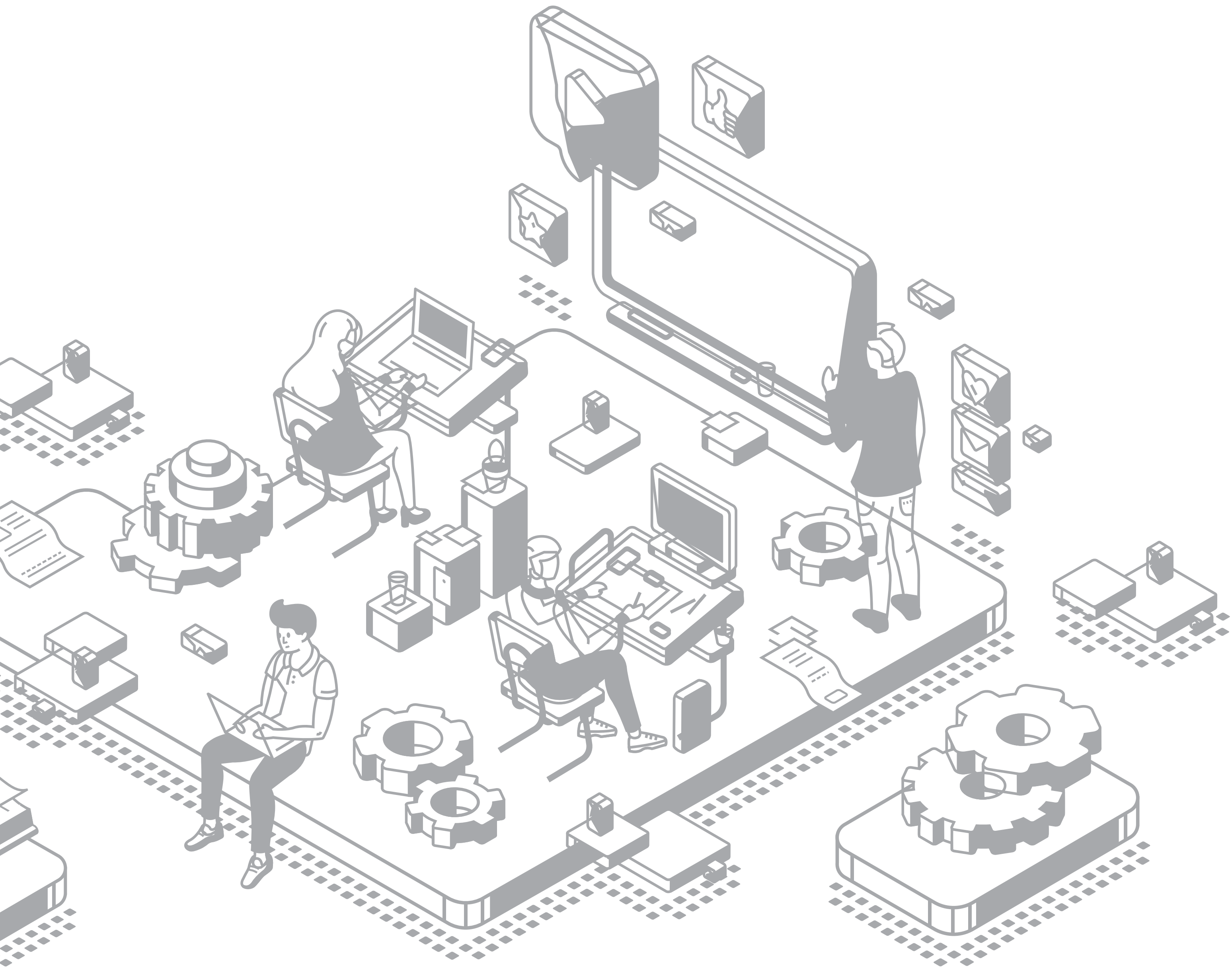

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“THIS REPORT CONTRIBUTES TO OUR MISSION TO HELP INDUSTRY PLAYERS UNDERSTAND THE IMPORTANCE OF PRODUCTIVITY MEASURING TO EXPLORE THE BENEFITS OF IBS AND DRIVE THE PRODUCTIVITY OF THE CONSTRUCTION INDUSTRY TO A LEVEL PLAYING FIELD.”

PREFACE

The world is changing faster, and technology is moving more rapidly than ever before. The construction industry as one of the most essential sectors in the world needs to keep up with the rapid evolution for the benefit of the society, environment, and economy. The population of the world's urban areas is increasing every day, all of whom need affordable housing as well as social, transportation, and utility infrastructure. In the face of these challenges, the industry is almost under a moral obligation to transform.

While most other industries have undergone great transformation over the last few decades, the construction industry has been hesitant about fully embracing the latest technological opportunities. This has resulted in its productivity being relatively stagnant. This unimpressive track record can be attributed to various internal and external challenges such as the persistent fragmentation of the industry, inefficient communication and collaboration mechanisms, difficulties to recruit talented and skilled workforce, and the exceeding reliance on cheap foreign workers, to name just a few.

The industry has vast potential for productivity improvements, thanks to digitalisation as well as new and innovative construction technologies and methods. The industry has long been acquainted with technologies such as Building Information Modelling (BIM) and Industrialised Building System (IBS). All of these technologies have the potential to boost productivity and increase quality and safety. However, the realisation of all this potential will require a committed and concerted effort by the industry across many aspects.

The Malaysian construction industry has been expending more effort to drive its productivity towards excellence. The journey of the industry's transformation started with rising issues in the housing industry, which has been affected due to rapid urbanisation. More and more people in the country migrate to urban areas to seek better opportunities and are demanding that the government provide more affordable homes. The government aims to build a million affordable houses within 10 years. Hence, the industry must bring their A-game to increase productivity even further to achieve this ultimate goal.

In this report, Construction Industry Development Board Malaysia (CIDB) and Construction Research Institute of Malaysia (CREAM) explains the importance of productivity in the construction industry and identifies types of productivity measurements which will eventually help to benchmark and increase the industry's productivity performance. This report contributes to our mission to help industry players understand the importance of productivity measuring to explore the benefits of IBS and drive the productivity of the construction industry to a level playing field.

CONTENT

EDITORIAL

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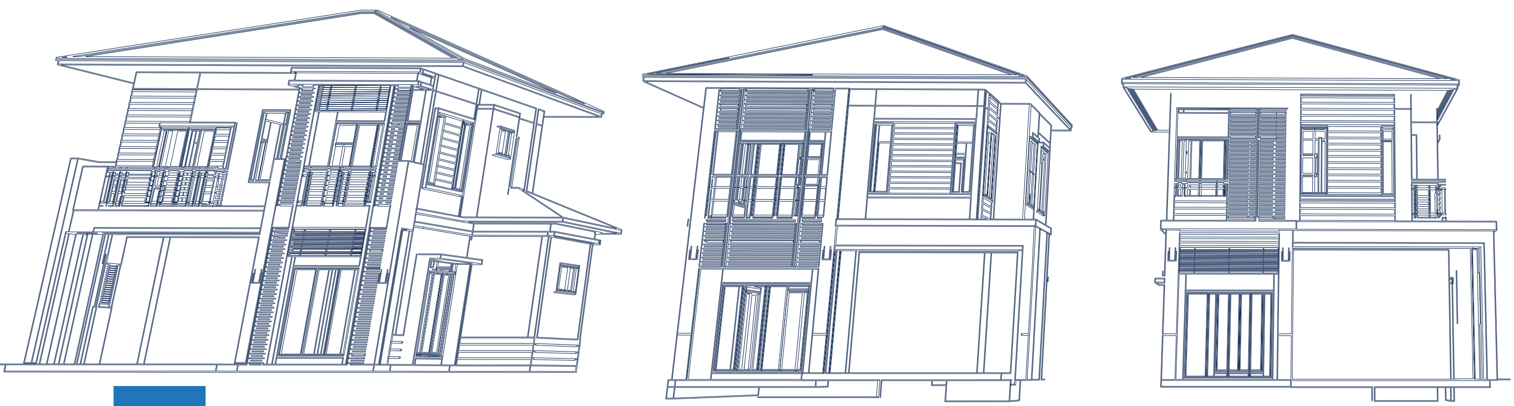


“PRODUCTIVITY MEASUREMENT IN THE CONSTRUCTION INDUSTRY IS VITAL TO BENCHMARK THE PRODUCTIVITY RATE IN MALAYSIA IN ORDER TO IDENTIFY THE PERFORMANCE OF THE INDUSTRY AND TO EXPLORE POTENTIAL AREAS THAT CAN HELP TO INCREASE PRODUCTIVITY PERFORMANCE.”

EXECUTIVE SUMMARY

Affordable housing is a key challenge facing many developed cities, worldwide. Access to quality, affordable housing is fundamental to the health and well-being of people. Yet in developing countries like Malaysia, cities struggle with the challenges of providing houses at a reasonable cost for low- and middle-income populations.

The Malaysian government has begun to explore options to address these issues head-on and is attempting to break the deadlock in which the industry appears to find itself. The Malaysian government sets a goal to build one million affordable homes within 10 years by continuously building 100,000 units every year to enable low-income earners to own a house. Therefore, the industry needs a more productive approach to ramp up in the delivery of affordable homes.

Today, digital revolution is transforming our world. Digital has been around for a while now and has impacted almost every industry to a different degree. However, while other sectors have been revolutionised, transformed their efficiency, and boosted their productivity, construction sector appears to be struggling in its digital adaptation journey. Industrialised Building System (IBS) is recognised as one of the advanced technologies to replace the traditional, labour-intensive construction method that can boost the productivity of the construction sector. Although the substantial benefits that would come from implementing IBS to raise the sector's productivity are well known and have long been discussed in the industry, progress has been limited. The construction sector in Malaysia appears to be stuck in a time warp as the country has become very familiar with the traditional method and reluctant to change. As a result, the productivity of the construction industry has suffered despite being the key industry in countries across the world.

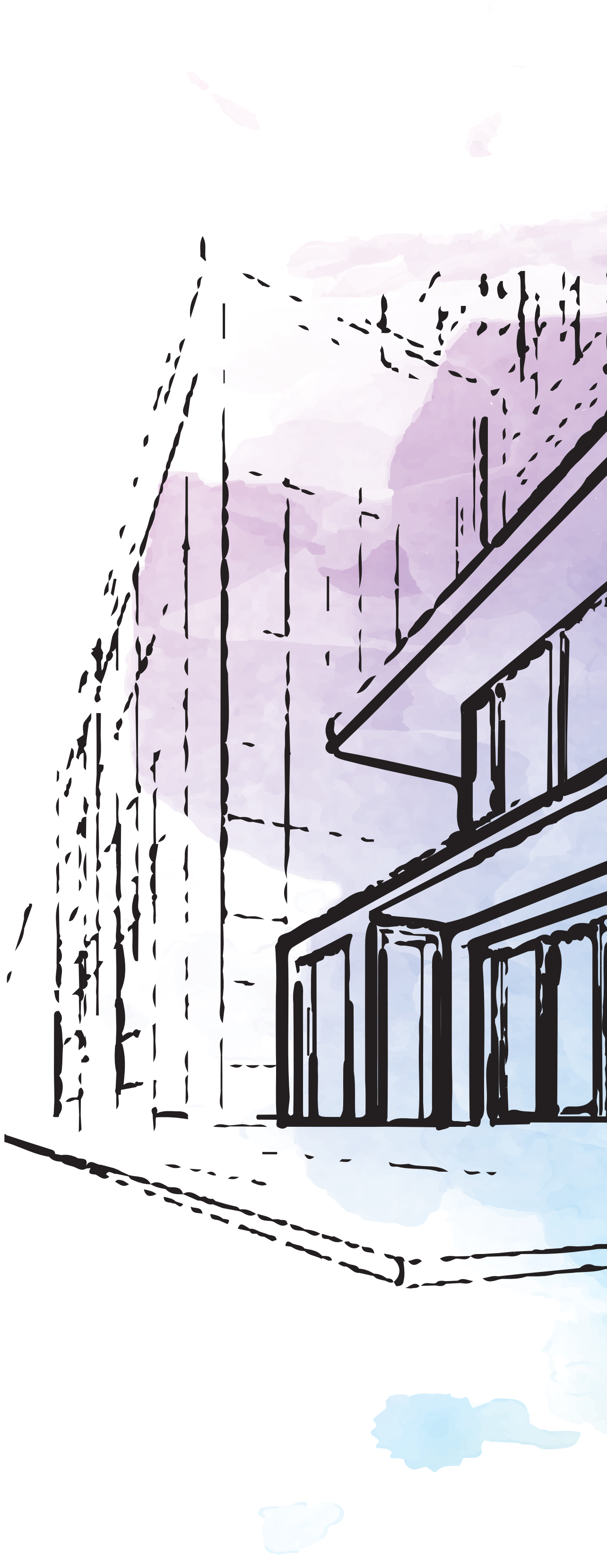
Therefore, there is a need to measure and quantify this matter to have a broad understanding of the challenges of productivity improvement. Productivity measurement in the construction industry is also vital to benchmark the productivity rate in Malaysia to identify the performance of the industry and to explore potential areas that can help to increase productivity performance.

In this study, a tool to measure productivity of building construction projects, particularly public housings, is developed to see how significantly IBS can improve productivity. The productivity measuring tool developed in this report defined the productivity of a building construction project as the total gross floor area (GFA) constructed per total man-days. This study also proposes a preliminary grading system to recognise productive building construction projects based on their productivity rates.

“ THE MALAYSIAN GOVERNMENT SETS A GOAL TO BUILD ONE MILLION AFFORDABLE HOMES WITHIN 10 YEARS BY CONTINUOUSLY BUILDING 100,000 UNITS EVERY YEAR TO ENABLE LOW-INCOME EARNERS TO OWN A HOUSE. THEREFORE, THE INDUSTRY NEEDS A MORE PRODUCTIVE APPROACH TO RAMP UP IN THE DELIVERY OF AFFORDABLE HOMES. ”

ONE

Introduction: A Glimpse into the Journey Towards a Productive Construction Industry in Malaysia



INTRODUCTION:

A GLIMPSE INTO THE JOURNEY TOWARDS A PRODUCTIVE CONSTRUCTION INDUSTRY IN MALAYSIA

The lack of affordable housing is one of the most urgent crises faced by the nation given that the urban population has continued to proliferate at an unforeseen rate over the years. Urbanisation driven by many opportunities offered by cities in a developing country like Malaysia is inevitable. The number of urban residents in Malaysia is expected to increase to 27.3 million people by 2030 (Asian Development Bank, 2006).

Although urbanisation brings about many positive effects on society, it is considered by many to be a double-edged sword because if it occurs too rapidly, it could become detrimental. Cities could become congested and consequently, the issues surrounding housing will become more prevalent than it already is. Urbanisation is also one of the key drivers for the housing demand in Malaysia as many citizens, especially those from a low-income group, find it difficult to find affordable homes in the city.

Since 1971, the government has intervened in the housing sector with its attention mostly focused on providing affordable housing to low-income groups. In 2019, the Housing and Local Government Ministry announced its intention to build one million units of affordable homes for the B40 group within the next 10 years. According to its Minister, Hajjah Zuraida Kamaruddin, the ministry aims to continuously build 100,000 units every year to enable low-income earners to own a house. This initiative is in line with the objective to improve the wellbeing of the citizens.

Minister Hajjah Zuraida Kamaruddin stated that the government was ‘on track’ to achieve the target. Accordingly, from July 2018 to November 2019, the ministry has nearly completed building 200,000 units of affordable homes — 46,666 units have already been built and another 151,933 units are under currently under construction (EdgeProp.my, 2020).

Another government initiative to achieve the 10-year target is by launching the National Housing Policy (2018–2025) and the National Affordable Housing Policy or Dasar Perumahan Mampu Milik (DRMM).

1.1 THE NATIONAL HOUSING POLICY (2018–2025)

The National Housing Policy (2018–2025) or Dasar Perumahan Negara (DRN) is a comprehensive housing policy that aims to detail out policies and action plans that consider current housing issues. The National Housing Policy serves as the national framework in driving housing development at the federal and state levels as well as being a catalyst in the systematic provision of housing based on needs and demands (Jabatan Perumahan Negara, 2018).

The DRN sets a goal to guide and drive the housing industry by emphasising a systematic and efficient housing planning, development, and management to generate sustainable, viable, quality, and inclusive environments for the people. It outlines holistic strategies and action plans to cater to the needs and safeguarding the welfare of the people as well as to drive the national housing industry. Its implementation is important to address current housing issues and acts as a comprehensive measure for the federal government to achieve the aspirations of a sustainable housing industry in the future.

The DRN is the basis for determining the planning and development direction for the housing sector in Malaysia. It is also a guide to all entities related to housing planning and development, whether at federal, state, local or private levels. The following are the objectives of the National Housing Policy (2018–2025):

01 to provide a housing sector development framework to assist the government and the private sector in providing housing based on the demands and needs of all walks of life

02 to strengthen the role of the housing sector to promote economic growth and the provision of liveable habitat

03 to ensure that the social allocation of the housing sector is available to qualified households

04 to encourage various access to housing through ownership and rental

05 to emphasise the provision and maintenance of affordable quality housing

To achieve these objectives, the DRN outlines five core focuses, 16 strategies and 57 action plans towards better national housing facilities as shown in Figure 1. Programs and projects outlined in the National Housing Policy plan are delivered in short, medium, and long terms: (1) short term: 2018–2020; (2) medium term: 2021–2023; and (3) long term: 2024–2025.

Figure 1: Five core focuses outlined in the National Housing Policy (2018 - 2025)

1.2 THE NATIONAL AFFORDABLE HOUSING POLICY (DRMM)

The National Affordable Housing Policy or Dasar Perumahan Mampu Milik (DRMM) is a sub-policy of the National Housing Policy (2018–2025). The main purpose of introducing this sub-policy is to address the housing affordability issues in the country in a holistic way. It provides detailed guidelines for housing developers who are interested in building affordable homes. The guidelines include the building standards, key specifications, and the ceiling price for affordable homes. DRMM outlines the concept of sustainable housing in the context of affordable housing using the following 17 criteria that need to be considered towards achieving the real goal of affordable housing (Jabatan Perumahan Negara, 2019):

- 01 House prices with income
- 02 Rental costs with income
- 03 Availability of interest rates and mortgages
- 04 Availability of rentable accommo-dation
- 05 Safety and security
- 06 Access to employment opportunities
- 07 Access to quality transportation facilities
- 08 Access to quality schools
- 09 Availability of housing products at affordable prices
- 10 Access to shopping areas
- 11 Access to childcare centres
- 12 Access to recreational facilities
- 13 Access to open space
- 14 Access to health services
- 15 Housing quality
- 16 Housing with energy efficiency
- 17 Access to solid waste management facilities

DRMM has identified five main challenges of the affordable housing industry in Malaysia:

To provide affordable, quality, safe, and accessible housing to the public, and to promote the establishment of a prosperous community, DRMM outlines the six main criteria of sustainable affordable housing as shown in Figure 2 below.

Figure 2: Six main criteria of sustainable affordable housing

DRMM has developed affordable housing standards as a guide for all parties involved in the construction and development of affordable housing in Malaysia to ensure the provision of quality and sustainable housing. One of the basic features of affordable housing outlined in the standards is construction technology. The government will begin to mandate the use of Industrialised Building System (IBS) in the construction of affordable housing. IBS is productive and can reduce the construction period as well as overall construction cost significantly. Hence, a high adoption of IBS is needed to help the government to achieve the target of 1 million affordable housing units within 10 years.

1.3 INDUSTRIALISED BUILDING SYSTEM (IBS) ILLUMINATES THE WAY FOR PRODUCTIVE CONSTRUCTION INDUSTRY

Industrialised Building System (IBS) is a term used widely in Malaysia to describe a construction method that manufactures building components in a controlled environment (on or off-site), before being transported, positioned, and assembled at the building's actual site (Abd Hamid, Azman, et al., 2011). In other words, IBS is a method of prefabrication. IBS eliminates several problems associated with conventional construction methods such as a large proportion of 3D (dangerous, dirty, and difficult) jobs in a messy, open-air setting with limited working hours has been moved into a safe, controlled factory environment with 24/7 production potential (de Laubier, Burfeind, Arnold, Witthoft, & Wunder, 2019). There are six types of IBS in Malaysia as shown in Figure 3 below.

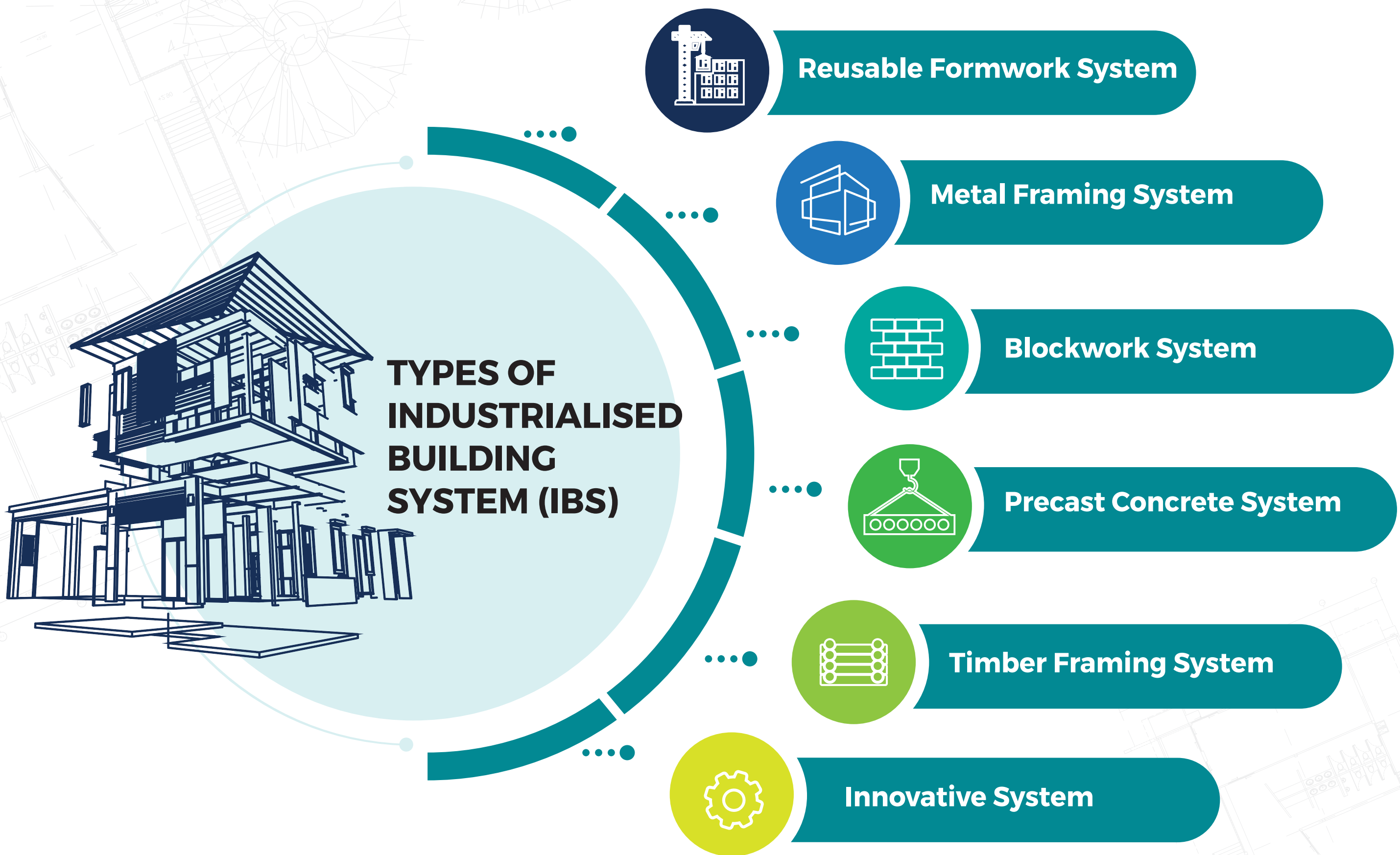


Figure 3: Types of IBS available in Malaysia

IBS adopts the concept of industrialisation in the construction industry. Industrialisation involves the rationalisation of the whole building process with less labour to handle the whole process to reduce production costs and increase productivity. The following are several aspects that are usually linked with industrialisation:

- **Use of mechanical power and tools**
- **Use of computerised steering systems and tools**
- **Continuous production process**
- **Continuous efficiency improvement**
- **Standardisation of products**
- **Prefabrication**
- **Rationalisation**
- **Modularisation**
- **Mass production**

Industrialisation in the construction industry is generally divided into 2 types: (1) off-site industrialisation; and (2) on-site industrialisation. Off-site industrialisation refers to prefabrication of building components that will be assembled on site while on-site industrialisation refers to the adoption of advanced tools and technologies on building sites (CIDB & CREAM, 2013).

The degree of industrialisation of IBS refers to the level of technology and the amount of capital employed in the fabrication and production of the components. Figure 4 shows that there are 5 degrees of industrialisation of IBS (Construction Industry Development Board Malaysia (CIDB), 2019).

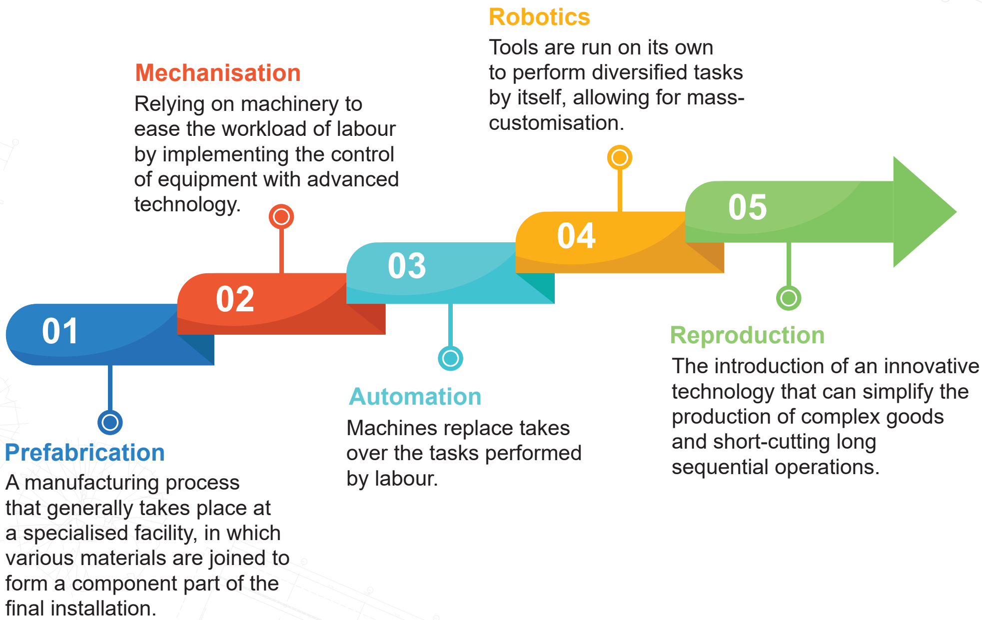


Figure 4: The degree of industrialisation

As fabrication of IBS components happens in a controlled environment, it reduces on-site complexity and hence, the productivity is higher. IBS also reduces the workforce required and offers higher safety and better quality, as well as lowers rework rates since it mostly uses manufacturing technology and automation which can reduce human error and increase consistency. It also enables the manufacturing process to be more efficient and allows faster inspections and quality checks. This ensures that the prefabricated units arrive on-site in a condition that requires little additional remedial work before or during assembly, thus reducing build time and increasing productivity (Barbosa et al., 2017). Figure 5 shows some of the benefits of IBS.

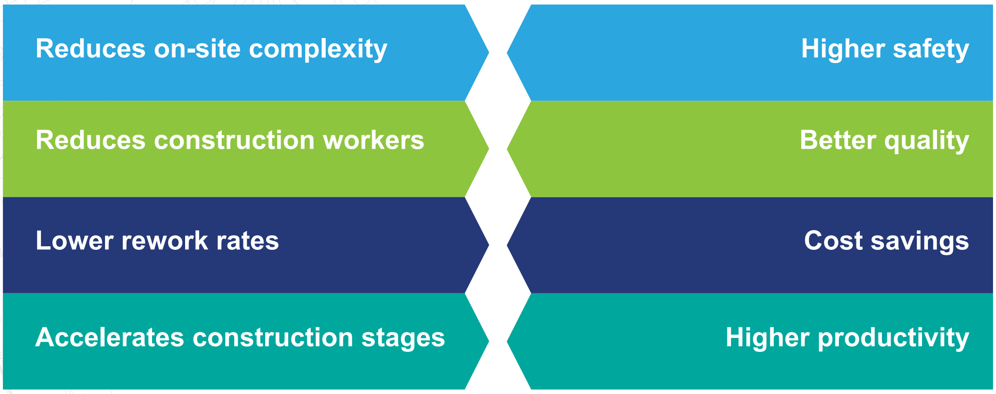


Figure 5: Benefits of IBS

Even though IBS has long been introduced in the industry globally and has many undeniable benefits, its adoption is still low, especially in Malaysia. There are many barriers or challenges to IBS adoption in the industry. Malaysia has become very familiar with the traditional method of construction, so the introduction to anything new or different faces barriers. The abundance of cheap foreign labour in Malaysia has also encouraged the industry to favour labour-intensive construction methods. The adoption of IBS also depends on the readiness and maturity of local contractors. Figure 6 describes some of the barriers to successful IBS adoption (Abd Hamid, Mohamad Kamar, & Alshawi, 2011).

Likewise, although the many benefits of IBS are well recognised in literature especially its ability to improve construction productivity, there is a lack of reliable and meaningful information in attaining a clear vision of productivity and determining to what extent does IBS improve construction productivity as compared to the conventional construction method. Therefore, it is important to study productivity measurements to see how significantly IBS can improve productivity. Hence, CREAM has done a study in developing a tool to measure the productivity of IBS projects to close this gap by collecting evidence to show if IBS truly can improve construction productivity. This evidence will be presented in Chapter 3.

1 Availability of Cheap Foreign Labour

The Malaysian construction industry still relies on cheap foreign labours as its abundance offsets the cost benefit of IBS implementation. As long as cheap foreign labours are available in the industry, builders will always prefer the labour-intensive methods and reluctant to change to move to IBS as labour rates will remain low and hence lowers the overall construction cost.

2 Reluctance to Change

Moving from conventional system to IBS requires a different mindset along with the right environment. Familiarity with the conventional system causes the industry to be reluctant to change to a mechanised-based system as it requires more investment to train the labours and to buy the machinery. The mentality of "why fix it if it isn't broken" arises as the conventional system has not created big problems for the contractors.

3 Inflexibility and Uniform Designs

To keep costs down and increase productivity, IBS encourages the use of standardisation. This cookie-cutter approach tended to conflict with building-site constraints and an individual owner's preference for some degree of customisation. This is also why IBS is not popular among design architects as the misconception that IBS will limit their creativity. The tailor-made components are not flexible to fit into another project.

4 Public Perception

The misconception that IBS prefers the use of standardisation or design repetitions could be another setback to IBS adoption. There is a perception that IBS is rigid and not flexible enough in both form and dimension to meet all the variable construction demands. This leads to the mistaken conclusion that IBS can only produce monotonous design and has unpleasant architectural appearance.

5 Lack of Integration in Design Stage

Construction projects are usually fragmented, diverse, and involve many parties. IBS manufactures and contractors are usually involved after the design stage and this lack of integration has resulted in the need for design changes and additional costs to be incurred if IBS is adopted.

6 Reliance on Closed System

IBS is not favourable in the industry as its components are usually not compatible and flexible to be used among contractors as the components have its own design and construction methods. A contractor is probably obliged to get supply from the same manufacturer throughout the construction and this causes the manufacturer to control the price and the component will be expensive and not commercially viable for small contractors.

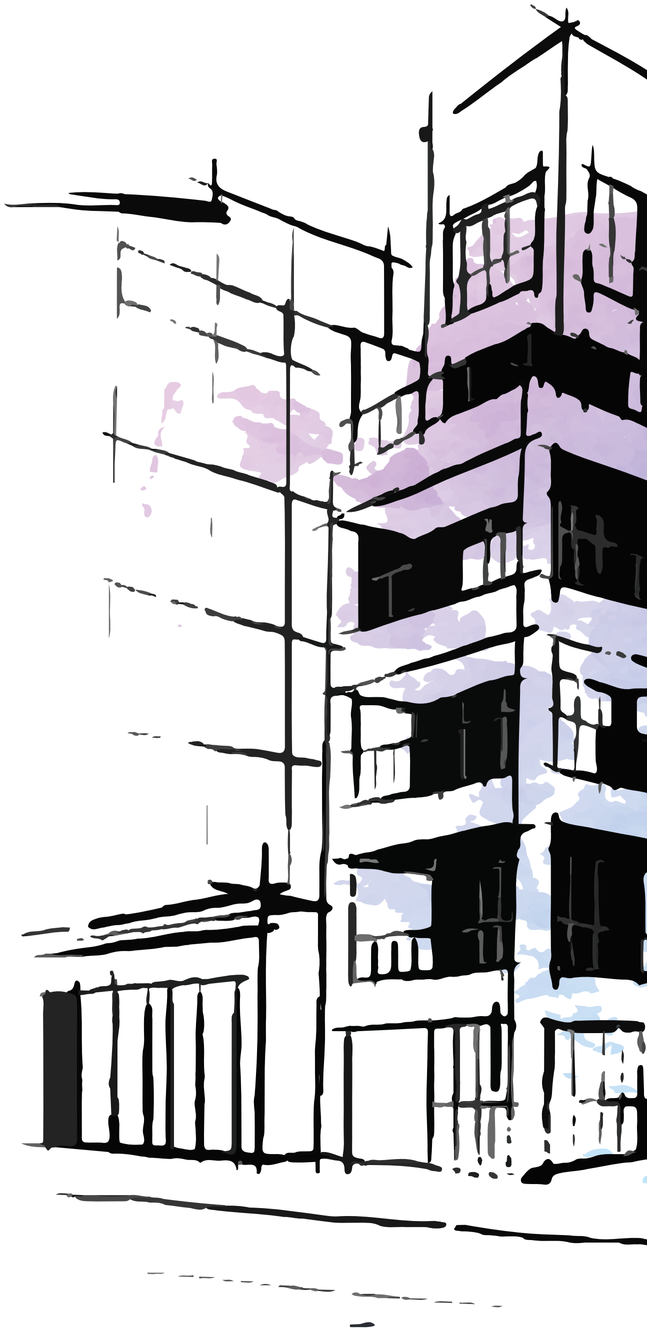
Figure 6: Barriers to IBS Adoption

“PRODUCTIVITY ISN’T EVERYTHING, BUT IN THE LONG RUN, IT IS ALMOST EVERYTHING. A COUNTRY’S ABILITY TO IMPROVE ITS STANDARD OF LIVING OVER TIME DEPENDS ALMOST ENTIRELY ON ITS ABILITY TO RAISE ITS OUTPUT PER WORKER.”

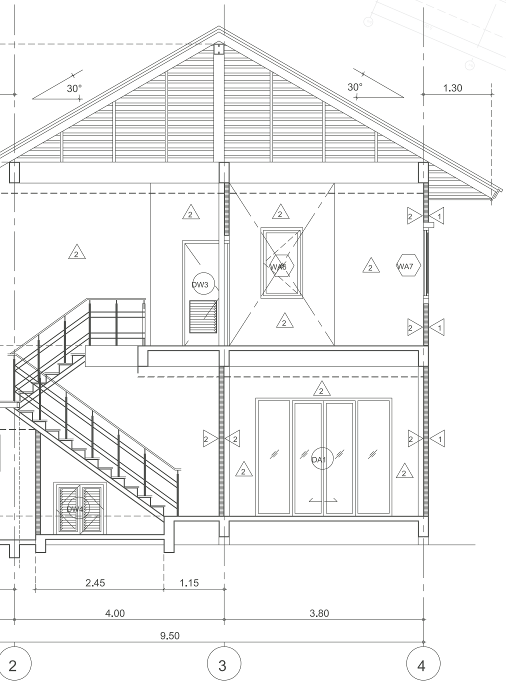
PAUL KRUGMAN, THE NOBEL PRIZE-WINNING ECONOMIST

TWO

The Productivity Study



THE PRODUCTIVITY STUDY



Productivity is generally defined as the relationship between output and input used to produce the output as shown in Equation 1. Higher productivity means achieving more with the same or lesser amount of input. This relationship measures the efficiency of production inputs used in an economy to produce a given level of output (Malaysia Productivity Corporation (MPC), 2019).

$$\textbf{Productivity} = \frac{\textbf{Output}}{\textbf{Input}} \quad \textbf{(1)}$$

As productivity measures how inputs are efficiently being used in an economy to produce a given level of output, productivity is important in all nations at all levels of development, and to all sectors of the economy (SCAL, 2016). Small differences in productivity growth rates can also make an enormous difference to a society's prosperity.

Productivity growth is important because it contributes to growth in output, income, and living standards. As productivity is the rate of output per unit of input, creating more output in terms of quantity and quality, for a given input results in better living standards (Green, 2016). The Nobel prize-winning economist, Paul Krugman once said:

“PRODUCTIVITY ISN'T EVERYTHING, BUT IN THE LONG RUN, IT IS ALMOST EVERYTHING. A COUNTRY'S ABILITY TO IMPROVE ITS STANDARD OF LIVING OVER TIME DEPENDS ALMOST ENTIRELY ON ITS ABILITY TO RAISE ITS OUTPUT PER WORKER.”

Higher productivity gives a lot of advantages to economic growth as presented in Figure 7. It lowers unit costs which will encourage higher demand, more output, and increase in employment. Higher productivity also improves competitiveness and trade performance in global markets. Higher productivity among workers also contributes to higher profits for companies and businesses can also afford higher wages. Growth in productivity helps the economy to grow as well and eventually the growth of national output also increases.

Figure 7: Importance of Productivity

At firm or industry level, many parties can benefit from productivity growth. For examples, better wages and conditions for the workforce, increased profits and dividend distributions to shareholders and superannuation funds, lower prices for customers, more stringent environmental protection, and benefits to governments through an increase in tax payments. Productivity growth helps to maintain the growth in living standards as labour utilisation declines and as costs associated with environmental protection increase (Parham, 2011).

Productivity encourages greater competition. It provides incentives for firms to improve their performance for survival and growth. Greater competition between economies through trade and investment brings opportunities for globalisation which can intensify productivity improvements. Likewise, technological changes provide opportunities for strong productivity growth and also assists globalisation by enabling better transfer of information and international coordination of economic activities (Parham, 2011).

Productivity is considered as a key source of economic growth and competitiveness. It is a piece of basic statistical information for numerous international comparisons and country performance assessments. Productivity growth is an important element in modelling a productive economy's capacity and it allows analysts to determine capacity utilisation which can enable us to gauge the position of economies in the business cycle apart from forecasting economic growth (Construction Industry Development Board Malaysia (CIDB), 2020).

2.1 PRODUCTIVITY IN MALAYSIA

Productivity is considered the most important factor in any country's long-term growth, including Malaysia. High-productivity nations can quickly adapt to changes in macroeconomic challenges, as well as fundamental shifts brought on by technological innovations.

Based on the latest annual statistics from The Conference Board (TCB), Total Economy Database (1950 – 2019) shows that although Malaysia's labour productivity is growing from 2018 to 2019, the productivity competitiveness is still falling behind when compared with developed countries such as the United States, Singapore, South Korea, and Japan. Table 1 and Figure 8 below show the level and growth of labour productivity Malaysia and selected developed countries in 2019 (The Conference Board, 2019).

Table 1: Level and Growth of Labour Productivity (The Conference Board, 2019)

Countries	Labour Productivity Level (USD)*	Growth (%)
Malaysia	68,473	3.0
United States of America	131,783	1.3
Singapore	153,124	1.0
South Korea	80,566	2.4
Japan	82,382	1.1

*Labour productivity per person employed in 2018 US Dollar

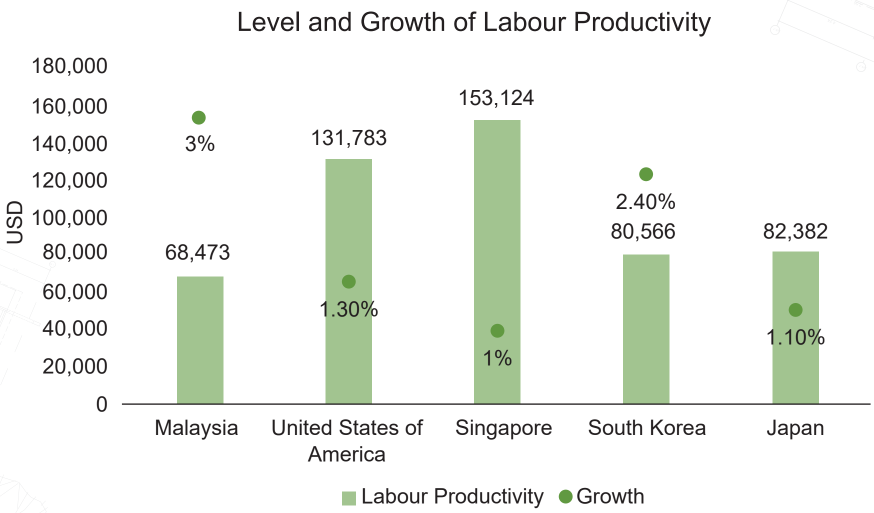


Table 1: Level and Growth of Labour Productivity in 2019 (The Conference Board, 2019)

Malaysia Productivity Corporation (MPC) has identified three accelerating initiatives for productivity improvement as shown in Figure 9 below (MPC, 2019).

Elevating Industry Benchmarks

To build momentum on the adoption of best industry practices and high productivity enterprises for the nation to achieve its full potential. Among the programmes introduced for this purpose are:

1. High Productivity Enterprise (HPE)
   - Recognises high productivity enterprises operating in Malaysia using local talent
   - Aims to use local talents to achieve excellent performance
   - Hopes to improve productivity and compeitiveness by identifying the best business practices
2. Best Practices Online Database (BOND)
   - To ensure information is easily accessible by industry players
   - The ultimate hub of best practices referrals in Malaysia
   - Aims to inspire recipients to work towards best practices for continuous productivity improvements
3. e-Benchmark
   - To cater the growing needs of expanding business community
   - To establish benchmarks for performance comparison between companies across the globe

Effective Measurement Tool

- Effective and easy-to-use tools are a good way to get a clearer idea of the productivity status, and to determine the status of current performance, set future targets, and inspire others to work together to achieve goals and profitability.
- The measurement tool should measure productivity performance improvement before and after the implementation of productivity initiatives
- The measurement tool should identify problems as well as opportunities or improvement
- To assist companies in determining their productivity performance

Technology Enhancement

- Malaysian industries are being transformed by Industrial Revolution 4.0 (IR 4.0) driven by the digital revolution and the Internet of Things (IoT) in line with global modernisation
- 5 strategic enablers are carried out through this initiatives:
  1. Funding and outcome-based incentives
     - to encourage companies to adopt new manufacturing technologies and processes, and invest in R&D
  2. Enabling efficient digital infrastructure
     - good and reliable internet speed rate is needed for implementing internet-based production technologies or services
  3. Regulatory framework and industry adoption
     - regulation is a key enabler of Malaysia's IR 4.0 transformation and is of improtance to SMEs who still have limited knowledge on digital adoption and IR 4.0
     - to foster accelerated transformation, mechanisms will need to be put in place to help manufacturing firms understand their current capabilities and what it will take for them to transform and implement IR 4.0 technologies
  4. Upskilling existing and producing future talents
     - to fundamentally reshape the jobs landscape and foster significant changes in how industrial workers perform their jobs
     - a qualified and skilled workforce is indispensable for the introduction and adoption of IR 4.0
  5. Access to smart technologies and standards
     - to encourage more adoption by working with global and local industry leaders to set up digital and IR 4.0 demonstration labs
     - to develop and commercial new technologies and processes that address specific needs in priority sectors will be crucial to retain Malaysia's position as a preferred high-tech and manufacturing hub and supply chain partner

Figure 9: Accelerating initiatives for productivity improvement

National productivity culture programmes and activities have been planned and executed through collaborations between many government agencies and industry players at national, sectoral, and enterprise levels. Realising the criticality of accelerating productivity improvement, the government has developed the Eleventh Malaysia Plan (11MP) to drive Malaysia forward from its position as a middle-income economy into an advanced economy and inclusive nation by 2020.

Under the Mid-term Review of 11MP, Malaysia targets to increase labour productivity from 1.8% to 3.2% in year-on-year growth, or from RM75,550 per worker to RM88,450 per worker by 2020 (Economic Planning Unit, 2018). The 11MP has also specified the potential of productivity as one of the six game-changers for Malaysia to achieve high-income status by 2020. The 11MP has introduced the Malaysia Productivity Blueprint in May 2017 as a strategy for unlocking Malaysia's potential. The Construction Industry Development Board Malaysia (CIDB) has also developed a transformation programme called Construction Industry Transformation Programme (CITP) 2016–2020 to guide the construction industry in raising productivity to the next level.

2.1.1 MALAYSIA PRODUCTIVITY BLUEPRINT

The Malaysia Productivity Blueprint (MPB) envisions Malaysia to serve as a model of excellence in driving productivity transformations, domestically and globally. It seeks to drive Malaysia towards more competitive and productive mindsets, as well as increase the nation's productivity to meet the 11MP targets. The blueprint also recognises that a transformation is essential to propel the nation into the ranks of advanced countries with sustainable economic growth. Delivering successfully on the blueprint will pave the way to achieving an annual labour productivity growth of 3.2% by 2020 as targeted by the Mid-term Review of 11MP (Economic Planning Unit, 2018).

The blueprint outlines three guiding principles to ensure effective implementation: (1) productivity must be addressed holistically, at national, sectoral, and enterprise levels; (2) strong coordination and governance are key to securing implementation certainty; and (3) productivity needs to be prioritised and embedded into the day-to-day work culture. The blueprint also addresses at least five productivity challenges at all levels, which are centred around talent, technology, incentive structure, business environment, and productivity mindset (Figure 10).

Talent

- More cohesive efforts are required to meet the demand of the future economy.
- Building a strong pipeline of skilled workers and gradually reducing reliance on low-skilled workers

Technology

- Higher industry adoption on technology and digitalisation through stronger collaboration between industry and academia

Incentive Structure

- Incentives need to be directly linked to productivity to improve efficiency and performance

Business Environment

- Regulations need to be applied with greater consistency and regulatory hurdles need to be reduced to improve ease and reduce cost of doing business for enterprises

Productivity Mindset

- High level of awareness and understanding of the importance and benefits of productivity, as well as guidance on how to monitor and measure productivity are needed at enterprise level

Figure 10: Challenges to Productivity Growth (EPU, 2017)

In line with the blueprint's aspirations, a holistic approach is developed towards unlocking the potential of the nation by accelerating productivity improvement strategies, initiatives, and programmes at the national, sectoral, and enterprise levels through five strategic thrusts (Figure 11):

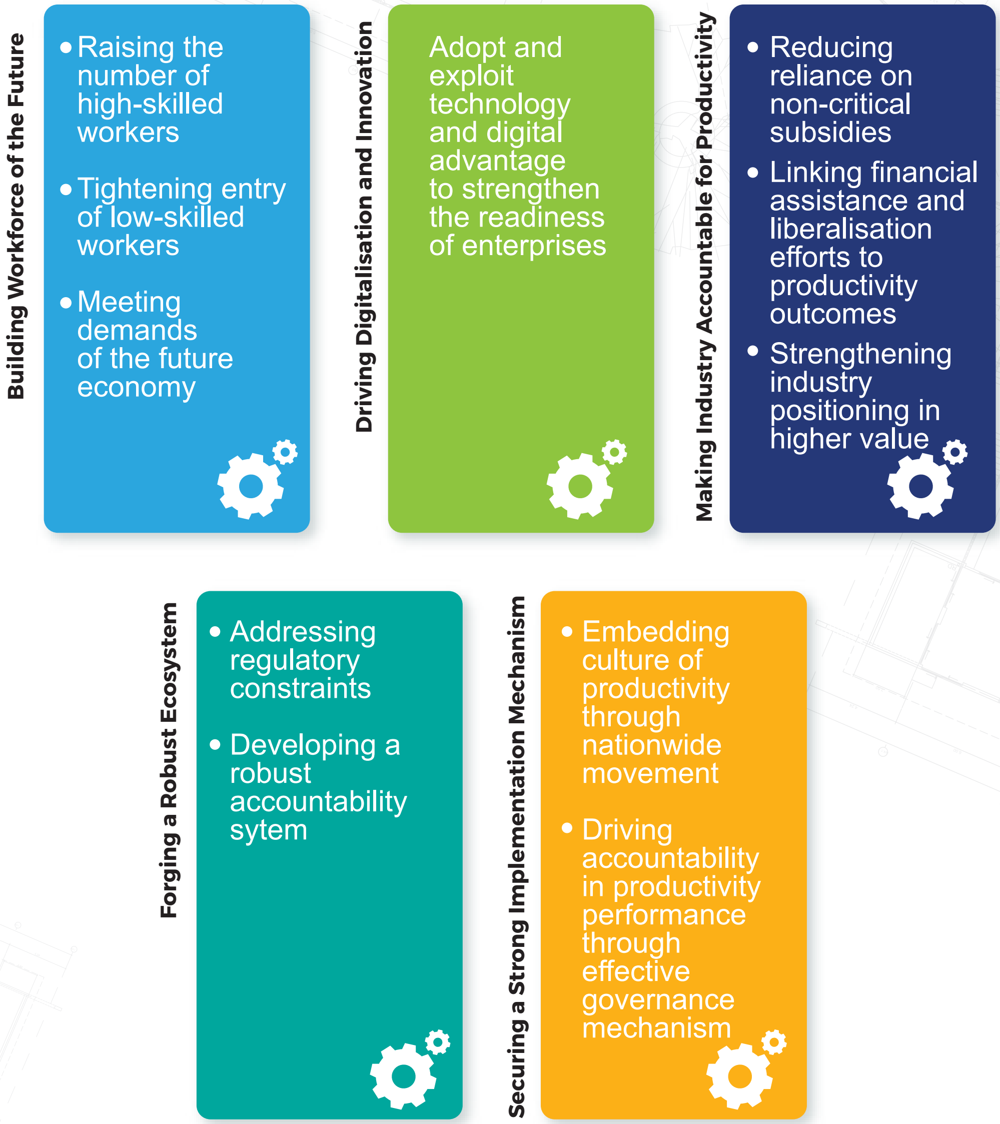


Figure 11: Five strategic thrusts in the Malaysia Productivity Blueprint (EPU, 2017)

2.1.2 CONSTRUCTION INDUSTRY TRANSFORMATION PROGRAMME 2016 – 2020

Malaysia has launched the “Construction Industry Transformation Programme 2016 – 2020”, which aims to transform today’s construction industry into a modern, highly productive, and sustainable industry. The programme also plans to enable Malaysia companies to compete with international players locally and globally.

The Construction Industry Transformation Programme or CITP has four strategic thrusts:

- Quality, safety, and professionalism
- Environmental sustainability
- Productivity
- Internationalism

Productivity was included in the programme due to:

A Largely low-skilled workforce and inadequate training and development;

B Over-reliance on low-skilled foreign labour;

C Limited adoption of modern practices, mechanisation and Industrialised Building System (IBS);

D Limited adoption of information technology such as BIM;

E Lack of data and information-driven decision-making in the industry; and

F High proportion of sub-scale SMEs, including Bumiputera SMEs and entrepreneurs.

Therefore, one of the aspirations of the programme is to strengthen productivity in the construction industry through the drivers of workforce, technology, and processes. Hence, the broad initiatives under the productivity thrust are:

A Continuous investment in human capital development in construction;

B Enhancing control and balance of workforce supply;

C Accelerating the adoption of Industrialised Building System (IBS), mechanisation and modern practices;

D Rollout technology advantage across project life-cycle;

E Enhancing the availability of strategic information via the National Construction Industry Information Centre; and

F Advancing SME/Bumiputera capacity and capability-building

2.2 PRODUCTIVITY IN THE CONSTRUCTION INDUSTRY

The construction industry is an essential industry to the society, environment, and economy. It is one of the first businesses that humankind developed and is essential as other businesses rely on the construction industry to provide and maintain their accommodations, plants, and infrastructures. Construction is vital to society as it determines where and how almost everyone lives, works, and plays (Philipp Gerbert, 2016).

The construction industry is also the single largest global consumer of resources and raw materials. It consumes 3 billion tonnes of raw materials to manufacture building products worldwide every year. Buildings are responsible for 25–40% of the global total energy and hence contributing hugely to the release of carbon dioxide (Philipp Gerbert, 2016). Therefore, improving productivity which simultaneously will provide a better quality of construction is essential for the environment.

Construction is one of the largest sectors in the world economy. With total annual revenues of almost $10 trillion and an added value of $3.6 trillion, the industry accounts for about 6% of global GDP. The industry is expected to continue growing with estimated revenues of $15 trillion by 2025. Construction also interacts with various other sectors by means of buildings or other constructed assets. Residential housing alone accounts for 38% of global construction volume, followed by 32% of transport, energy, and water infrastructure, 18% institutional and commercial buildings, and 13% of industrial sites (Philipp Gerbert, 2016). However, the industry has struggled to evolve in its approaches as other industries, causing its productivity to lag behind other sectors for decades. According to the McKinsey Global Institute (MGI), there is a $1.6 trillion opportunity to close the gap (Barbosa et al., 2017).

Productivity has been the subject of much debate in the construction industry in many countries for many decades. The concept of productivity is not well understood in construction; many find it complex and difficult to understand. For many reasons including the nature and inherent features of the construction industry and constructed items, it is difficult to define, measure, interpret, and compare indicators of construction productivity. However, productivity is growing even more important now in the construction industry.

Average labour productivity growth in the construction sector is 1% a year, globally, over the past two decades as compared to the world economy which is 2.8%. This poor performance is due to the industry being extremely fragmented, extensively regulated, highly cyclical and very dependent on public-sector demand. The construction sector's poor productivity is also because of how the sector is split into two:

OPTION

01

DATA INFO

Large-scale players engaged in heavy construction such as civil and industrial work, as well as large-scale housing; and

OPTION

02

DATA INFO

a large number of fragmented specialised trades such as mechanical, electrical, and plumbing (Barbosa et al., 2017).

Productivity in the construction industry has commonly been defined as a ratio of a volume measure of output to a volume measure of input use (Organisation for Economic Co-Operation and Development (OECD), 2001). Productivity is considered as increasing in three situations:

- Reduce inputs to produce the same output
- Increase output for a given level of inputs
- A bit of both

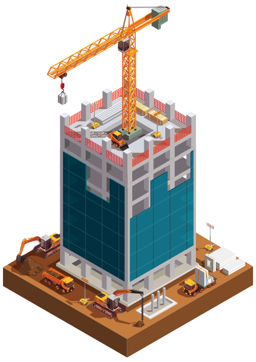
In the construction productivity, the output is usually defined as gross value added (GVA) on-site and labour on-site is identified as the input in terms of hours worked. Therefore, the value added by construction is not the building, but the process of assembling the building (Green, 2016).

Construction productivity gives so many advantages, especially to contractors. If construction productivity increases, projects can be completed faster with reduced costs and the overall project will be more profitable.

2.2.1 OBSTACLES TO CONSTRUCTION PRODUCTIVITY IMPROVEMENT

Construction productivity is influenced by a plethora of factors such as project conditions, weather variability, materials shortage, lack of experienced or skilled personnel, issues in design and procurement, ineffective construction management, and restrictive government policy. A study in Singapore classified some of these factors into three categories:

1. Nature of construction activities



Construction work is undertaken in response to expressed demand where in most cases, contractors have no control over it. Construction work is also labour-intensive, unique, and difficult to mechanise or standardise. It is known as the 3D job — dirty, dangerous, and difficult — as it deals with heavy equipment and elements, and also involves many activities in several trades which increase the risk of incidents. The 3D job also affects the image of the industry to attract and retain skilled workers and recent graduates. Besides that, construction is also location-specific and therefore faces the realities and uncertainties in the physical environment such as subsoil conditions, weather changes as well as social and community issues. Logistics can also be challenging for projects located in remote areas (SCAL, 2016).

2. Influence from the construction industry

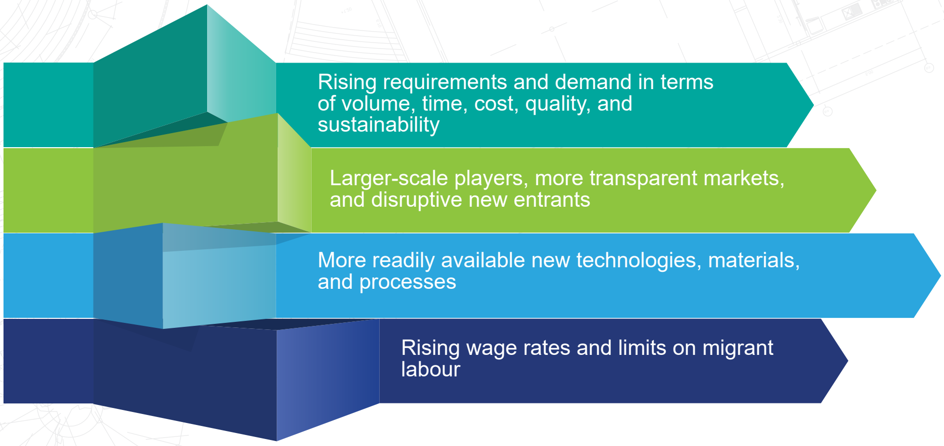
A fragmented industry is also one of the obstacles to better productivity performance. There are still shortcomings in design approaches, management practices, work methods, business practices and human resources. Variations in standards, processes, materials, skills, and technologies required by different types of projects are also one of the obstacles to construction productivity improvements. There are issues of design changes during construction which is supported by the interviewees of the study which will be demonstrated later in Chapter 4, and other issues like the poor motivation of workers and poor prioritisation of productivity improvements (SCAL, 2016).

3. Influence from outside the control of the construction industry

There are also matters coming from outside parties which are inevitable and uncontrollable by the industry. For instance, governments. Governments have control over construction productivity in terms of public-sector project opportunities, procurement arrangements, and contract conditions. The productivity of a project is controlled by strict regulations like approvals, certifications, and inspections needed for the project. Other issues like variations in building codes, permission processes, and regulations in states and localities also have a negative impact on productivity There is a large number of provisions that need to be complied with and this invites more parties or a big number of players into the process and hence could increase uncertainty and inefficiency (SCAL, 2016). Evidence was presented in a US study that land use regulation has a small negative impact on productivity growth in construction. They also estimated that regulation increases construction costs by 3.7% and reduces productivity growth in construction by 0.1% a year (Sveikauskas, Rowe, Mildenberger, Price, & Young, 2014).

2.2.2 CONSTRUCTION PRODUCTIVITY IMPROVEMENT STRATEGIES

Nonetheless, the following four external trends could disrupt the inertia in the construction sector and transform the industry:



These four disruptions are likely to increase pressure on the industry to usher in a new era of higher productivity. To change, regulators can mandate the use of BIM to build transparency and collaboration across the industry; reshape regulations to support productivity; create transparency on cost across the industry; publish performance data on contractors; and consider labour interventions to ensure skill development, rather than rely heavily on low-cost foreign workers (Barbosa et al., 2017).

In Figure 12, McKinsey Global Institute has identified seven innovative actions that can boost the productivity of the construction sector by 50–60% (Barbosa et al., 2017):

ACTION 1: RESHAPE REGULATION AND RAISE TRANSPARENCY

- Monitor KPIs across key regulatory areas
- Streamline permitting and approvals processes
- Allocate grants and budgets for innovation and training
- Encourage transparency across the industry and combat informality
- Mandate use of technology
- Shift fully to outcome/productivity-based regulation
- Establish “single-window clerance” approach to optimising permitting and approvals
- Move from grants to investments in areas such as innovation and skill building
- Combat land fragmentation to drive scale development

ACTION 2: REWIRE THE CONTRACTUAL FRAMEWORK

- Negotiate and contract beyond cost for value
- Establish a single source of truth
- Add incentives to traditional contracts
- Priotise integration and interface management
- Move to alternative contracting strategies such as IPD
- Invest in up-front planning and scoping, typically with early contractor and expert input from multiple sources
- Formalise contracting and budget only after estimates are robust and triangulated via multiple inputs

ACTION 3: RETHINK DESIGN ENGINEERING PROCESSES AND INCREASE STANDARDLISATION

- Improve design process and outcomes
- Ensure early collaboration from all parties involved in design
- Encourage repeatability of design across projects
- Design for manufacturing and assembly (DfMA) right from the start
- Institutionalise design to value and constructability reviews in design

ACTION 4: IMPROVE PROCUREMENT AND SUPPLY-CHAIN MANAGEMENT

- Use standard procurement tools and levers seen in other sectors
- Invest in a central procurement organisation
- Leverage clean sheeting to improve supplier and subcontractor management
- Invest in supply-chain and inventory capabilities to tackle the shift to a production system
- Move to digisted procurement-management system, including analytics and simulations, and real-time and predictive supply-chain practices

ACTION 5: IMPROVE ON-SITE EXECUTION

- Introduce rigorous integrated planning
- Implement collaborative performance management
- Mobilise projects effectively
- Collaborate to reduce waste and variability
- Utilise a LPS-based system to ensure effective “milestone-back” workforce planning, in addition to central planning
- Develop a single source of truth with a central control tower, used by all contractors and subcontractors

ACTION 6: INFUSE DIGITAL TECHNOLOGY, NEW MATERIALS, AND ADVANCED AUTOMATION

- Invest in a chief digital/technology/innovation office and team
- Make 3D BIM universal
- Introduce drones and unmanned aerial vehicles for scanning, monitoring, and mapping
- Use digital collaboration and mobility tools on portable devices
- Mobilise 5D BIM across the project life cycle with augmented/mixed reality interfaces
- Leverage the Internet od Things-enabled fully connected sites
- Implement advanced analytics on project and firmwide data
- Develop alternative and innovative materials
- Implement automation equipment on sites

ACTION 7: RESKILL THE WORKFORCE

- Build an apprenticeship model
- Develop frontline training
- Ensure knowledge retention and management
- Introduce e-enabled micro training for frontline workers
- Run field and forum - mix of classroom and field-based training to make adult learning more effective
- Create internal academies to institutionalise best practices and roll out across sites

Figure 12: Innovative actions to boost the productivity of the construction industry

The usage of construction labour varies as a project progresses from structural work, architectural and finishing work, and mechanical and electrical (M&E) work. The ratio of foreign to local workers are also different through these stages. CIDB Singapore has surveyed manpower to identify the areas where manpower usage is high in construction and the results are constructed in Table 2 below (CIDB Singapore, 1992).

Table 2: Usage of Workers in Construction

Types of Work	Usage of Workers (%)	Usage of Foreign Workers
Structural	50	80–85
Architectural & Finishing	30–35	50–60
Mechanical & Electrical	15–20	30

(Source: CIDB Singapore, 1992)

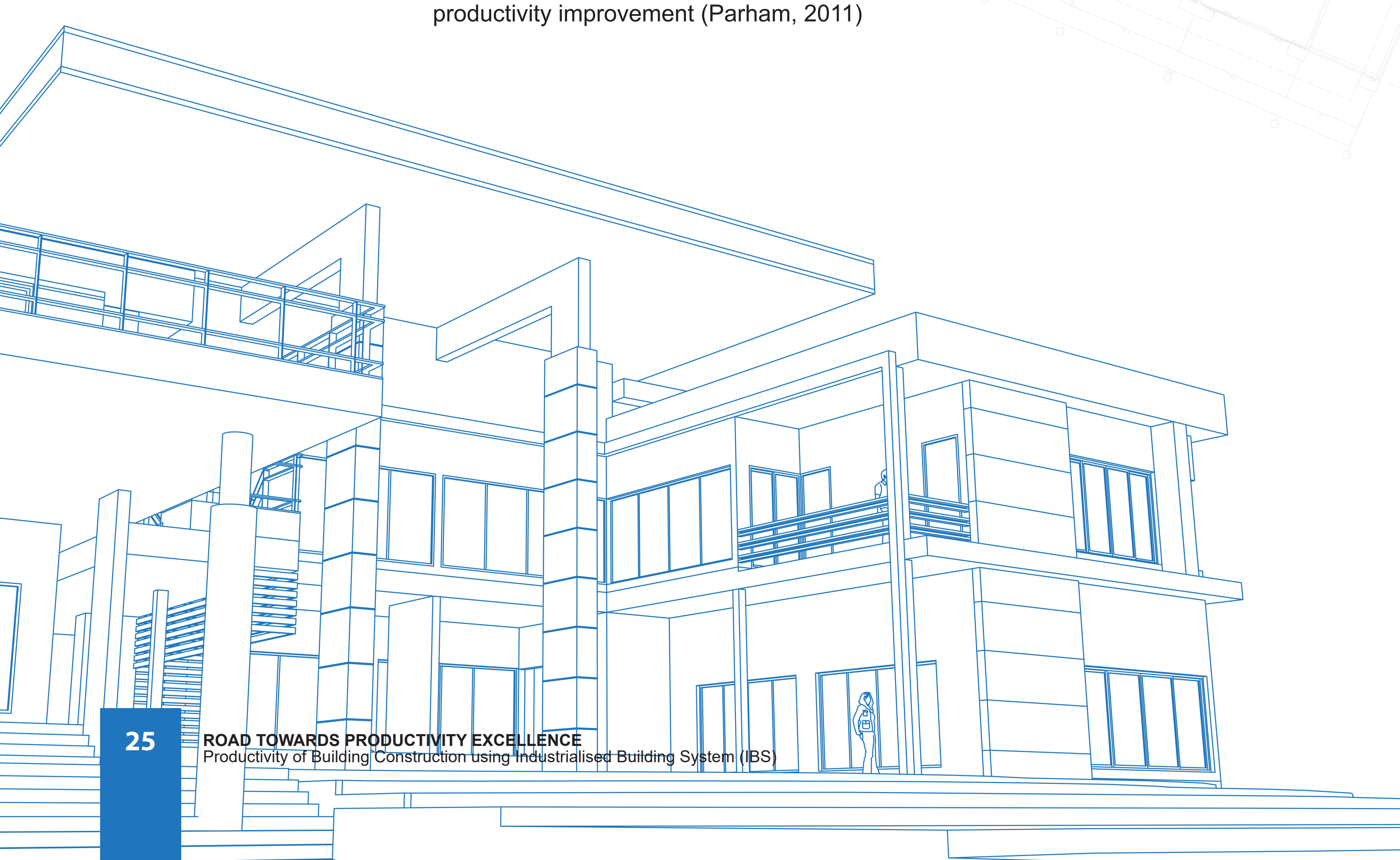
Table 2 above shows that structural work uses the largest number of workers, especially foreign workers. Therefore, the productivity improvement efforts should focus more on building work, followed by architectural and finishing work, and lastly, M&E work. To improve the productivity of structural work, CIDB suggests replacing the skills from manual to assembly by using technology such as Industrialised Building System (IBS).

Looking at trades involved in the structural work, CIDB identified three key trades which are formwork carpentry, steel reinforcement fixing, and concreting. Formwork carpentry requires the most skills, followed by reinforcement and concreting. Therefore, a high use of prefabricated structural components will significantly improve productivity performance. Designs that use fewer beams will also be more productive to construct as beams are the highest consumer of site labour in terms of both formwork carpentry and reinforcement work.

Meanwhile, architectural and finishing work requires a mixture of manual and assembly trades. The more assembly work there is, the higher the productivity that can be achieved. The use of precast walls or prefabricated curtain walls can be the alternative to the use of an external brick wall with plaster which is the highest consumer of labour. This change can improve productivity by four to six times. Similarly, lightweight concrete blocks or precast lightweight walls can be the substitution for brick and plaster for internal walls. Although brick and plaster are cheaper, they are also labour-intensive. Architectural components such as doors, windows, tiles, and ceilings designs can be standardised to improve productivity even further.

M&E trades are generally assembly work involving equipment and distribution system installation such as wiring, pipes, ducts etc. These trades can be prefabricated off-site for better productivity performance.

Construction is commonly known as a “backward industry” as it has failed to innovate in comparison to other sectors (Winch, 2003). Construction has retained its manual method of operation while other sectors modernised through the adoption of innovation and hence, construction fell further behind the rest of the manufacturing industry in terms of productivity, quality, and value for money. The innovation of remedial measures such as recruiting and training the younger generation to develop necessary skills, process improvement, standardisation, and knowledge transfer is needed to improve productivity performance (Alinaitwe, Mwakali, & Hansson, 2005). Therefore, the education and training system, as well as innovation system, play an essential role in developing skills and knowledge needed for productivity growth. Flexibility to experiment, innovate, and adapt to change is also important in productivity improvement (Parham, 2011)



As mentioned in Chapter 2, the housing demand is very high and currently, there is a big number of construction projects is happening in Malaysia to achieve the goal of the government which is to build 1 million affordable houses in ten years. When the demand for construction products increases, industrialisation is needed to increase the productivity of the industry generally. Industrialisation can be done through standardisation, a high degree of organisation work, as well as mechanisation and automation, to replace human labour wherever possible. The mission to provide housing in a limited time would be possible by implementing industrialisation in construction where most of the products can be standardised (Alinaitwe et al., 2005).

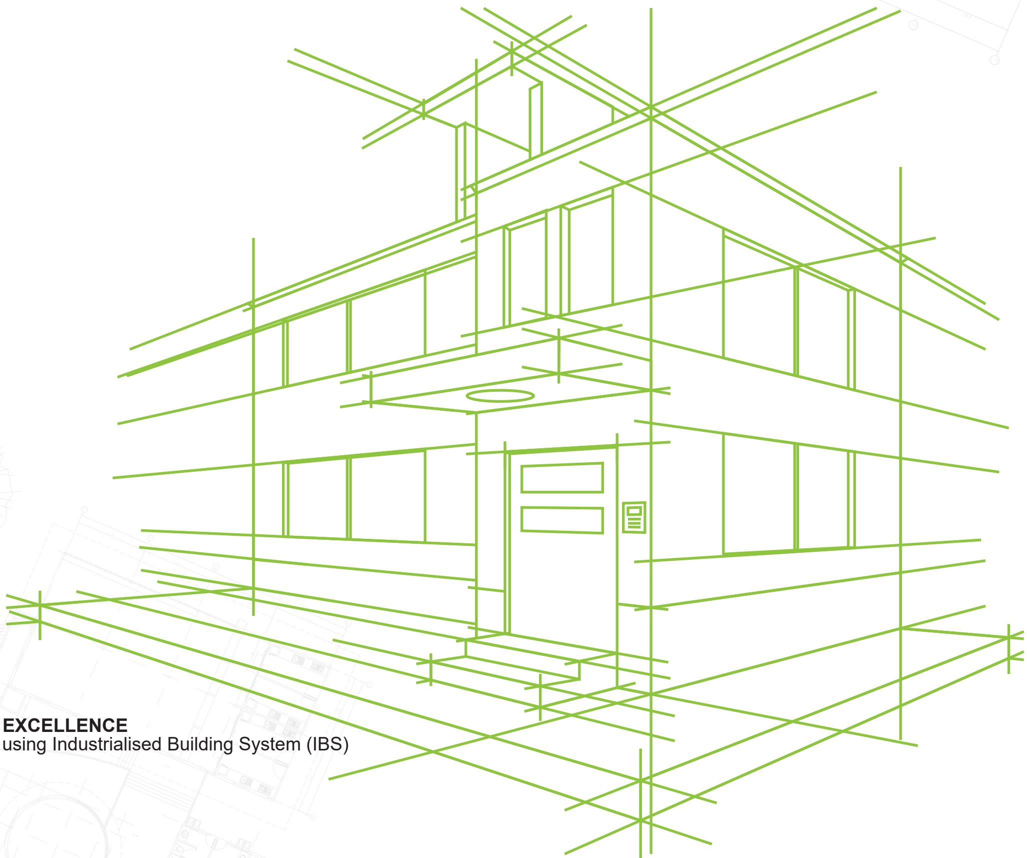
The Civil Engineering Research Foundation (CERF) in the US suggests that all industry stakeholders should collaborate to develop metrics and tools for productivity growth to have a broad understanding of productivity. When there is a need to measure and quantify a certain situation, productivity can be increased. Therefore, construction stakeholders should have a measuring procedure in place to determine how it is doing relative to the benchmark. The benchmarking process is used to improve performance by understanding the required methods and practices to achieve better performance levels (Kähkönen & Sexton, 2005). By measuring performance relative to the benchmark and by implementing improved processes and procedures, the construction industry can work towards better productivity improvement (Alinaitwe et al., 2005).

2.2.3 CONSTRUCTION PRODUCTIVITY MEASUREMENTS

The necessity to measure productivity differs among stakeholders of the construction industry. For example, governments and economists measure productivity as an indicator which enables a ready assessment of performance in the industry as well as to compare with other sectors of the economy and other countries. At the company level, productivity is also measured to enable organisations and project or task leaders to plan for activities, control costs, motivate their workers, evaluate performance, set benchmarks, and guide wider company-level policy and action (SCAL, 2016). For instance, one measures productivity to identify changes in efficiency while another measures productivity to trace technological change over time in a production process (OECD, 2001).

In an engineering world, full efficiency means that a production process has achieved the maximum amount of output that is physically achievable with the current technology and given a fixed amount of inputs. Changes in productivity reflect changes in efficiency to transform inputs into outputs over a period of time. Differences in productivity measures can help in identifying inefficiencies and benchmarking specific production processes (OECD, 2001). The technology required in transforming inputs to outputs may change through innovations in equipment, organisation, information, or management (Weber & Lippiatt, 1983). Productivity measurement is also significant in assessing living standards. For instance, labour productivity helps to better understand the development of living standards i.e. per capita income (OECD, 2001). Productivity measures also capture effects in human capital improvements and scale economies which are captured in multi factor productivity (Parham, 2011).

There are countless sources behind productivity growth and every source is important in real cost savings. The identification of real cost savings is therefore a pragmatic way to describe the purpose of productivity measurement. It helps organisations to make more cost-effective investments in productivity-enhancing technologies and enables the monitoring of the activities of the components in its value chain and provide targets for each of them to achieve continuous improvement (SCAL, 2016).



2.2.3.1 Types of Construction Productivity Measurements

There are different types of productivity measurements depending on their intent and data availability. Productivity measurement can be classified as Single Factor Productivity (SFP), which relates a measure of output to a single measure of input and Multi Factor Productivity (MFP) that relates a measure of output to a package of inputs. Multi Factor Productivity is also a synonym for Total Factor Productivity (TFP) (OECD, 2001).

SFP shows the use of each input per unit of output produced over time and it can be measured as labour productivity and capital productivity. Labour productivity is the most common SFP measure and it calculates value-added per worker or value-added per hour worked. Higher labour productivity means a higher value can be produced with the same or fewer resources, which translates into lower cost for owners, higher profitability for contractors, and higher wages for workers (Barbosa et al., 2017).

Labour productivity is the most common type of productivity measurement used in the industry, which is also used in this study (see Chapter 4). It is defined as the ratio of the total output to the labour input. Labour productivity rates are used as indicators of construction time performance. It is used in construction planning and scheduling, controlling of the cost and worker's performance, as well as in estimating and accounting (Alinaitwe et al., 2005).

The issue with labour productivity is the determination of labour work hours associated with measured output because it can be measured in different input times which will require different productivity measurements. Labour productivity measured in terms of the paid time provides useful information to contractors for scheduling and estimating purposes. Labour productivity measurements based on time available for work provides the basis to analyse the effects of weather conditions on labour productivity. Meanwhile, labour productivity measures that are based on productive time helps to determine the effect of various factors on productivity such as constructability and delays (Alinaitwe et al., 2005).

The factors affecting labour productivity can be classified into four categories: (1) design; (2) manpower; (3) management; and (4) environment, as shown in Figure 13 below.

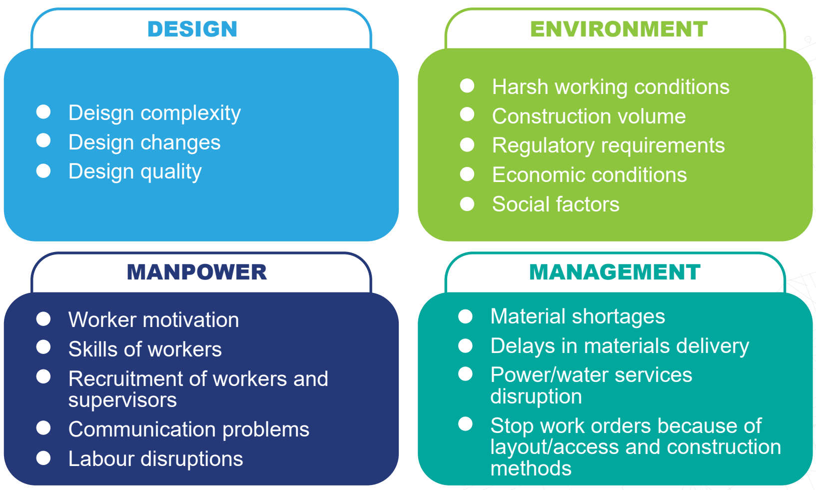


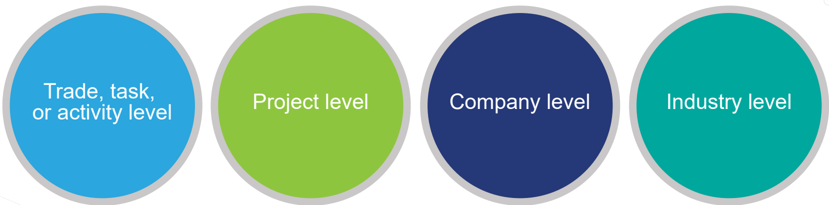
Figure 13: Factors affecting labour productivity

Capital productivity measures the relation between output and capital input, while intermediate productivity relates a measure of output to intermediate inputs. Although SFP is relatively easy to calculate, it only considers a single input or a specific resource. As any activity involves the combination of several inputs which are interrelated, SFP is somewhat ambiguous as it inaccurately reflects the effect of many other factors (SCAL, 2016).

MFP takes into account the contribution of both capital and labour inputs to output and is usually expressed in terms of the growth rate. It indicates the efficiency with which inputs are being utilised in the production process to produce output (MPC, 2019). MFP growth is the rate of growth of added value with respect to time while labour input and capital input remain constant. In other words, MFP is the ability to produce more output with the same inputs. It is a useful indicator as it represents the ability to gain a competitive edge without input price reductions (SCAL, 2016).

Today's globalised economy has formulated a new approach in measuring MFP which is known as KLEMS (Capital, Labour, Energy, Materials and Services). The KLEMS approach utilises more broadly defined input factors by considering intermediate inputs such as energy, materials, and services. Capital and labour input factors are now decomposed into more detailed segments: labour quality and quantity for labour input, and ICT and non-ICT capital for capital input (MPC, 2019). TFP has been widely accepted as the best productivity indicator for an industry. However, many countries face difficulties in their efforts to develop TFP indices because of a lack of data. TFP relates to gross output and considers labour, capital, and intermediate inputs. It measures how the overall productive capacity of the economy shifts over time due to advances in knowledge and improvements in equipment, methods, and materials applications, as well as improvements in management and organisation (SCAL, 2016).

Construction productivity can be studied at four levels:



At trade level, labour productivity (LP) data are useful to contractors to calculate the project cost, set targets, and monitor site activity. LP represents the productivity of labour in terms of the personal capacities of workers as well as reflects the efficiency of labour and other factors of production combination, and is expressed as (a) units of output per dollar; (b) units of output per work-hour or (c) units of output per man-day. Typical output units in a construction project are linear, area, volume, tonnage, or number. LP is the most commonly used productivity concept in the construction industry (SCAL, 2016).

2.2.3.2 Challenges in Measuring Productivity

Measuring construction productivity has been a challenge for many decades. While some significant improvements have been made, many fundamental challenges still exist. For example, at project level, any construction project involves several closely related activities done by different groups of workers and undertaken in different work locations at different project stages. Therefore, there are limitations in measuring productivity and using its data as benchmarks as it is difficult to measure the time taken to complete any single trade and assumptions will not be the same on all sites. The effects of technological change and quality improvements of materials on productivity are also difficult to determine and quantify. The time taken to complete any single trade is also difficult to measure, making productivity measurement at project level a challenge (SCAL, 2016).

Finding accurate data and deciding what measure to use for output and labour input are some of the issues of measuring productivity at the industry level. Some use added value to measure the output while others measure gross output. As for labour input, the measures could be (SCAL, 2016):

Productivity measurement is also difficult in the construction industry as it is a broad industry that produces a wide variety of types of constructed items. The construction industry is composed of four segments: residential, commercial/institutional, industrial, and infrastructure. All of these segments have different characteristics in terms of complexity, required skills, use of materials, technologies, and knowledge. The industry has also been described as an industry with very limited satisfactory data and information, and hence it is difficult to study and understand its performance to make improvements (SCAL, 2016).

2.2.3.3 Construction Productivity in Other Countries

This section discusses initiatives and approaches to the measurement of construction productivity in several countries, mainly, the US, UK, Australia, and Singapore.

United States of America

In 2011, the American Society of Testing and Materials International (ASTM) published a new guide called ASTM E2691 for productivity measurement in construction. ASTM E2691 provides a new approach to productivity measurement through a tool known as Job Productivity Measurement (JPM) where two measurements are used:

- Construction production rate and
- Productivity

JPM measures the overall production rate by comparing construction put in place (CPIP) to the time elapsed in the construction schedule. It also measures overall job productivity through a comparison of labour usage to a reference point (SCAL, 2016).

JPM also takes into consideration the difficulty of installation at any given point on a job when measuring productivity and evaluates relative productivity changes using trend monitoring. It identifies any productivity gain or loss and it covers the following scopes (SCAL, 2016):

01 Comparing labour hours used against CPIP to allow for unified measurement of established building elements

02 Measuring labour productivity of the installation processes on a construction job

03 CPIP is measured with input from the labour performing the installation, utilising elements of statistical process control (SPC) and industrial engineering

United Kingdom

Productivity is one of the key performance indicators (KPIs) of the UK construction industry and data on the KPIs are published every year. The construction KPIs are classified into three categories as shown in Table 3:

Table 3: Construction KPI Categories in United Kingdom

KPI Categories	Types of Sub KPIs
Economic	Client Satisfaction — product, service, value for money Contractor Satisfaction — performance, provision of information, payment Defects (impact at handover) Predictability Cost — project, design, construction Predictability Time — project, design, construction Profitability Productivity
Environment	Product Performance
Respect for People	Construction Process Performance

In the UK, productivity is defined as value-added per (full-time) employee. The value-added is defined as the turnover less the cost of goods and services purchased from other parties or subcontracted to other parties. The productivity for the UK construction industry was increasing from the year 2010 to 2015 as shown in Table 4 below (SCAL, 2016).

Table 4: Value-added per employee in United Kingdom

Year	Productivity / Value-added per Employee
2010	£48,900
2011	£59,300
2012	£60,000
2013/14	£60,900
2015	£61,300

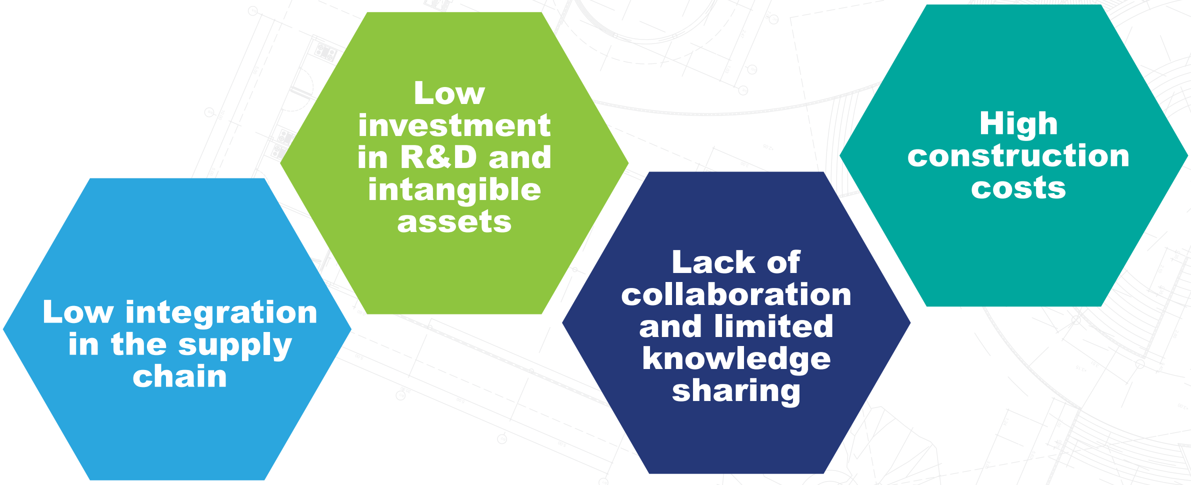


Figure 14: Challenges on Productivity in the UK Construction Industry

The UK government and industry have done a strategic review to identify the challenges on productivity in the UK construction industry as shown in Figure 14 below.

To face these challenges, the United Kingdom proposed a vision for construction which include:

01	Improve the image of the industry through a coordinated approach to health and safety as well as improving performance in the domestic repair and maintenance market
02	Lead the world in research and innovation as well as embrace digitalisation, technology, and advanced materials
03	Strong, integrated supply chains, and productive long-term relationships
04	Drive procurement efficiency and exploring options for further efficiency gains in the procurement process

Through this vision, the UK construction industry aims to achieve the following ambitions by 2025:

01	33% reduction in both the initial cost of construction and the whole life cost of assets
02	50% reduction in the overall time from inception to completion for new build and refurbished assets
03	50% reduction in greenhouse gas emissions in the built environment
04	50% reduction in the trade gap between total exports and total imports for construction products and materials

Singapore

Singapore's Building and Construction Authority has developed a construction productivity R&D roadmap to identify new knowledge, process, and technology areas for development, adaption, and adoption to transform the construction industry and raise its productivity. The government has launched a $250 million package of incentives to enable the construction industry to prepare for the policy changes to be introduced as one of the measures taken to increase productivity in Singapore's economy. The incentives covered workforce development, technology adoption, and capability development. BCA measures productivity at trade and project levels to track productivity performance (SCAL, 2016).

BCA published a guidebook on trade-level productivity to assist on productivity measurement for 12 key trades most commonly found in construction projects. The guidebook provides productivity monitoring forms for each key trade to provide information on the activities and parameters that should be monitored and measured. The 12 key trades are:

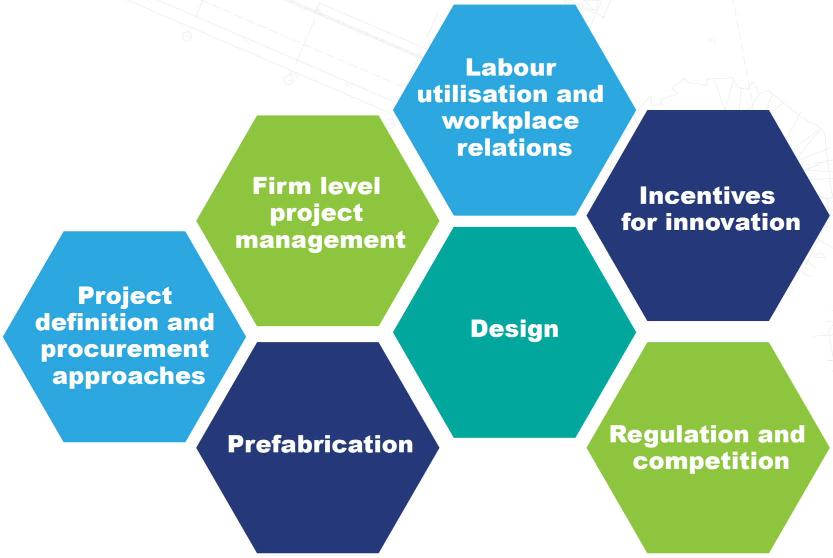
- Formwork
- Reinforcement
- Concrete placement
- Drywall
- Painting
- Timber door
- Wall tiling
- Floor tiling
- Suspended ceiling
- Air-conditioning ducting
- Electrical conduit
- Water pipe installation

Singapore's success in monitoring and measuring the productivity of its industry is due to its regulation to make it compulsory for construction firms to submit data to BCA if they are working on projects with a total area of 5,000 square metres and above. The projects are classified into six categories: (1) landed private residential; (2) non-landed private residential; (3) public housing; (4) commercial; (5) industrial; and (6) institutional. The Industry Overall Productivity Indicator is determined by calculating the total GFA (square metres) per man-day (SCAL, 2016).

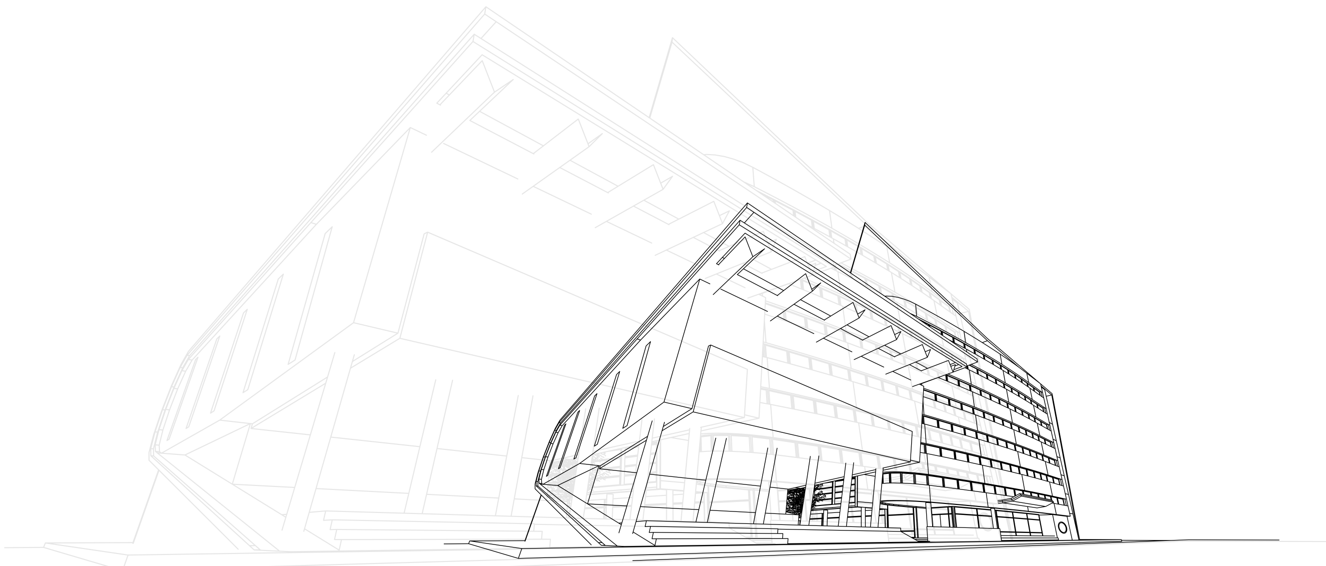
BCA has also been awarding good performance and achievement in construction to create greater awareness and ownership in productivity amongst various stakeholders of the construction value chain. This is to recognise practitioners and companies for their achievements in improving productivity as well as to promote productivity in the industry.

Australia

Australia's Productivity Commission has identified at least seven productivity challenges facing the construction industry:



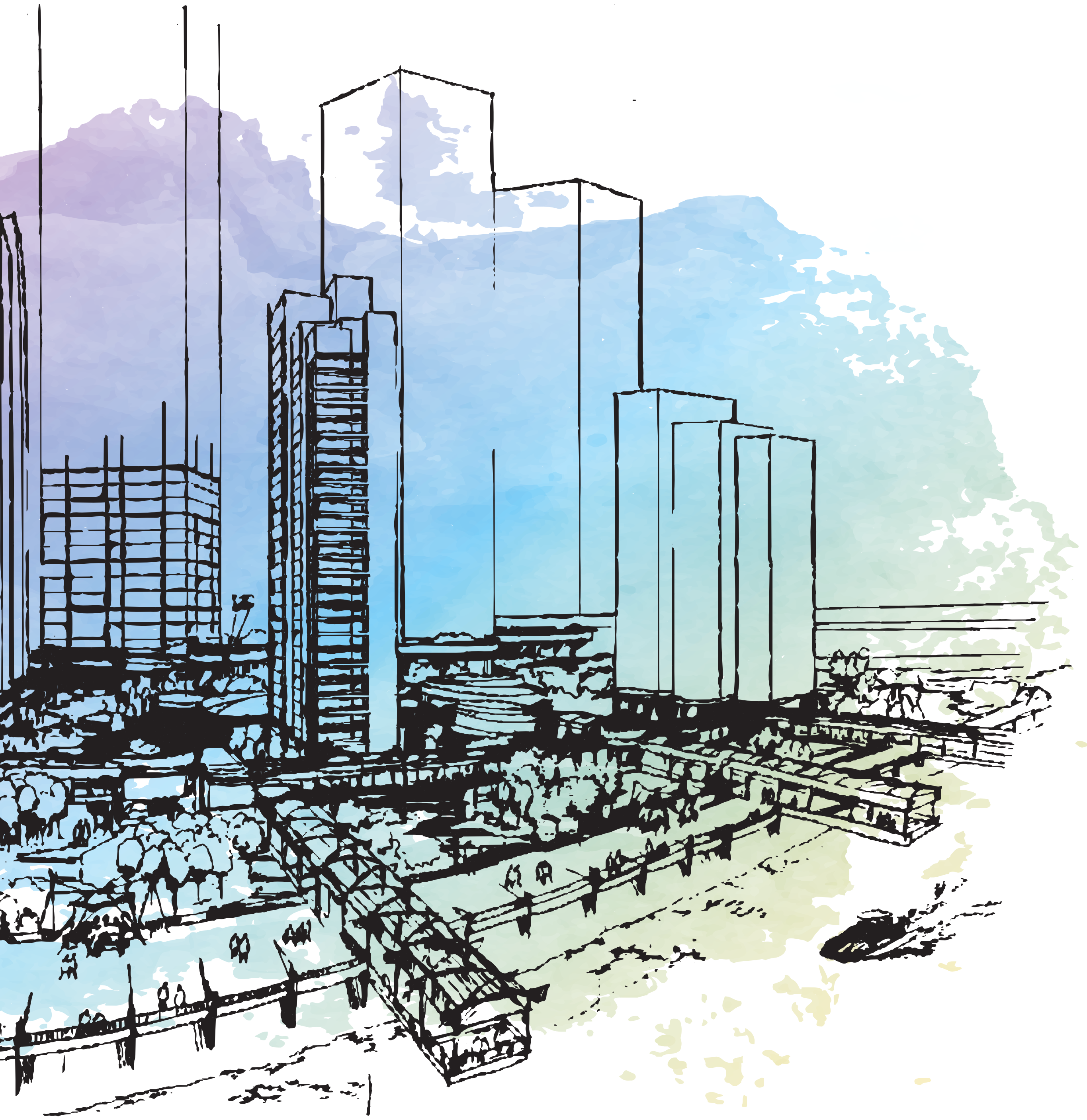
Therefore, Australia has appointed three Royal Commissions to improve its productivity performance. In 2002, the first Royal Commission found that the main contributors to construction productivity growth were stronger competition, greater trade openness and access to new technologies, and increased flexibility to adjust the production and distribution process. It also identified other factors that contribute to productivity gains such as improvements in project planning, corporate operating, and managerial processes, prefabrication and design, the use of technology, labour utilisation, and workplace relations as well as regulatory and competition policy structures. The Australian Bureau of Statistics (ABS) publishes labour productivity, capital productivity, and multi factor productivity indices for the construction industry (SCAL, 2016).



“PRODUCTIVITY IS DEFINED AS THE TOTAL GROSS FLOOR AREA (GFA) CONSTRUCTED PER TOTAL MAN-DAYS”

THREE

The Productivity Measuring Tool (PMT) Study



THE PRODUCTIVITY MEASURING TOOL (PMT) STUDY

3.1 THE RATIONALE

This study aims to develop a measuring tool to calculate and measure the productivity of building construction using IBS method. The following are the objectives of the study to achieve the aim:

01 To conduct a benchmarking study to review methods of productivity measurement among industry players and in other countries as well as to review parameters required to calculate and measure the productivity of building construction

02 To get an overview of the IBS method to gain a general understanding of how it can improve the productivity of the Malaysian construction industry

03 To develop a formula that is practical to calculate the productivity of IBS projects in Malaysia

In this chapter, the approach and the methods of the study are explained. The structure and contents of the collaborative activities with industry players such as workshops, interviews, field study, and survey questionnaire are also outlined in this chapter. The results of the collaborative activities are also analysed and discussed in this chapter.

In this study, the overall productivity of a certain IBS project in Malaysia is measured using gross floor area (GFA) and man-days because the data are straightforward and easy to access as they are usually made available for building construction. It is useful in identifying how productive a certain project is and how it is influenced by labour in terms of manpower involved per project. According to Equation 2 below, the smaller the number of manpower involved in a construction project, the higher the productivity of the project. Therefore, this study can verify how the adoption of IBS in building construction can reduce the number of manpower on-site.

Productivity of a project also depends on the length of the construction period of a construction project. Likewise, Equation 2 shows that the shorter time it takes to complete a construction project, the higher the productivity of the project. Therefore, productivity measurement in this study can also validate the benefit of IBS in terms of reducing the overall construction period as compared to conventional projects.

3.2 RESEARCH SCOPE AND LIMITATIONS

This study aims to develop a formula as a measuring tool to calculate productivity rate of building construction projects that use IBS method. This study focuses on residential projects and the data collected to calculate the productivity rate concentrates on completed public housing projects in Malaysia. As it is mandatory for public housings in Malaysia to score at least 70 IBS Score which also means that public housings in Malaysia comprise at least 70% IBS components, public housings are selected as the research area to ensure the target of the study which is to measure productivity rate of IBS projects is achieved.

By measuring productivity rate of IBS projects, the benefit of IBS in terms of gaining better productivity compared to the conventional method as recognised in literature can be proven. However, the findings from this study are not sufficient to be used to compare the difference in productivity between the two methods as no data from conventional projects are collected. Hence, to get a clearer picture of how IBS is beneficial in improving the productivity of a construction project, samples from conventional building construction should be included to obtain the productivity difference between IBS projects and conventional projects.

It should be emphasised that the measuring tool developed in this study only considers GFA and man-day which are not sufficient in demonstrating the productivity of a certain project. There are many other factors that productivity measurement should take into consideration such as unit types, unit sizes, design complexity, logistics, etc. Consequently, the findings from this study are only sufficient to look at the overall productivity of construction without considering these other factors.

Besides that, the measuring tool developed is non-specific where productivity variations between different types of IBS cannot be identified. The productivity rate formula developed in this study also does not consider the quantity of IBS components used in the projects. Therefore, a more focused measurement that considers other factors and characteristics should be developed as an improvement from this study.

3.3 PRODUCTIVITY

In this study, productivity is defined as the total Gross Floor Area (GFA) constructed per total man-days, where GFA includes the total property square footage including finished areas inside the property such as common areas, lobbies, stairwells, etc. One man-day in this context is defined as 1 manpower working for 1 day. In other words, man-days can be calculated using the total number of manpower involved in the project and the total length of the construction period of the project. Therefore, productivity rate in this study represents how many GFA can 1 manpower construct in 1 day. The more output in terms of gross floor area constructed that a manpower can produce within a day, the more productive the manpower is. Equation 2 below represents the formula developed in this study to calculate the productivity of certain IBS projects.

Productivity

$$= \frac{\text{Total gross floor area (sq ft)}}{\text{Total man - days}}$$

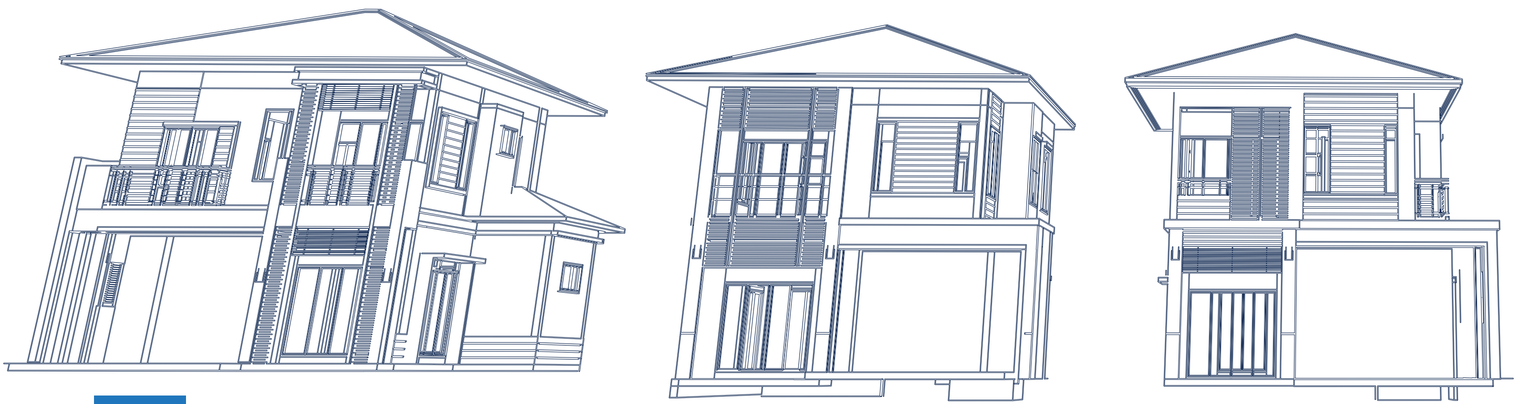
$$= \frac{\text{Total gross floor area (sq ft)}}{\text{Total number of manpower} \times \text{Total length of the construction period (months)}} \quad (2)$$

A project is deemed to be more productive if more square feet of gross floor area can be constructed with the same number of man-days. Therefore, the higher the value for productivity, the more productive a project is. Figure 15 shows the parameters required to calculate the productivity rate which are the total GFA of IBS projects as well as the total number of manpower involved in the project and the total length of the construction period of the project. The total construction period in this sense is the duration from the beginning of piling work until the Certificate of Practical Completion (CPC) is issued.

FACTORS AFFECTING PRODUCTIVITY RATE

GROSS FLOOR AREA	NUMBER OF MANPOWER	CONSTRUCTION PERIOD

Figure 15: Factors affecting productivity rate



3.4 RESEARCH METHOD

The main elements of the research method adopted for the study were; a one-day workshop with a technical working group (TWG) of the construction industry which was organised by Kementerian Kerja Raya (KKR); a series of semi-structures interviews with practitioners working in construction companies in Malaysia; industrial engagement with prominent IBS manufacturers to obtain real data for the study; and a quick questionnaire-based survey to which IBS contractors in Malaysia were invited to respond.

3.4.1 FIELD STUDY

A field study was done in this study to get hands-on experience in the adoption of IBS in building construction. Please note that the field study only focused on precast IBS systems. Two IBS contractors in Malaysia were selected for the field study and a group of researchers was engaged and attached with the field study. The role of the researchers was to visit the production plant and sites to observe and learn how IBS contractors run their projects to sustain productivity while maintaining the quality of the products and the safety of their manpower.

During the field study, the researchers had the opportunity to observe how IBS panels were manufactured off-site and assembled on-site. The researchers also observed what kind of trades were involved during IBS production and assembly or installation.

3.4.2 WORKSHOP WITH TWG

On 24th June 2019, the Ministry of Works Malaysia as a member of the Inter Agency Planning Group (IAPG) of services sectors established a Technical Working Group (TWG) to discuss in more detail the issues and direction of the Malaysian construction industry as part of the development planning for Post-2020 and Twelfth Malaysia Plan. The Construction Research Institute of Malaysia (CREAM) as the appointed facilitator for the Construction Productivity Core, has conducted a focus group workshop to bring relevant people together and provide a method and structure to make a good start on raising the productivity of the industry through Construction 4.0.
The workshop was attended by construction stakeholders such as Gamuda IBS, Johawaki, Setia Precast Sdn Bhd, Sany Construction Industry Development Sdn Bhd, Sime Darby Property, Malaysian Productivity Corporation (MPC), Royal Institution of Surveyors (RISM), REHDA and many more industry players who are experts in the industry and interested in bringing productivity towards a higher level. The focus group was divided into three groups to ensure the workshop could be run efficiently and interactively. During the workshop, a framework was developed by CREAM as a guideline for the participants. In the framework, the participants were asked to discuss current issues and challenges in the construction industry that are causing the productivity of the industry to fall behind. The participants were then asked to come out with solutions and recommendations on how to resolve the issues and challenges and help the industry to become more productive.

The framework was divided into six elements consisting of the construction ecosystem which plays a vital role in improving the productivity of the construction industry. The six elements are called DPIE3 which consists of design, production, installation, equipment, education, and entrepreneurship. DPIE3 was developed by Sany Construction Industry Development Sdn Bhd. The participants were asked to discuss the issues and challenges, way forward or solutions as well as recommendations according to the six stakeholders. Table 5 shows how the framework was provided for the participants during the workshop for discussion.

Table 5: Framework provided during the workshop

DESIGN	Issues & Challenges	
	Way Forward	
	Recommendations	
PRODUCTION	Issues & Challenges	
	Way Forward	
	Recommendations	
INSTALLATION	Issues & Challenges	
	Way Forward	
	Recommendations	
EQUIPMENT	Issues & Challenges	
	Way Forward	
	Recommendations	
EDUCATION	Issues & Challenges	
	Way Forward	
	Recommendations	
ENTREPRENEURSHIP	Issues & Challenges	
	Way Forward	
	Recommendations	

3.4.3 FACE-TO-FACE INTERVIEWS

Interviews were held with practitioners who were among the developers, manufacturers, and contractors in Malaysia. In total, 13 industry players were called for the face-to-face interviews and only 6 of them turned up (46% response rate). A guide prepared for this purpose covered:

01 The interviewee's general views on how the migration from conventional construction method to IBS method can improve productivity and reduce the use of foreign labour

02 The interviewee's experience in monitoring and measuring the productivity of their projects

03 The interviewee's point of view on the importance of having competent personnel, education qualification, and industry experience in sustaining productivity

04 The interviewee's capacity in design, production, and installation teams

05 The interviewee's methods of handling and tackling issues on mould and how the use of mould in IBS projects can affect productivity

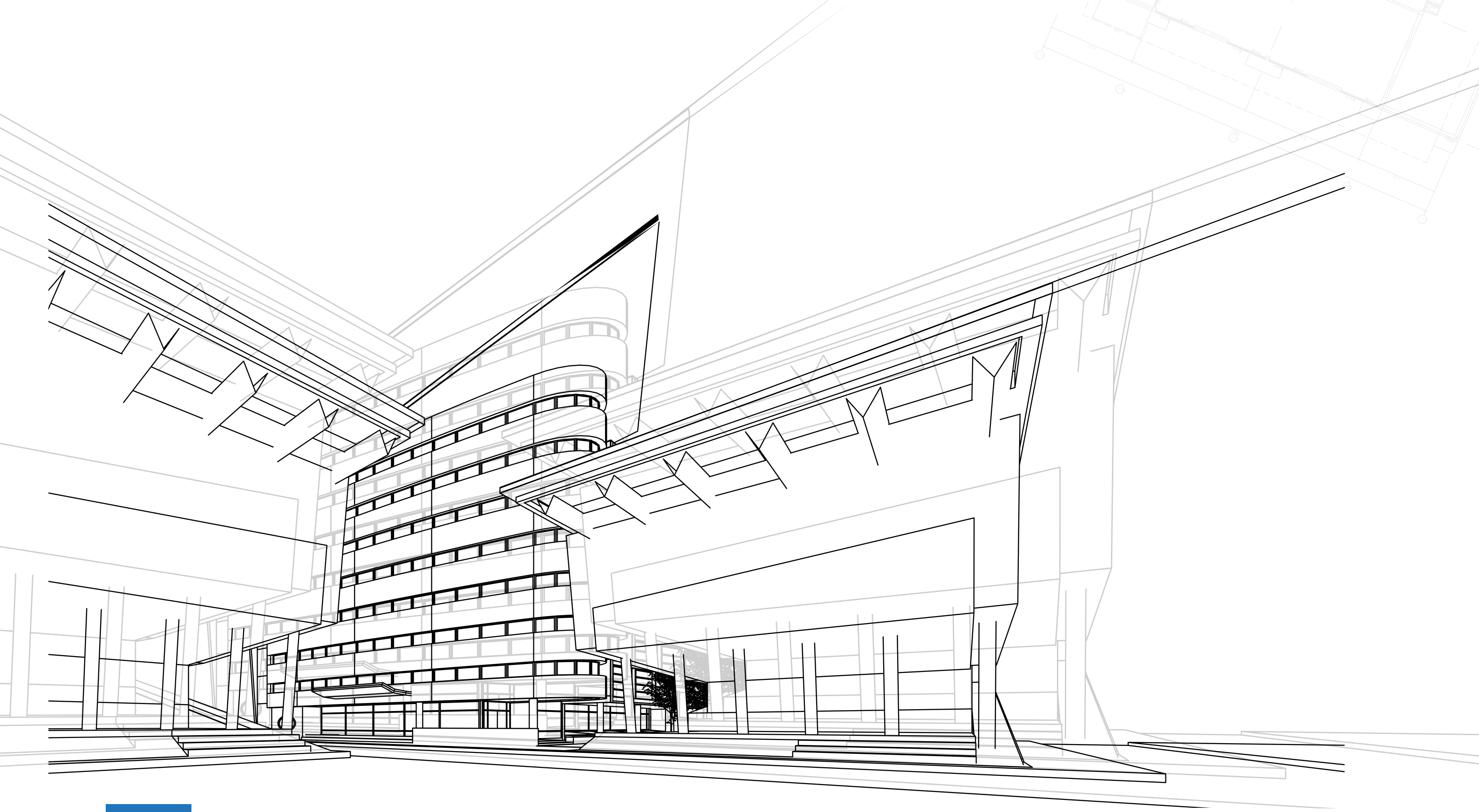
3.4.4 THE QUESTIONNAIRE-BASED SURVEY

A quick survey of productivity rate based on real IBS projects in Malaysia was also undertaken. A list of brief questions was prepared to obtain the overall productivity of completed IBS projects and was sent via e-mail to the contractors as respondents. 8 IBS contractors were approached and only 6 of them responded to the survey (75% response rate). The respondents were requested to provide answers or data based on their real completed IBS projects via e-mails as well as phone and face-to-face interviews. The questionnaire had two main sections: (A) background information of the respondents; and (B) project information where the respondents were asked to choose one building construction project as a reference to answer the quick survey. The questions in Section B were all related to the productivity measurement of IBS projects in the country:

01 Specifying the project title, location, and project status of the chosen building construction

02 Stating the project name, gross floor area (GFA), the total number of house units, and unit size of the chosen building construction project; and

03 Stating the total manpower, total construction period, and total working days/month of the chosen building construction project. It should be noted that the productivity rate calculated in this study assumed that every manpower works for 26 days per month and the total manpower as well as total construction period in this sense are taken from the beginning of piling work until the Certificate of Practical Completion (CPC) is issued.



3.5 RESULTS AND DISCUSSION

3.5.1 FIELD STUDY

IBS CONTRACTOR A

IBS Contractor A implement offsite manufacturing and digitalisation in their operation where it requires less manpower in the production process as it uses Building Information Modelling (BIM) to operate the robots in the production process which is mostly run in factories and in a controlled environment. The use of BIM allows close collaborative work between design engineers, architects, and consultants to come up with the piece-by-piece shop drawings, which are then translated into the robotic production system (Construction Plus Asia, 2019). Implementation of offsite manufacturing and digitalisation has a big positive impact in productivity performance.

The robotic production system runs on a BIM platform which dictates the operations of the robots to ensure precise, efficient, and highly customisable products. The robots operate in a carousel line that allows panels to move around the factory instead of workers to ensure productivity, efficiency, accuracy, safety, and quality. Panels are moved via pallets on the carousel line and the carousel brings pallets from one station to another. The production process involves moulding using a shuttering system, casting, concreting, and demoulding. Installation works on-site are also minimised because IBS has eliminated a few trades such as welding and carpentry.

IBS CONTRACTOR B

IBS Contractor B also implement offsite manufacturing but still require construction workers to work certain trades manually, but they improve their productivity by having the factory close to their sites to alleviate logistics issues. They also improve their productivity by having standardised designs for their projects where the design specifications are kept quite similar for every project. Besides improving productivity, standardisation also helps to reduce waste.

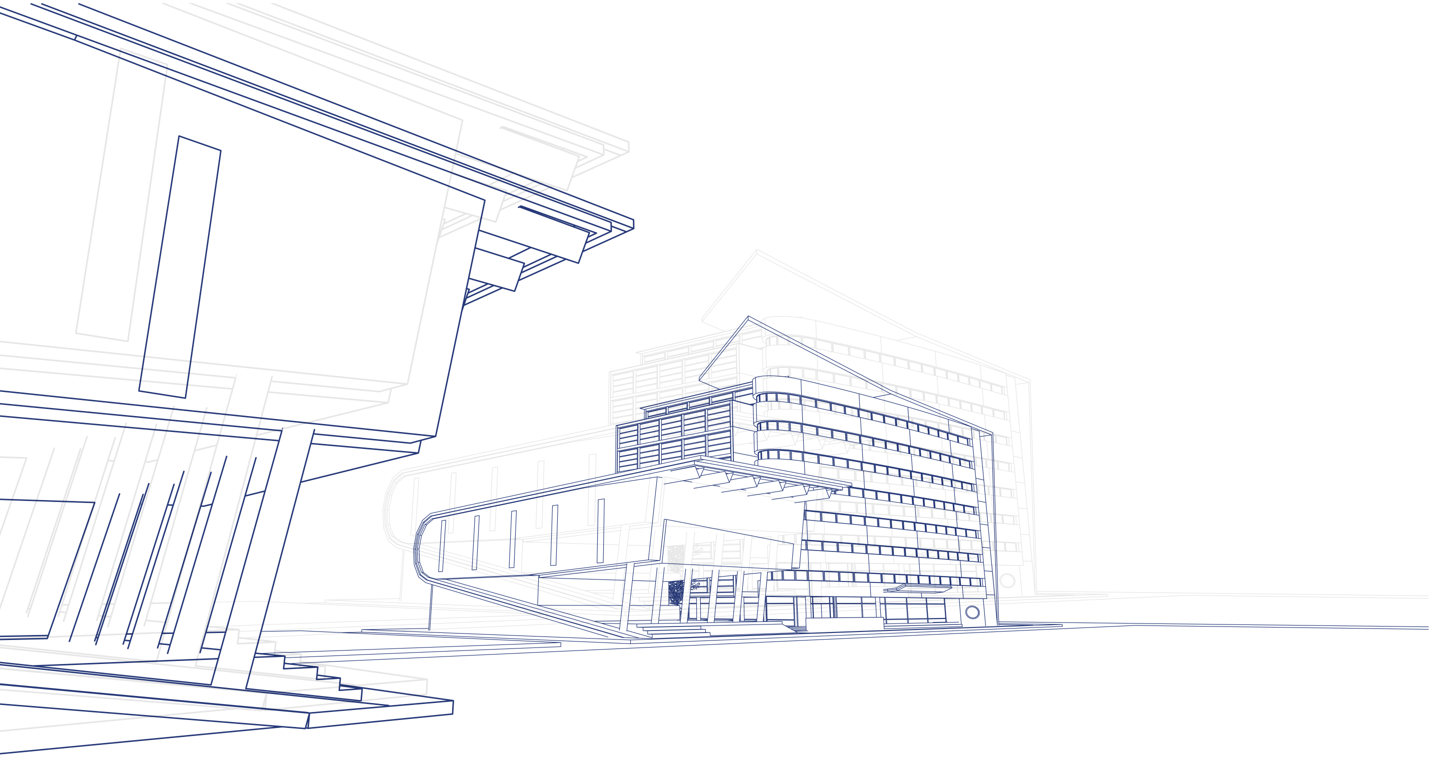
IBS Contractor B also schedule their production and installation works in the morning and afternoon, respectively to maintain the productivity of their construction workers. All production works are scheduled to run in the morning until midday (6:00am to 12:00pm) to avoid hot weather to improve the performance of their workers. In Malaysia, heavy rains usually occur in the evening and since the factory is located in an open yard, the production works are also scheduled in the morning to prevent heavy rains from interrupting the production works. Installation works are then operated in the afternoon until evening (2:00pm to 5:00pm). This also ensures the use of the 'Just-in-Time' (JIT) concept to further improve the productivity of the project.

3.5.2 WORKSHOP WITH TWG

The results from the workshop are presented in this report according to groups and will be summarised in the discussion. Table 6, Table 7 and Table 8 below display the results gathered from Group 1, Group 2, and Group 3 during the discussion on current issues and challenges of the construction industry as well as a way forward and recommendations for the industry. The participants in Group 1 suggested adding another element in the ecosystem which is legal or regulatory as the participants opined that the regulatory aspect also plays an important role in transforming the productivity of the industry.

Table 6: Results gathered from Group 1 during the discussion on current issues and challenges of the construction industry as well as a way forward and recommendations for the industry

DEISGN	Issues & Challenges	1. Different authorities have a different set of parameters 2. Designs are not standardised
	Way Forward	1. Set standardised parameters: Floor-to-floor height 2. Repetition in designs 3. CIDB to regulate the industry 4. Open concept, closed concept, Preapproved Plan (PAP) 5. Standard designs for housing in Malaysia
	Recommendations	-
PRODUCTION	Issues & Challenges	1. Size of panels/weight of panels
	Way Forward	1. Vendor development program where different suppliers produce different components to reach design standardisation to improve productivity 2. Manufacturers should allow for innovation 3. Repetition but still allows for flexibility 4. Guidelines on base standardisation
	Recommendations	1. The government should give incentives to embark on automation factory for small players 2. Magnets for mould
INSTALLATION	Issues & Challenges	-
	Way Forward	1. SMEs should be involved in installation
	Recommendations	-
EQUIPMENT	Issues & Challenges	1. Limitation on cranes
	Way Forward	-
	Recommendations	1. The government should allow contractors, practitioners, or installers to have incentives on renting/buying cranes that are suitable for IBS or PPVC



EDUCATION	Issues & Challenges	1. Local authority has no competency in technology such as IBS, BIM 2. SMEs lack knowledge on digitalisation 3. Lack of vocational players 4. Educators do not have experience on sites 5. Cost
	Way Forward	1. Local authority should be trained 2. CIDB should calculate IBS score before the project can be submitted to local authority 3. Education must start from schools 4. Industry players should give lectures in schools to give a real-life situation of the construction industry 5. Apprenticeship Programme in universities 6. Institutions should be more involved with MoE
	Recommendations	1. Industry engagement
REGUL	Issues & Challenges	1. Entrepreneurs lack knowledge on digitalisation 2. Cost - developers want to build the cheapest but sell at high prices
	Way Forward	1. Allocate some fund to train SMEs on construction 4.0/digitalisation to work synchronically with industry players 2. SMEs should support the industry throughout the construction lifecycle
	Recommendations	-
LEGAL/ REGULATORY	Issues & Challenges	1. Lack in project management system, common data environment because it is very costly
	Way Forward	1. The industry needs open access data
	Recommendations	1. JKR and CIDB should be the drivers

Table 7: Results gathered from Group 2 during the discussion on current issues and challenges of the construction industry as well as a way forward and recommendations for the industry

DEISCN	Issues & Challenges	1. Design scope is being limited by designer (conventional thinking) 2. Silo and waterfall method in the design process 3. IBS is not incorporated from the start 4. Benefits of IBS not fully realised
	Way Forward	1. Expand design scope 2. Design with production in mind
	Recommendations	1. Establish a framework for implementation of BIM and IBS 2. All parties should be involved from start 3. Create an environment for data sharing (CDE)
PRODUCTION	Issues & Challenges	1. The complexity of the design (difficult to produce) 2. No standardisation of sizing & measurement 3. Production of IBS component still labour intensive (Quality issue)
	Way Forward	1. Design with production in mind 2. Strict enforcement on the usage of standardisation
	Recommendations	-
INSTALLATION	Issues & Challenges	1. IBS project being managed conventionally. 2. Lack of integration on BIM in IBS project
	Way Forward	1. Need to apply Just-In-Time (JIT) concept 2. use BIM as prerequisite
	Recommendations	1. Adopt BIM 4D - mandate usage of BIM
EQUIPMENT	Issues & Challenges	1. High cost 2. Limited availability of high capacity cranes 3. Limited numbers of local equipment manufacturers
	Way Forward	1. Tax exemption on equipment in IBS projects. 2. Create opportunities for PPVC to be used 3. Reduction in corporate tax 4. Locally produce
	Recommendations	1. Review existing policies on incentives of IBS and introduce incentives for BIM 2. introduce matching grant 3. introduce incentives to encourage more local manufacturers
EDUCATION	Issues & Challenges	1. Lack of exposure on BIM and IBS in the current education system 2. High cost of BIM training and low take-up 3. lack of contractors' participation in BIM
	Way Forward	1. Incorporate BIM and IBS syllabus/courses starting at Diploma level 2. Widen the current BIM apprenticeship program 3. Forced training funds submitted to client to arrange BIM training for contractors' personnel
	Recommendations	-
ENTREPRENEURSHIP	Issues & Challenges	1. Lack of opportunities for entrepreneurs to go to local and international markets. 2. High dependency on incentives at SME level
	Way Forward	1. Joint venture with an established company in Construction 4.0 2. Provide handholding for budding entrepreneurs
	Recommendations	1. Create an incubation centre for entrepreneurs

Table 8: Results gathered from Group 3 during the discussion on current issues and challenges of the construction industry as well as a way forward and recommendations for the industry

DEISGN	Issues & Challenges	1. Acceptance and realisation of BIM usage in projects (government and private) 2. No awareness on using BIM among decision makers and industry leaders 3. Leadership decision - transition from CAD to BIM 4. Low adoption of BIM in projects 5. Changes and revolution must be holistic, not a single party 6. Poor ecosystem in construction project 7. Small budget for planning in the construction industry 8. Decisions are made by the consultants/designer 9. During pre-contract, BIM execution plan is not being implemented 10. In conventional way, every stakeholder knows their roles and responsibilities, but in precast construction, everyone (stakeholders) is not clear with their roles (process) 11. Everyone puts full responsibility on the architect to pull out the project outcome 12. Awareness on procurement and decision making 13. Different procurement approaches 14. Lack of integration and interoperability between stakeholders 15. The needs on using BIM in contract (e.g.: MEP does not want to use BIM) 16. No model in quantity take off for costing 17. Professionals are still working in silo - lack of coordination and collaboration 18. Level 2 of BIM does not include costing 19. Integration and collaboration between stakeholders 20. Disclosure of project problems 21. No funds are given to support BIM implementation in projects 22. Affordability issue of software and hardware as well as maintenance 23. Architect does not adopt IBS/modular in early stage 24. Operation and maintenance are not included in early stage 25. Different 3 tiers in governance structure requirement 26. Quality of design 27. Issues in procurement methods
	Way Forward	1. Employing technology to achieve productivity 2. Change the ecosystem 3. Design must be done virtually (so that the risk in a construction site can be reduced as the new law imposes) 4. Authorities are the bodies involved in decision making law regarding design 5. An architect must start going for digitalisation, followed by C&S and MEP 6. Must follow and have BEP in every project in construction (which defines the project brief and project needs) 7. The main stakeholders should take responsibilities in leading the project and project outcome 8. The ecosystem should be revolutionised 9. Cubicost can link the scheduling and model to come out with the costing for the projects — save a lot in costs, can track delay 10. A post-mortem on the failures or success of previous projects 11. Cost allocation should be provided to implement BIM in projects 12. Operation and maintenance should be included in an early stage 13. Claim 5% of fees upon the confirmation of project (architect) 14. All compliance must comply with overall requirement and law — waiting and approval time can be reduced (process for submission) 15. Open tender projects can increase competitiveness in terms of quantity 16. Linkage of design and cost during the early stage can be monitored and calculated
	Recommendations	1. Date transparency must be advanced 2. Changes in data sharing (integrity) 3. Research on ROI for architects, C&S, MEP, and QS 4. The owner must drive the use of BIM, otherwise, no changes can be made 5. Minimum LOD 200 if using BIM

PRODUCTION	Issues & Challenges	1. Pre-casters need to redesign IBS/modular design (double handling work) 2. Initial cost of using IBS in a construction project — the mould 3. No incentives from the government to enhance the usage of IBS 4. Imported technologies affect the business model and development of IBS production in Malaysia 5. Certain developers or contractors do not want to implement BIM — high cost 6. BIM Family library is not ready to implement BIM (not enough capacity and numbers) 7. Manufacturers are not BIM-ready (not providing data to the designer) 8. Quality of production 9. Economic of scale (in terms of standard design) 10. Compliance regulation - 6 months to wait for the approval
	Way Forward	1. Incentive for using IBS system 2. Provide suppliers with BIM family library 3. Already stated National Housing Policy — IBS & BIM, QLASSIC for affordable housing 4. Incentives can be given to the user of BIM - needs to be spent first, then claim back (BCA's approach) 5. Reduction of wastages can be monitored through BIM
	Recommendations	1. Own Malaysian BIM family library to be shared to the public 2. Minimum LOD 300 if using BIM
INSTALLATION	Issues & Challenges	1. Not enough certified installers - cannot comply with government requirement i.e. 1 million affordable houses 2. Perception of the owner, stick to the conventional way 3. Not many local skilled workers in IBS 4. Poor coordination for the logistics (operational wise) - slow down the installation process 5. Poor planning of production and installation sequence - slow down the construction process 6. Lack of QAQC because the factory is an open yard 7. Weather, shelter, and automation issues of open yard factories 8. Lack of QAQC during installation 9. Different manufacturers and installers
	Way Forward	1. Incentive in using IBS system 2. Increase the standard of a factory (consideration of distance to the site and closed yard) 3. Involvement of the stakeholders
	Recommendations	-
EQUIPMENT	Issues & Challenges	1. Different installers have different equipment and skills 2. Design does not ensure the safety of contractors during construction 3. Training a certified person to run the equipment 4. Decision making in types of equipment to be used 5. High cost of purchasing, operation, and maintenance 6. Technology evolvement i.e. renting equipment instead of buying
	Way Forward	1. Incentive in using IBS system 2. Design should be safely constructed by using simulation (need to tackle the issue on how to bring in the equipment) 3. Mandate on OSHCIM
	Recommendations	-

EDUCATION	Issues & Challenges	1. No allocation for research in project improvement 2. No information sharing for future improvement 3. The missing link (less collaboration between industry and academia — using new construction technology) 4. Different stages of education level and level of exposure of BIM to students 5. Mismatch of place for industrial training 6. Lack of cooperation from industry to access data for education and research purposes
	Way Forward	1. Education cost/training must be included in the contract e.g. SL1M 2. Data comparison on IBS/modular vs Conventional — to prove that by implementing BIM, projects are more profitable 3. More training on local skill workers 4. Close collaboration with industry to provide training /certified competency 5. Enhancing TVET-3 6. Industrial training/attachment at colleges and industry on using technology — to meet the real issue in the industry 7. Revamp the education syllabus to meet the requirement from industries 8. Industrial training (2 years in the industry, 2 years in academic)
	Recommendations	1. Prove BIM implementation can show profits to the organisation 2. BIM course for the students in college and university
ENTREPRENEURSHIP	Issues & Challenges	1. No data on PPVC in Malaysia 2. Early investment on factory 3. Change business model (conventional to IBS/modular) 4. Sustainability in investment (Return of Investment) 5. Clients do not pay extra fees for contractors to implement BIM 6. KPKT does not provide incentives for IBS and PPVC in government projects
	Way Forward	1. Collaboration between stakeholders for successful project i.e. government to private stakeholder's engagement) 2. Assist local manufacturing to go abroad in bringing their technology (expanding business model) 3. Employment of technology must be integrated (include IBS, BIM etc) 4. Decision maker should enhance data sharing
	Recommendations	1. Financing facilities for Construction 4.0 (cloud, 3D printing etc) 2. Enhance Integrated Digital Delivery (IDD) process (IBS, BIM, Safety & Health etc)

From Table 6, Table 7 and Table 8 above, it was found that issues of costs are the main barrier in implementing new technology throughout the whole construction lifecycle. Several main points have been highlighted as issues and challenges in design by the participants. For instance, the lack of integration and interoperability between stakeholders as well as low adoption of BIM in projects are inhibiting the productivity of projects. In implementing BIM and IBS in construction projects, integration and collaboration are the key points that need to be tackled and solved to ensure the benefits of implementing both can be reaped.

A few solutions were suggested during the discussion such as technology adoption to assist the project implementation and BIM Execution Plan (BEP) needs to be prepared early in the projects. BEP is crucial to ensure that every stakeholder plays their role at various construction phases. This leads to good communication and collaboration as it delivers a stronger project execution and less time is needed for data sharing (Kelly, 2016). Some recommendations on design also highlighted the need for an IBS and BIM framework to be established for project implementation, early involvement and collaboration between all stakeholders, and data transparency between stakeholders.

The high initial cost of moulds has always been listed as one of the major barriers to implementing IBS in projects because different projects need different mould specifications according to design drawings. Apart from that, the economics of scale, as well as design complexity and standardisation, are also some of the challenges faced in IBS production. For BIM implementors, it is important to have the BIM family libraries in IBS production, otherwise, it would take some time for the designers to create objects. Here, the role of vendor development programme (VDP) for design standardisation will take place where it can reduce the cost for mould production and save time for design. Moreover, the participants suggested that more incentive allocations be provided by the government to assist the SMEs to start-up their automation factories.

There is a need for high competency skilled workers to be equipped at a site to ensure IBS installation safety. Lack of competent IBS installers has been identified as one of the main issues and challenges in installation. Furthermore, the lack of BIM integration in IBS projects is also highlighted as part of the main issues. Hence, it is important to have the involvement of SMEs in IBS installation which will create an end-to-end construction ecosystem, and this will increase the competency level of skilled workers in Malaysia, especially local workers.

One of the most crucial parts in IBS is the use of the concept of Just-in-time (JIT) to improve productivity in construction. To leverage the full benefits of BIM, BIM must be part of the project implementation requirements. Otherwise, the industry will not take the opportunity to explore the BIM project implementation. From the discussion, several recommendations can be considered by the stakeholders to boost our construction productivity such as incentive mechanisms for IBS installation, the involvement of every stakeholder in changing the construction ecosystem and increasing the factory standard from conventional method to IBS.

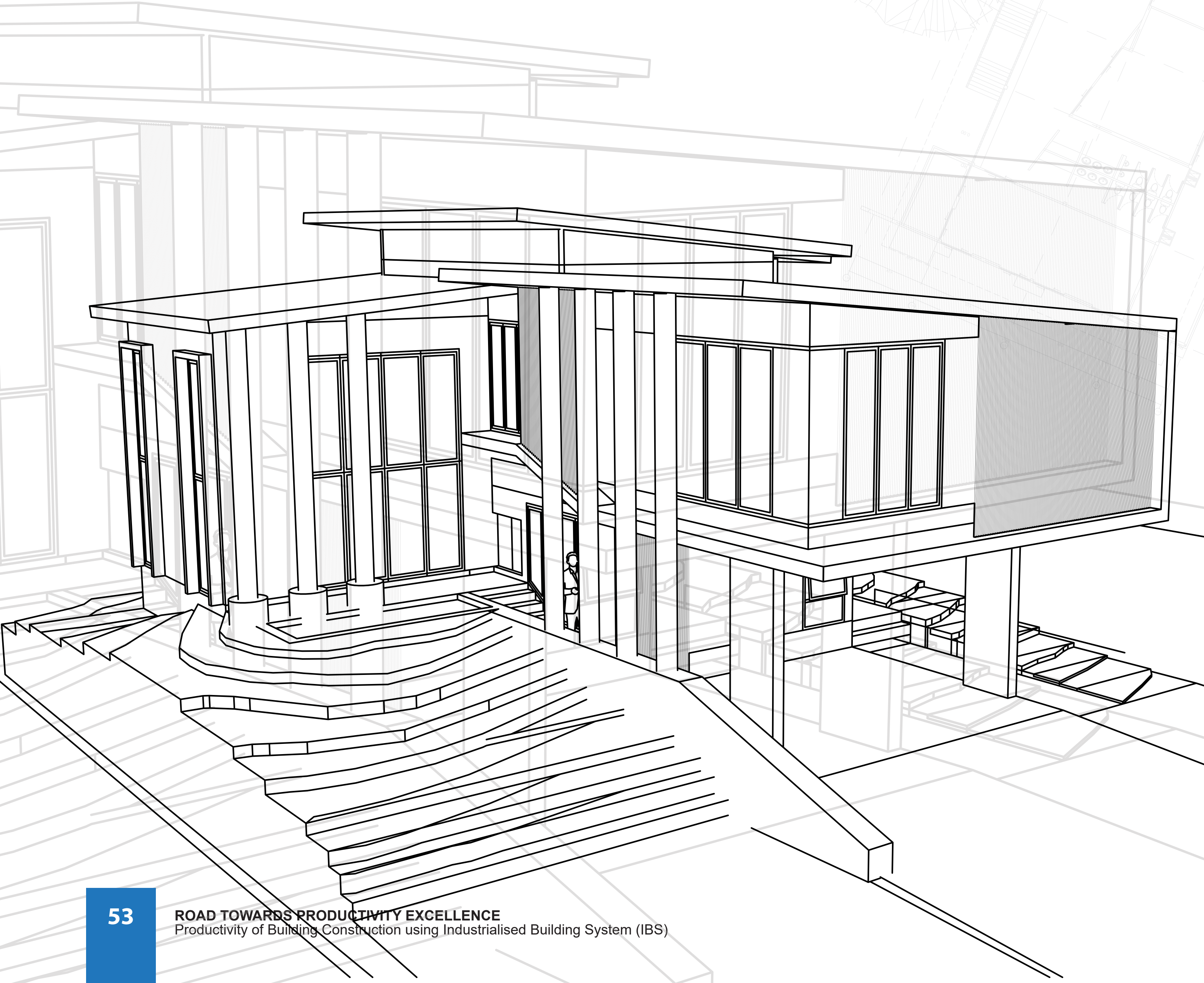
Machinery and equipment also play important roles in project implementation. Without both of these, none of the construction projects will be a success. However, there are several issues and challenges faced by the industry such as the limitation on machinery and equipment available in the industry and a limited number of high capacity cranes for IBS projects. As most IBS components are heavy, it would require the contractors to buy or rent the high capacity cranes which are limited in the industry. Indirectly, this will affect the time taken to complete the projects and make the contractors stick to the conventional method as it is more convenient and cheaper. Moreover, the high cost of machinery and equipment, as well as its operation and maintenance, are also identified as one of the main issues and challenges faced by developers and contractors in ensuring business continuity.

To overcome this issue, the government can provide tax reduction or exemption on machinery and equipment in IBS projects to help developers and contractors for business continuity. Furthermore, Prefabricated Prefinished Volumetric Construction (PPVC) has also been identified as a productive method of construction which can increase productivity, especially at factory and site. Although it needs high capacity cranes to deliver the PPVC components, it can reduce the number of machinery and equipment needed at site and allow for a fast construction method. The participants have suggested that incentives are given to the contractors, practitioners and installers for renting or buying the machinery and equipment as well as suggesting the for reviewing existing policies regarding BIM and IBS related to the machinery and equipment. Last but not least, a matching grant scheme between the government and industry also has been put forward to be considered by the government in helping the industry to become more productive.

To improve the construction industry thoroughly, it must start from the root level, in this context, education at university and industry levels. The main issue that has been faced by the industry nowadays is the lack of exposure to digitalisation in the education syllabus, especially in universities. Apart from that, low competency among local authorities in technology adoption has also been identified as one the main factors that impede productivity in construction. The missing link between academician, industries, and the government is the main issue that needs to be tackled to improve collaboration and integration.

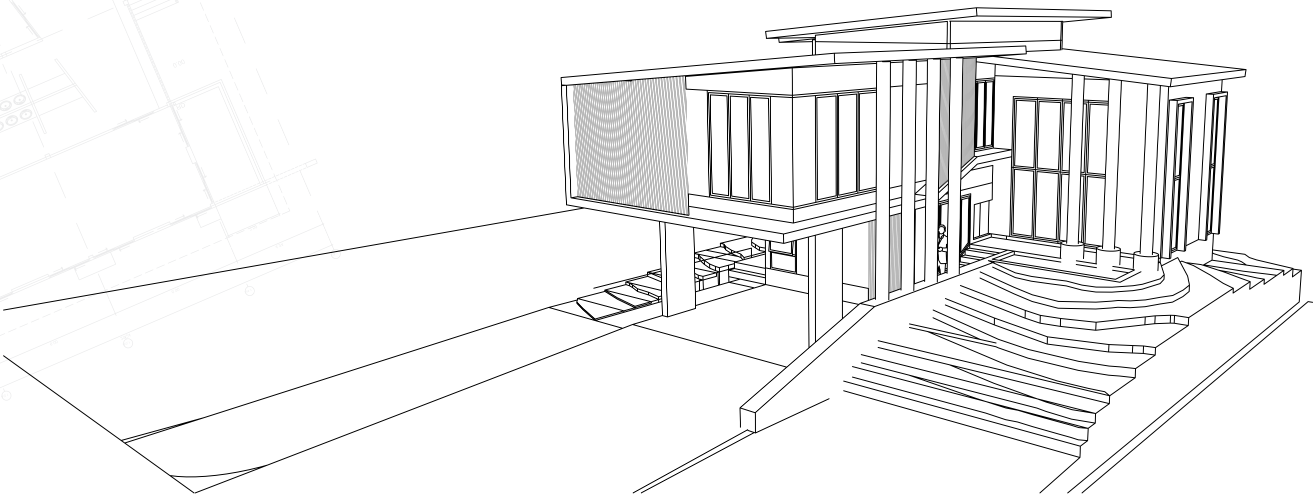
Therefore, a syllabus revision needs to be done by the responsible party to suit the current situation in the construction industry. The level of competency in technology adoption among local authorities needs to be increased as well through training and some industrial engagement. Providing training or certified competency to graduates needs to be done to prepare them with at least the basic knowledge up to certified skills gains throughout the industrial training and syllabus. It is also important to conduct research on Proof of Concept (PoC) for BIM and IBS implementation which can provide a significant proof that BIM and IBS are profitable for business in the long run.

An organisation's business model will involve the aspect of entrepreneurship as part of the business continuity. Most of the industry players are facing some issues of lack of knowledge and exposure in digitalisation. Costs for investment to change their business model are also some of the barriers in implementing technology adoption. Until now, there is a lack of research and proof on how technology adoption can provide a positive Return of Investment (RoI). However, some actions can be taken by the industry players to counter the issues on entrepreneurship such as allocation of funds to train the SMEs on emerging technologies in Construction 4.0 or digitalisation.



Changing the mindset and full support from every SME throughout the construction life cycle will bring the whole ecosystem into digitalisation. A strong connection through a joint venture with an established company in Construction 4.0 needs to be reached to assist in project completion. This will ensure a sharing of knowledge between the advanced party and the newcomer to gain more experience and knowledge in digitalisation. Moreover, the Integrated Digital Delivery (IDD) process also can be applied throughout the whole construction projects to improve the productivity of the construction industry.

Last but not least, legal or regulatory aspects has been proposed to be included by the participants as some of them are facing issues of lack of a project management system and common data environment. In a BIM environment, data sharing is important to enhance the project delivery to be more efficient and faster. However, there are certain legal issues on data sharing which inhibit the data sharing platform as it is a risk to data security and integrity. To counter this, an open access data platform between industry should be established but controlled in a limited way by a single party. Through this, project delivery can be more efficient throughout the digital platform. Government agencies such as JKR and the CIDB should take responsibility to authorise, manage, and control the open-access data system.



3.5.3 FACE-TO-FACE INTERVIEWS

Section A

In Section A, the interviewees were asked general questions on how migration from conventional methods to IBS affects their productivity performance and whether the adoption of IBS can reduce the use of manual foreign labour. They were also asked their processes in monitoring and measuring productivity, as well as essential parameters or indicators to measure project productivity. The interviewees were also asked about the importance of having competent personnel and whether education qualification and industry experience can help in sustaining productivity in their companies. The interviewees were also asked if productivity is important for developers and besides manufacturers, contractors, and developers, which other construction stakeholders are also responsible to improve the productivity of the industry.

NO	QUESTIONS	RESPONSES
1	Do you agree that migration from conventional construction method to IBS can improve the productivity of a certain project?	• 100% of the respondents agreed that migrating from a conventional construction method to IBS can improve productivity because: - construction activities of IBS are more simplified or involved fewer trades such as welding - IBS process can be operated 24 hours a day - IBS reduces the use of labours - IBS is more efficient
2	Is there any overall productivity improvement in your company after migrating from conventional construction method to IBS?	• 100% of the respondents agreed that overall productivity does improve after migrating to IBS
3	How do you monitor and measure the productivity of your project?	• Primary elements when monitoring and measuring productivity are: - time - man-hour, man-day or man-month - monthly output • Productivity measurements: - m^3/month - m^2/month
4	What parameters are important in measuring the productivity of a project?	• Output of each worker per day • Volume produced per day • Human capital • Sub-contractor's performance • Logistics • Input • Time • Cost
5	Do you think that IBS can reduce the use of manual foreign labour?	• 100% of the respondents agreed that IBS can reduce the use of manual foreign labour as IBS has eliminated a few trades especially during installation on-site such as welding and carpentry works.
6	Is it important to have competent personnel in sustaining productivity?	• 100% of the respondents answered yes
7	From a scale of 1 to 10, rank the importance of having education qualification and industry experience (10 being the most important)	• On average: - Education qualification: 6–7 (important for managers, designers, and engineers) - Industry experience: 8–9 (experience in precast production)

NO	QUESTIONS	RESPONSES
8	How important is productivity in the construction industry for developers?	• 100% of the respondents agreed that it is important because: - faster production, faster delivery, faster installation, thus payment can be claimed faster - better productivity, better quality, better cash flow
9	Besides manufacturers, contractors, and developers, who else in the construction stakeholders are responsible to improve productivity of the industry?	• The government • Local governments • Consultants • Policy providers • Designers

Section B

As mentioned in Section 2.2.3.1, design stage has a significant influence on labour productivity. Therefore, in Section B asked the interviewees the capacity in their design team in terms of manpower and technology used. The interviewees were also asked if they use technology such as BIM to communicate within the design team and how frequent do design drawings change and how that may affect their productivity performance?

NO	QUESTIONS	RESPONSES
1	How many personnel are involved in the design team?	• 100% of the respondents answered 11 and above • drafters, architects, civils, mechanical engineers, and electrical engineers
2	What type of modelling does the design team use?	• 30% of the respondents are only using 3D modelling such as Revit, Sketchup and Planbar • The other 70% are using both 2D (AutoCAD) and 3D modelling

Question 3: How many hours does your personnel work per day?

As shown in Figure 16, 50% of the respondents said that their personnel work for 8 hours per day, 25% of the respondents answered more than 8 hours per day and the other 25% said that working hours depend on project types.

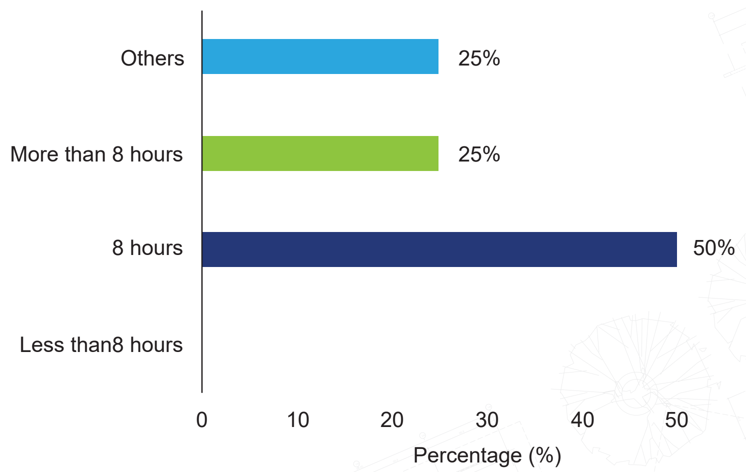


Figure 16: Number of working hours per day

Question 4: What is the age range of your personnel in the design team?

As shown in Figure 17, 50% of the respondents said that their personnel in the design team are around 19–30 years old and the other 50% responded that their personnel are around 31 to 40 years old.

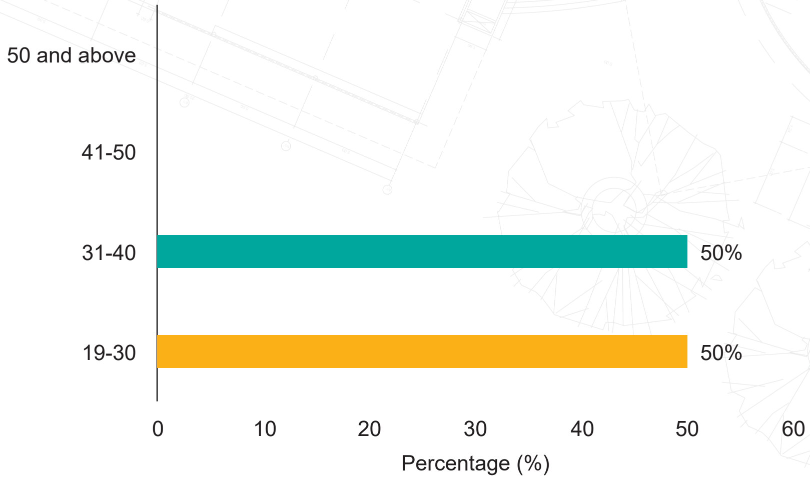


Figure 17: Age range of personnel in the design team

Question 5: Do you have interoperability with the design team using BIM?

As shown in Figure 18, 75% of the respondents use BIM to facilitate interoperability between the design team and 25% do not exchange information between the design team using BIM.

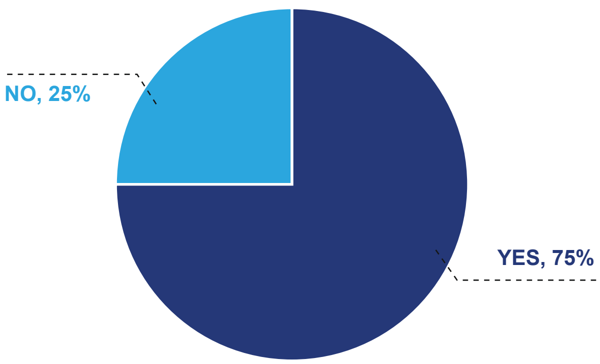


Figure 18: Interoperability between the design team using BIM

Question 6: Based on your experience, how often does the design drawing change?

As shown in Figure 19, 75% of the respondents said that design drawings are always changing and only 25% of the respondents seldom experienced changes in design drawings.

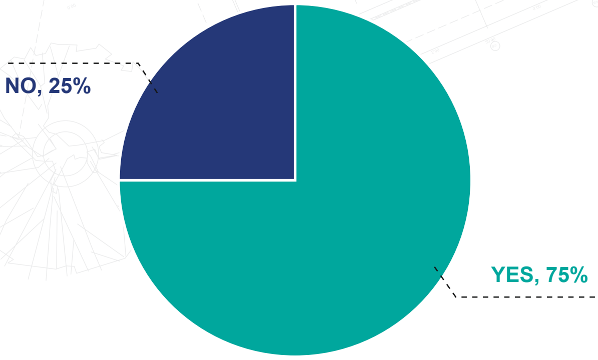


Figure 19: Changes in design drawings

Section C

IBS encourages the standardisation of components or design repetition to reduce construction cost by recycling or reusing the same moulding for other projects, as most moulds used to cast IBS components cannot be dismantled. This is one of the success factors of IBS in improving productivity (Jabar, Ismail, & Mustafa, 2013). However, standardisation is one of the reasons industry players are still reluctant to adopt IBS as it limits the creativity of designers or architects in producing different designs for building projects. There are also issues of having a limited number of moulds per project to reduce cost, but this would affect the production period as more time is required to finish production if only a limited number of moulds are made available for casting. Section C asks manufacturers questions on moulding to get an understanding of how they handle and alleviate the issues regarding moulds.

NO	QUESTIONS	RESPONSES
1	How do you handle or tackle issues on moulding?	• 100% of the respondents said to recycle or reuse suitable moulds to save cost • Design component's specifications based on existing moulds
2	How do the issues on moulding affect productivity in terms of cost?	• If the design of moulds is not right, it would have a major impact on productivity • Productivity would decrease

3.5.4 THE QUESTIONNAIRE-BASED SURVEY

As mentioned earlier, a quick questionnaire-based survey was conducted via emails, face-to-face interviews, and phone interviews with local IBS contractors to access data from their real-life IBS projects to calculate the productivity rate. 6 IBS contractors responded to the survey and in total, 7 IBS projects were gathered as samples for this study.

Table 9 below illustrates the productivity rates for the 7 IBS projects gathered for this study. Project B had the highest productivity rate of 12.7 sq ft/man-day and project K had the lowest productivity rate of 1.3 sq ft/man-day. As shown in Table 9, Project B had 70 workers involved in the project and it was completed within 22 months. In contrast, Project F required 180 workers for the project, and it took 48 months to complete the project. Thus, this validates the hypothesis made earlier which stated that productivity rate is high when a small number of manpower is involved to complete the project within a short period, whereas a larger number of manpower and a longer time needed to complete a building project lowers the productivity rate.

Table 9: Data on Measuring Productivity Rate

Project	GFA (sq ft)	Manpower (pax)	Construction Period (Months)	Productivity Rate (sq ft/man-day)
Project A	1,089,394	256	24	6.8
Project B	508,197	70	22	12.7
Project C	1,370,364	189	24	11.6
Project D	170,000	30	24	9.1
Project E	143,095	40	30	4.6
Project F	302,000	180	48	1.3
Project G	182,000	100	36	1.9

*Total man-days = no of manpower x construction period (months) x (26 days/month)
Assuming every worker works for 26 days per month

Proposed Grading System

Based on the results from the questionnaire-based survey, this study proposed a preliminary grading system to further emphasise the current productivity rate of IBS projects in Malaysia. The proposed grading system was developed together by the researchers with the industry players involved in this study.

The main objective of the proposed grading system is to grade the results from the survey according to their productivity rates and recognise productive construction projects. Table 10 tabulates the grading system used to grade the calculated productivity rates developed through collaboration with industry players.

Table 10: Grading System Used to Rank the Productivity Rates

GRADES	PRODUCTIVITY RATE, x (sq ft/man-day)
A	$x \geq 10.0$
B	$7.5 \leq x < 10.0$
C	$5.0 \leq x < 7.5$
D	$2.5 \leq x < 5.0$
E	$0 \leq x < 2.5$

At the moment, Malaysia has not defined the highest productivity rate of IBS projects to be used as a benchmark in this study. However, based on literature review done for this study, it was found that the overall site labour productivity for public housing in Singapore was 1.0 m2 per man-day which is approximately equivalent to 10 sq ft/ man-day (Ming & Suan, 2006). As public housing in Singapore at that time was built by using the IBS method, it is therefore relevant and appropriate to use 10 sq ft/man-day as a benchmark to be applied in Malaysia.

Likewise, the lowest productivity rate for building construction is not defined in Malaysia. However, from the desktop study, it was abundantly found that IBS projects should have a higher productivity rate compared to conventional projects. Therefore, the lowest productivity rate in the grading system developed should represent the productivity rate of conventional projects.

A hypothetical study was done to estimate the productivity rate of conventional building construction. Project A from the questionnaire-based survey samples was chosen as reference for the hypothetical study. The estimation was done by using data i.e. number of workers and the length of construction period from past experiences of constructing buildings using the conventional method. As shown in Table 11 below, it was found that if Project A was to be constructed using the conventional method, the productivity rate was found to be 2.3 sq ft/man-day. Therefore, the 2.5 sq ft/man-day rate proposed in this study is appropriate to represent the lowest grade of productivity rate in building construction.

Table 11: Estimation of productivity rate of conventional projects based on Project A

Methods	Manpower (pax)	Construction Period (Months)	Productivity Rate (sq ft/man-day)
IBS (real project)	256	24	6.8
Conventional (hypothetical project)	500	36	2.3

*The GFA for Project A is 1,089,394 sq ft

Table 12 below shows the grades of IBS projects based on the productivity rates calculated. It is worth noting that the grading system was developed for this study. If it is intended to be practised in the industry, the grading system can be revised and improved to suit the level of IBS adoption in Malaysia.

Table 12: Grades of IBS Projects Based on the Productivity Rate

Project	GFA (sq ft)	Manpower (pax)	Construction Period(Months)	Productivity Rate (sq ft/man-day)	Grade
Project A	1,089,394	256	24	6.8	C
Project B	508,197	70	22	12.7	A
Project C	1,370,364	189	24	11.6	A
Project D	170,000	30	24	9.1	B
Project E	143,095	40	30	4.6	D
Project F	302,000	180	48	1.3	E
Project G	182,000	100	36	1.9	E

*Total man-days = no of manpower x construction period (months) x (26 days/month)
Assuming every worker works for 26 days per month

3.5 CONCLUSION AND RECOMMENDATIONS

The Productivity Measuring Tool (PMT) study concludes that the construction industry in Malaysia still has a long journey ahead in becoming a productive industry to compete with other sectors. The industry players agreed that there are still a lot of issues that need to be resolved and they voiced out their opinion that they are not the only party that bears the responsibility to enhance construction productivity. Other stakeholders, especially the authorities such as the government should play their roles in bringing and supporting the use of competitive technologies, advanced materials, skilled professionals, local youths and graduates, innovative talents etc. to effect a meaningful transformation of the industry.

The industry players also opined that the government should provide some kind of incentives to support the industry to move towards modernisation. Tax reduction or exemption on machinery and equipment can be one of the pull factors to attract SMEs to venture into IBS as one of the main factors of low adoption of technology in the industry is it is an expensive investment. The exposure or awareness on the importance of digitalisation and industrialisation should also be spread from the outset, in this context, education level. The study also presents the importance of effective communication within all project stakeholders and how early involvement of everyone is beneficial in creating a productive construction project.

Although the samples collected for this study are limited, this study shows that construction projects in Malaysia have adopted the use of IBS in their projects, especially public projects as the government has mandated that public projects must achieve a 70 IBS score. However, the productivity rates of the project samples are still low. The productivity defined in this study suggests that to increase productivity rate, a project should not be labour-intensive and can be completed in a short period. However, this study needs to increase its samples and expand its focus to looking at the productivity rate of conventional construction projects as well, in order to compare the two methods and benchmark the productivity rate of the Malaysian construction industry.

This study also proposes a preliminary grading system to grade construction projects based on their productivity rate. This study suggests that the grading system be used as a preliminary study and larger samples should be collected to get a closer representation of the productivity of the construction industry in reality. The grading system was proposed to recognise productive construction projects and as a starting point to prepare Malaysia in providing incentives to encourage more players especially SMEs from the get-go to adopt productive technologies and simultaneously increase the productivity of the industry.

“PRODUCTIVITY CAN BE UNQUESTIONABLY IMPROVED IF EVERY CONSTRUCTION STAKEHOLDER WORKS TOGETHER TO BRING THE INDUSTRY INTO A NEW ERA THAT WILL BRING GREAT BENEFITS TO THE SOCIETY, ENVIRONMENT, AND ECONOMY.”

FOUR

The Way Forward

THE WAY FORWARD

The construction industry will remain a cornerstone of the world's economy and almost all other industries. However, the industry is still lagging behind other industries and its productivity has been static for decades. This inertia, however, can be disrupted by pushing the industry into modernisation by bringing digitalisation, innovation, and the accelerated adoption of innovative technology into the industry. This can elevate Malaysia's current level of productivity and strengthen the competitiveness of SMEs.

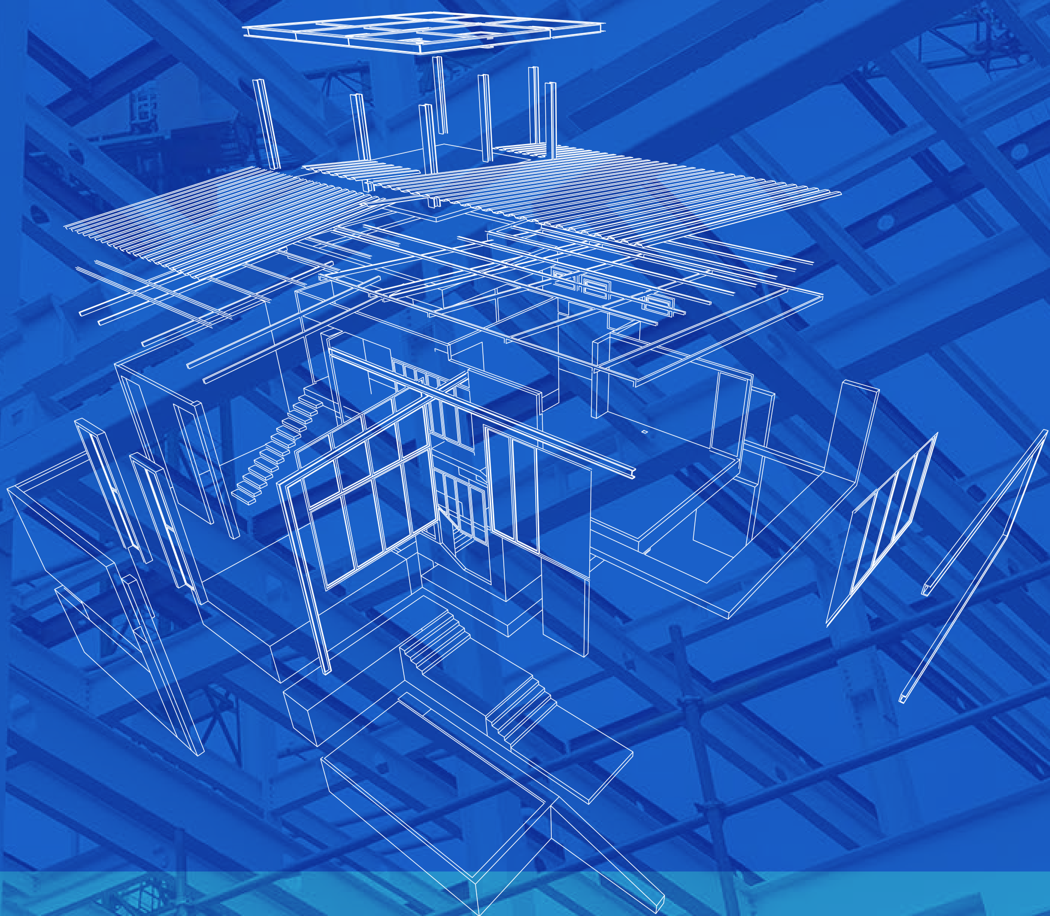
The use of IBS has long been introduced in the industry, but the slow rise in productivity indicates that the adoption of the technology is still low. Therefore, there is a need to measure and quantify this situation to have a broad understanding of the challenges of productivity improvement. Productivity measurement in the construction industry is also vital to benchmark the productivity rate in Malaysia. The benchmarking process is important to identify the performance of the construction industry and to explore potential areas that can help to increase productivity performance.

Productivity rate gives an overview of the overall productivity of construction projects. However, to truly understand the concept of productivity in the industry and to give a powerful impact on productivity performance, it is essential to look at productivity from every angle. As explained in this report, structural work has the highest potential for productivity improvement as its process is very labour-intensive. Therefore, the productivity improvement efforts should be focused on structural work by measuring the productivity of each trade involved in the process through trade productivity.

Hence, this study recommends developing a productivity measurement tool using trade productivity for future research to understand the process of each key trade in construction projects. By looking at productivity from this angle, potential areas where productivity can be improved by reducing the number of construction workers through the adoption of technology can easily be identified and it can also guide SMEs to embark on the adoption of technology in their projects.

Without doubt, the productivity of the Malaysian construction industry can be improved. However, the efforts should also come from authority. The government should promote the use of productive technologies in the industry by providing incentives as a catalyst to attract more players, especially SMEs to engage in modern construction and by recognising productive construction projects to promote competitiveness in the industry. Productivity can be unquestionably improved if every construction stakeholder works together to bring the industry into a new era that will bring great benefits to the society, environment, and economy.

“ THE BENCHMARKING PROCESS IS IMPORTANT TO IDENTIFY THE PERFORMANCE OF THE CONSTRUCTION INDUSTRY AND TO EXPLORE POTENTIAL AREAS THAT CAN HELP TO INCREASE PRODUCTIVITY PERFORMANCE. ”



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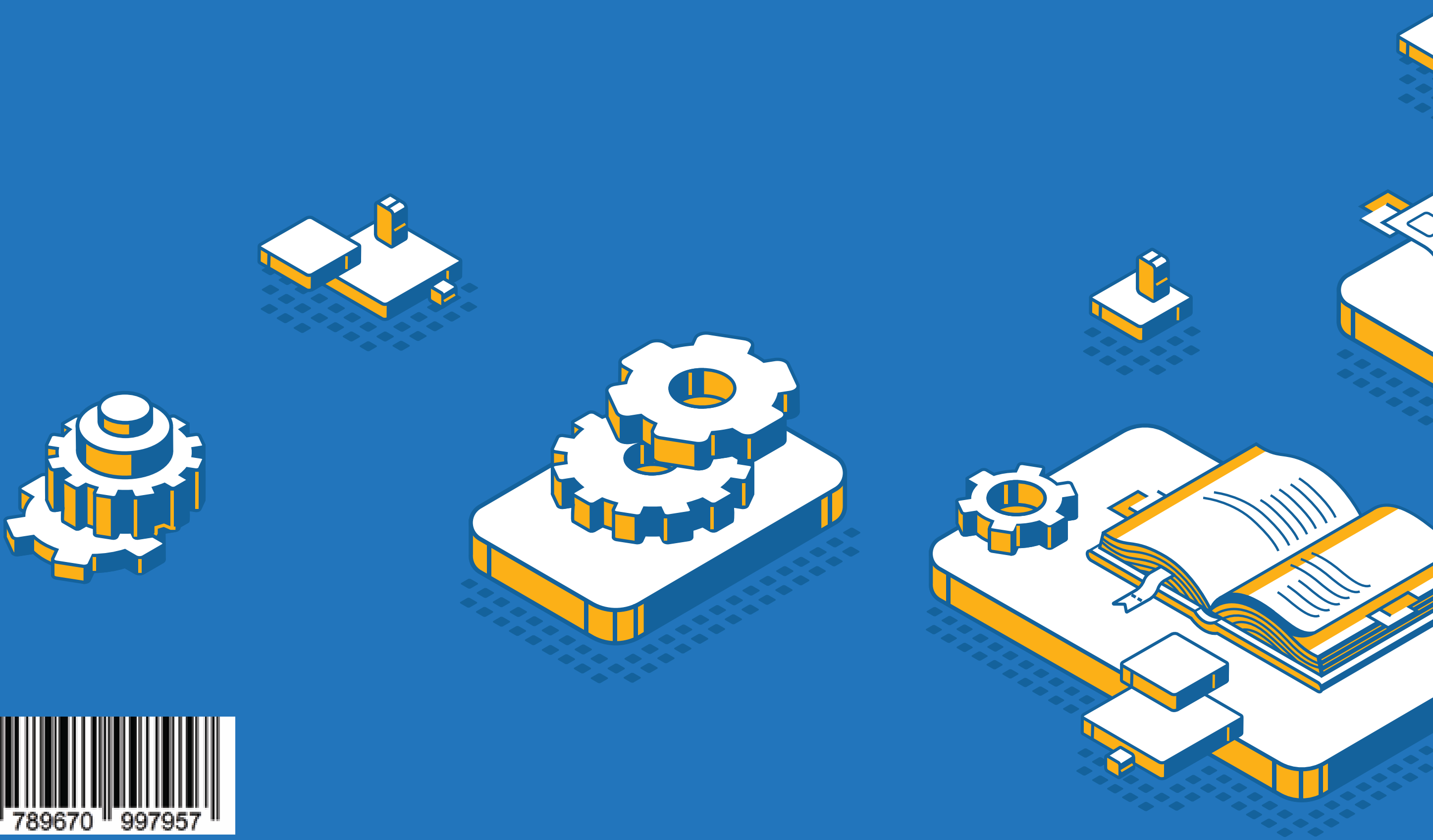
CIDB MALAYSIA

ROAD TOWARDS PRODUCTIVITY EXCELLENCE

PRODUCTIVITY OF BUILDING CONSTRUCTION USING INDUSTRIALISED BUILDING SYSTEM (IBS)



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