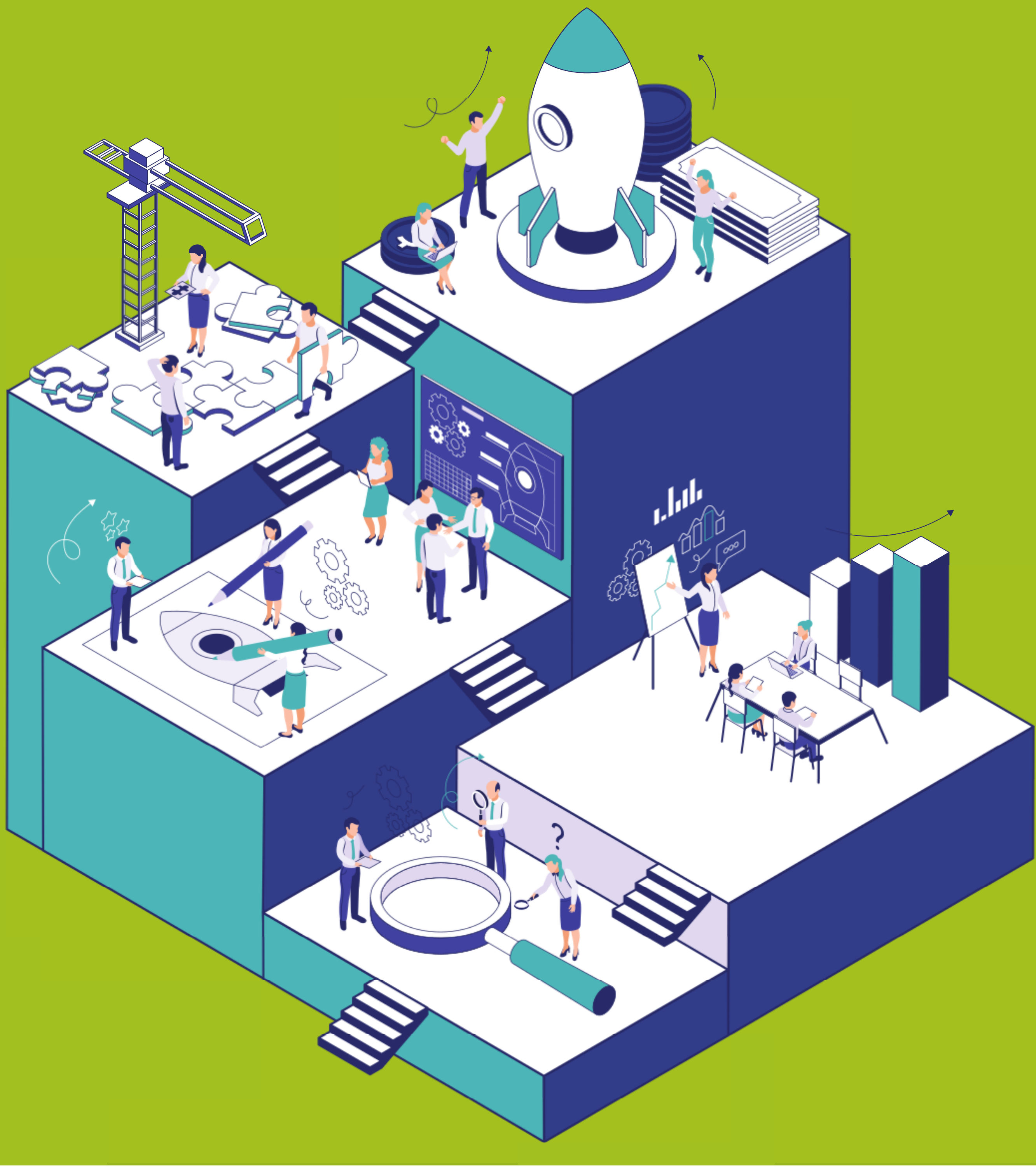
ROAD TOWARDS PRODUCTIVITY EXCELLENCE: PRODUCTIVITY OF BUILDING CONSTRUCTION PROJECTS USING INDUSTRIALISED BUILDING SYSTEM (IBS) AND CONVENTIONAL METHOD OF CONSTRUCTION

CIDB MALAYSIA



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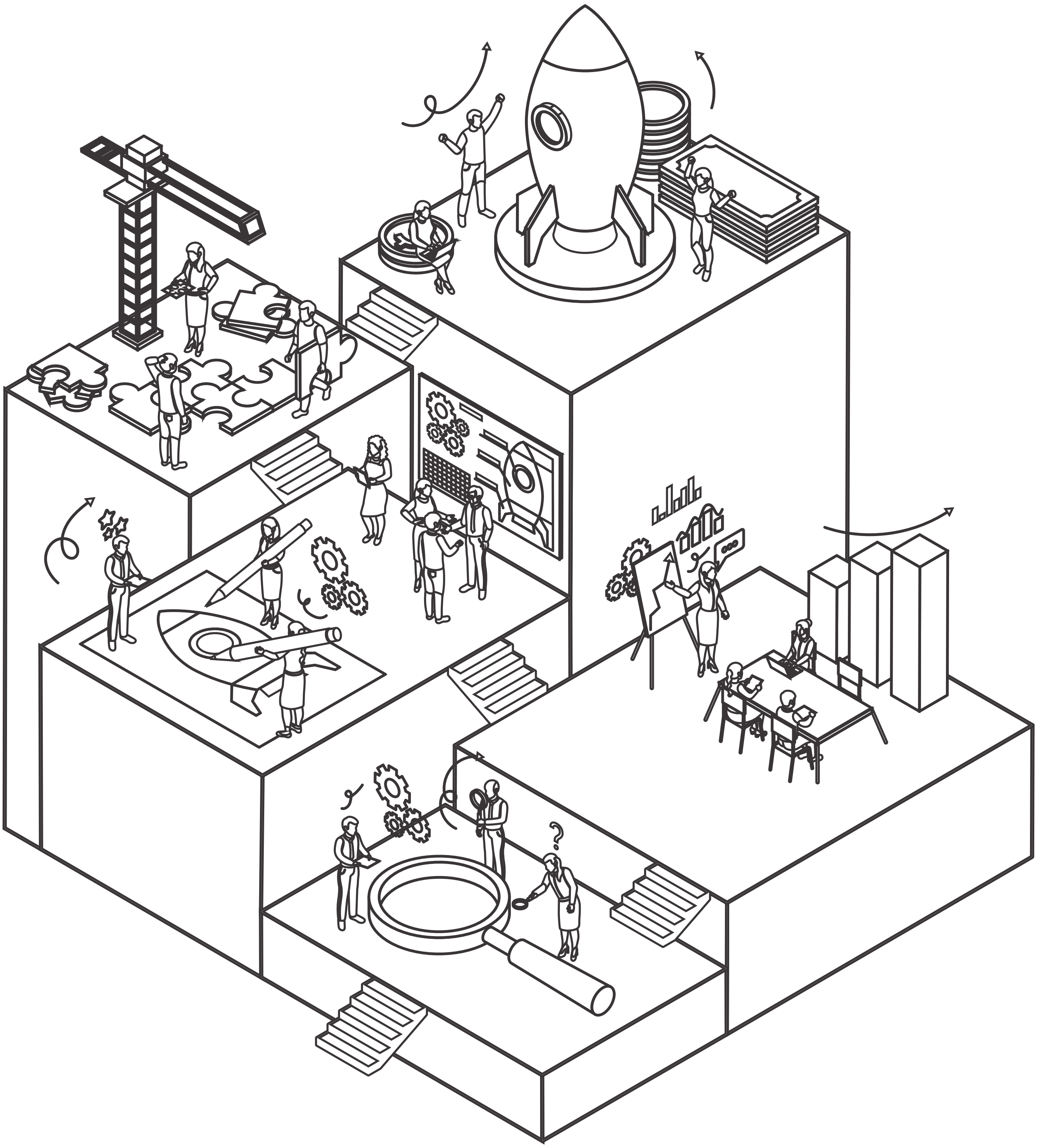

Preface

As one of the most vital industries globally, the construction industry's productivity has been relatively stagnant. One reason behind this unimpressive track record is that the industry has been hesitant about fully embracing the latest technological opportunities. The industry has huge potential for productivity improvements, thanks to new and innovative construction technologies and methods. The industry has long been acquainted with technology like Industrialised Building System (IBS), and this technology has the potential to boost productivity while sustaining quality and safety.

IBS is a recognised technology that can replace the conventional construction approach and boost the productivity of the construction sector. Despite this well-known advantage that has long been discussed in the industry, progress is still limited as the industry has become very familiar with the conventional method and reluctant to change. As a result, the productivity of the construction industry suffered.

Therefore, to provide evidence that IBS is more productive than the conventional building system, there is a need to measure the productivity difference. This research is a continuation of our previous publication entitled "Road Towards Productivity Excellence: Productivity of Building Construction using Industrialised Building System (IBS)". In this publication, the Construction Industry Development Board Malaysia (CIDB) and Construction Research Institute of Malaysia (CREAM) developed a tool called Productivity Measuring Tool (PMT) specifically to measure the productivity of construction projects. The PMT developed includes productivity measurement calculation to calculate the productivity performance of a certain construction project and a grading system to grade and rank construction projects according to the productivity performances. Hence, this research aims to measure the productivity of building construction projects using the PMT developed and compare the productivity difference between conventional building system and IBS.

This research recommends the industry to fully adopt and implement IBS in building construction projects to boost the productivity of the industry and put the industry among other best productive industries. IBS can help eliminate the poor image of work in the construction industry as "dirty, difficult, and dangerous" and guide the industry to be on the right track towards productivity excellence.

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Editorial Board

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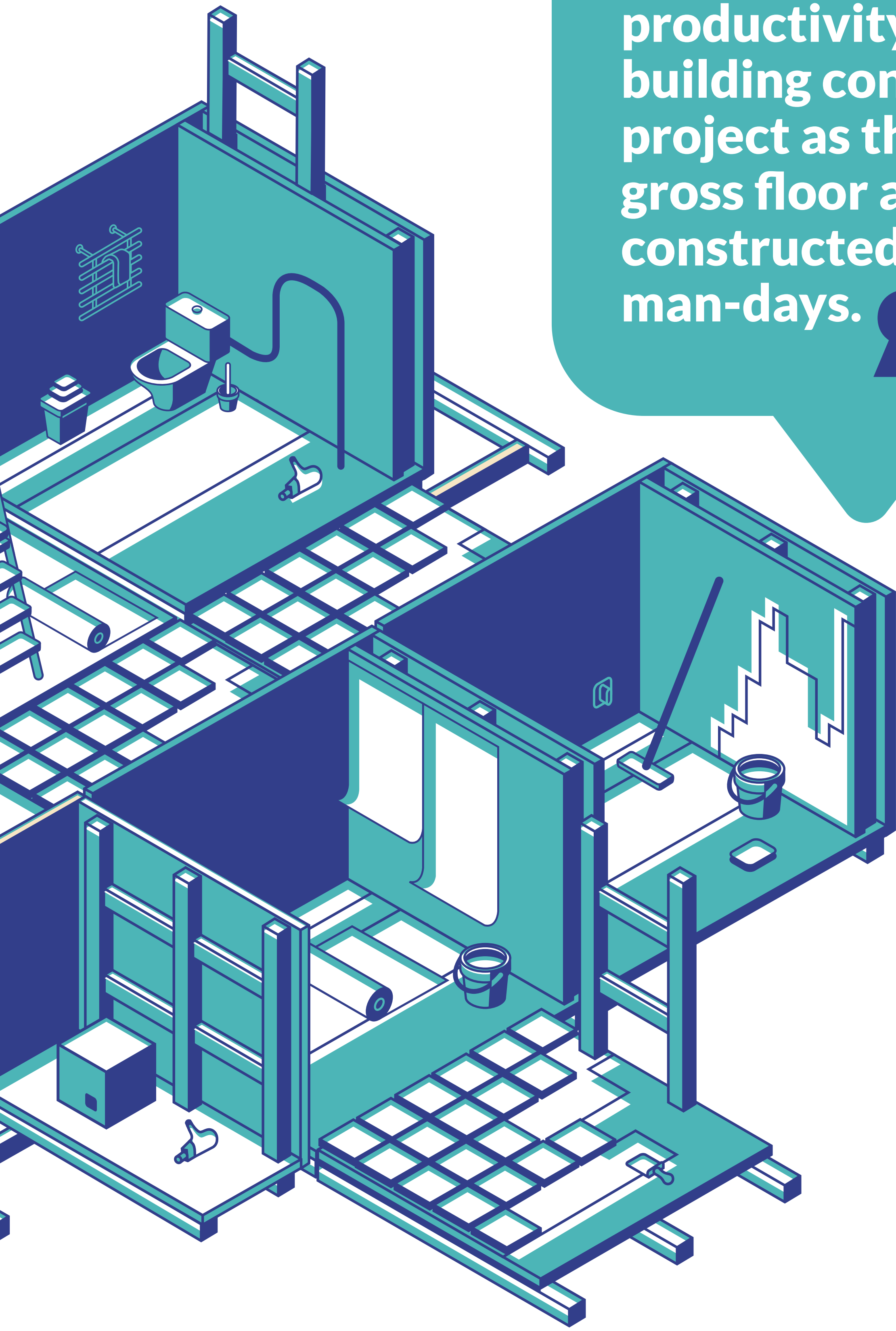
CONSTRUCTION INDUSTRY DEVELOPMENT BOARD (CIDB)

CONSTRUCTION RESEARCH INSTITUTE OF MALAYSIA (CREAM)

Abbreviation

CIDB	**Construction Industry Development Board**
CREAM	**Construction Research Institute of Malaysia**
GDP	**Gross domestic product**
GFA	**Gross floor area**
IBS	**Industrialised Building System**
PMT	**Productivity measuring tool**

ONE
Introduction



PMT defines productivity of a building construction project as the total gross floor area constructed per total man-days.

1 INTRODUCTION

Construction is one of the largest sectors in the world economy and becomes an essential industry to the society and environment. 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 (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 decades. The concept of productivity is not well understood in construction; many find it complex and difficult to understand. For many reasons, 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.

Productivity is generally defined as the ratio of output and input. Higher productivity means gaining more output with the same or lesser input (Malaysia Productivity Corporation (MPC), 2019). Construction Industry Development Board Malaysia (CIDB) (2020) developed a tool called Productivity Measuring Tool (PMT) to define and measure the productivity performance of building construction projects in Malaysia. PMT defines productivity of a building construction project as the ratio of the total constructed gross floor area to the total man-days as shown in the following Equation 1. One man-day in this context is defined as 1 manpower working for 8 hours per day. The PMT also involves a grading system used to rank building construction projects according to their productivity performance. The grading system is summarised in Table 1.

Equation 1: Productivity equation

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

$$= \frac{\text{Total constructed gross floor area (sq. ft.)}}{\text{Total number of manpower} \times \text{Total length of the construction period (days)}}$$

Table 1: Grading system used to rank the productivity performance measured

GRADES	PRODUCTIVITY PERFORMANCE, 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	$0 \leq x < 2.5$

This research aims to identify the difference in productivity between two construction methods, the conventional building system and the industrialised building system (IBS), using PMT. IBS includes cast-in-situ, composite, and fully prefabricated construction methods shown in Figure 1 (Kadir et al., 2006).

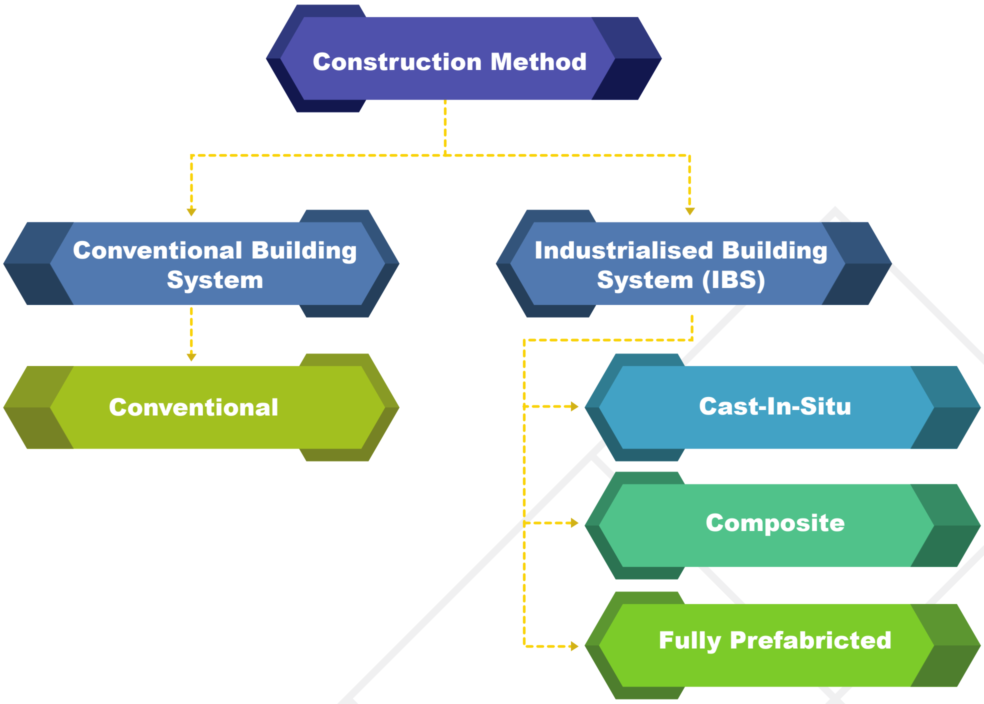


Figure 1 Types of Construction Methods

A conventional building system is a system of current practice using in-situ concreting with temporary wooden formwork. Building construction projects that use conventional building system basically fabricate their building components on-site through the processes of timber or plywood formwork installation, steel reinforcement, and cast-in-situ. This construction method is labour-intensive, has a low-speed construction time, and involves intensively huge transportation activity (Haron et al., 2005).

IBS is a term commonly used in Malaysia to describe a construction method that produces building components in a controlled environment before being transported, positioned, and assembled at a construction site (Abd Hamid et al., 2011). IBS is also defined as a construction system built using prefabricated components that are systematically manufactured using machine, formworks, and other forms of mechanical equipment and then delivered to the site for assembly and erection (Baharuddin et al., 2006).

The following are the six types of IBS (Construction Industry Development Board Malaysia [CIDB], 2020a):

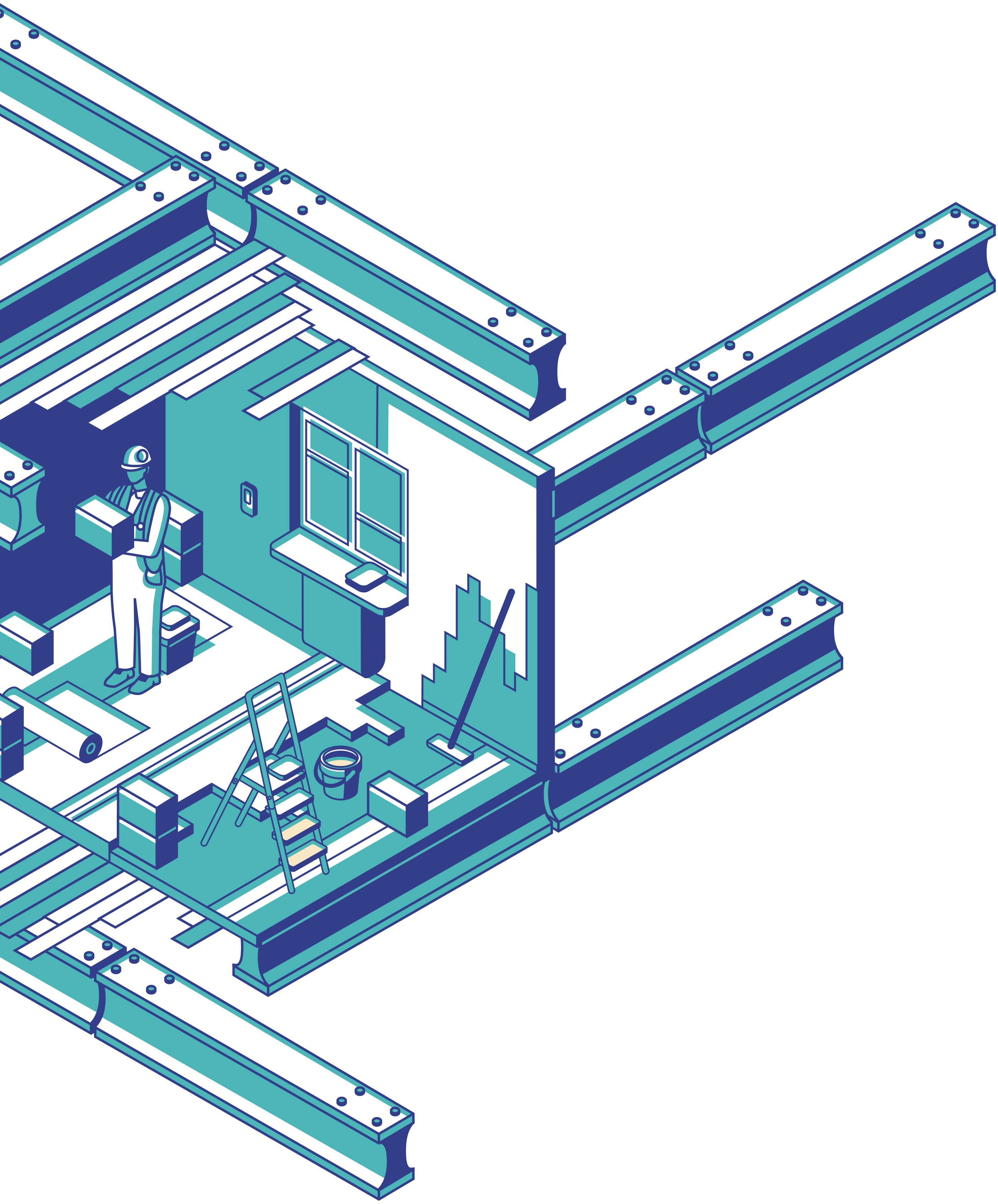
1. **Precast concrete system** – a form of concrete prepared, cast, and cured off-site using reusable moulds. Precast concrete components are joined to other components to produce a complete structure.
2. **Metal framing system** – a fast-structural system designed for panel construction and continuous walls, individually standing low-rise buildings, and high separation walls.
3. **Reusable formwork system** – consists of prefabricated modules with a metal frame and is covered by material with the desired surface structure (steel, aluminium, timber, etc.) on the application side (concrete).
4. **Blockwork system** – the construction of concrete or concrete blocks larger than standard clay or concrete bricks. The blocks are rectangular and made of concrete with hollow cores. They are produced in an automated manufacturing process that consists of mixing materials, laying the material in a mould, and later transferred to the curing operation. Blockwork consists of lightweight block and concrete masonry block.
5. **Timber framing system** – forms a skeletal structure to support the weight and the number of loads carrying member.
6. **Innovative system** – a range of innovations that implements the use of IBS.

IBS is considered nonconventional, and it is aimed to improve productivity and quality of construction work through the adoption of better construction machinery, equipment, technology, and materials.

Construction technology has become the main driver of the construction industry to improve efficiency and productivity. Construction technology has the opportunity to give the industry a dramatic productivity boost. As one of the many construction technologies available globally, IBS has the potential to improve productivity by shifting many aspects of construction works away from conventional construction sites and into factories with off-site manufacturing.

> “IBS aims to improve productivity and quality of construction work through the adoption of better construction machinery, equipment, technology, and materials.”

TWO
Research Methodology



2 RESEARCH METHODOLOGY

This research used a case study method through questionnaires to measure the productivity performance of building construction projects using IBS and conventional building system. Questionnaires were distributed to collect at least 90 building construction projects: 60 IBS projects and 30 conventional projects. The questionnaire includes eight sections to provide sufficient information for the study. The first section is the main section which is compulsory, and it includes two subsections: respondent background and project background. Personal information of the respondent background includes name, contact number and organisation. Project background gathered information on the project name, IBS Score (if any), project sector, project type, number of working days per month, construction period in months, GFA of the project, total number of house units, unit size, and types of IBS used in the project (limited to IBS projects only). The other seven sections gathered information on different building systems: precast concrete, metal framing, reusable formwork, blockwork, timber framing, innovative, and conventional. The respondents were asked to only answer sections according to its type of building system used in their projects. Each section gathered information on the number of manpower involved and the duration of each construction stage involved. Different types of building system have different construction stages, as shown in Table 2.

Table 2: Types of stages involved in different building systems

BUILDING SYSTEMS	STAGES				
Precast concrete	Design	Production	Installation	Architectural works & finishing	
Metal framing	Design	Production	Logistics	Installation	Architectural works & finishing
Reusable formwork	Design	Installation	Construction	Architectural works & finishing	
Blockwork	Design	Production	Construction	Architectural works & finishing	
Timber framing	Design	Installation	Production	Construction	Architectural works & finishing
Innovative	Design	Production	Logistics	Installation	Architectural works & finishing
Conventional	Design	Construction	Architectural works & finishing		

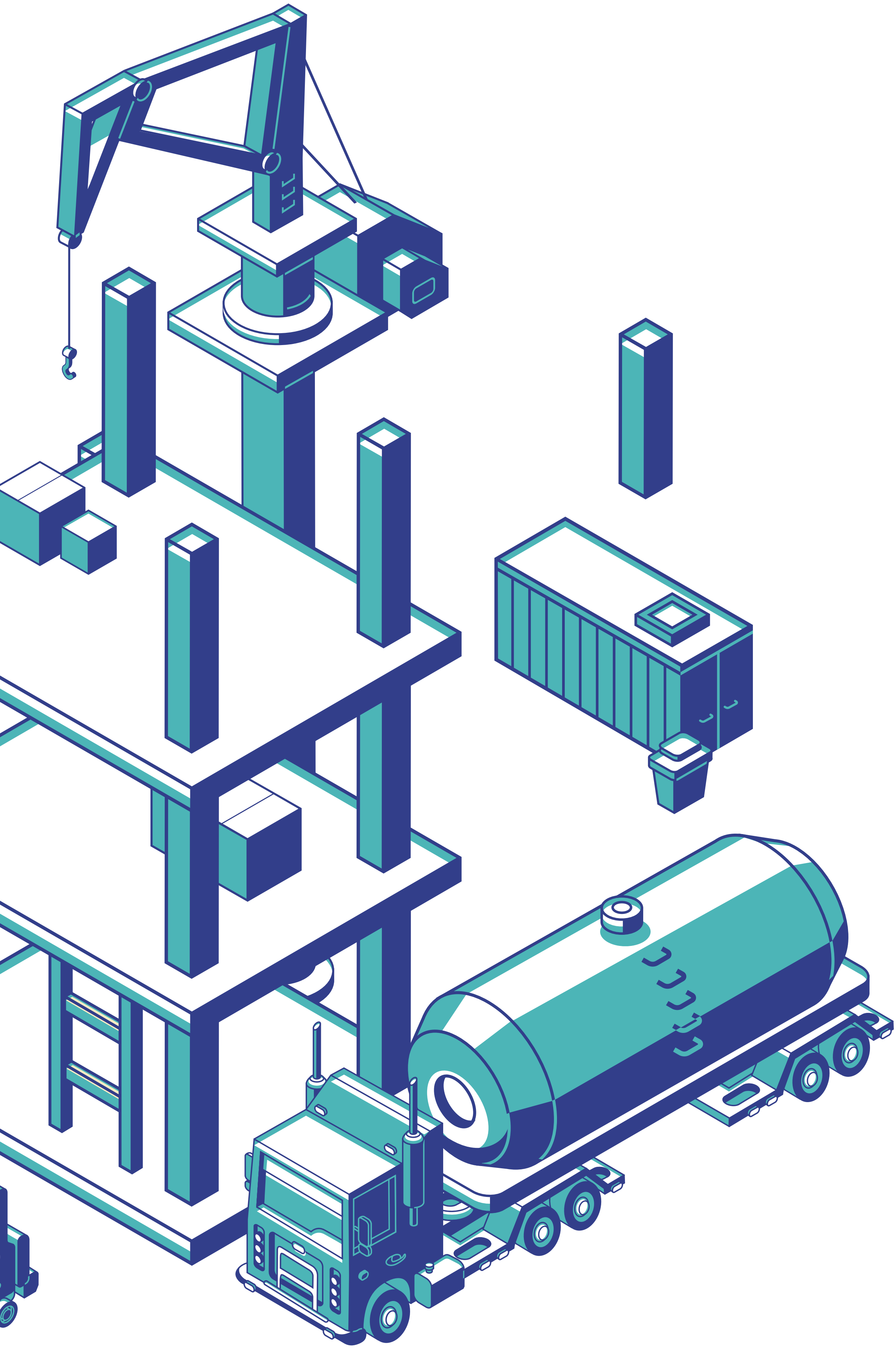
A response rate of 100% was achieved for this research, where a total of 90 building construction projects were gathered: 60 IBS projects and 30 conventional projects. However, only 56 data were valid (62% validity). The other 34 data were invalid as there are insufficient data given to measure the productivity performance. The following Table 3 summarises the number of projects successfully collected for every type of building system.

Table 3: Data gathered for case study via questionnaires

BUILDING SYSTEMS	NO. OF PROJECTS
Industrialised Building System	
Precast concrete	3
Metal framing	7
Reusable formwork	5
Blockwork	3
Timber framing	4
Innovative	6
Conventional Building System	28
Total building construction projects	56

The productivity performances of these 56 building construction projects were then measured using the PMT developed.

THREE
Research Analysis



3 RESEARCH ANALYSIS

In total, there are 56 building construction projects collected for this research, whereby 28 of them were IBS projects and the rest 28 projects were projects using conventional building system. The average productivity performance for IBS projects and conventional projects were measured using the developed PMT to see the productivity difference between the two approaches. The measurement was made at two work

1. overall work stage that considers design, production, logistics, installation, construction, architectural works and finishing; and
2. construction work stage that only considers works at the construction site: installation, construction, and architectural works and finishing.

Table 4 tabulates the average productivity performances and grades for both building systems at the overall work stage and construction work stage. The results are also visualised in Figure 2.

Table 4: The average productivity performances of IBS and conventional method of construction for overall and construction work stages

WORK STAGES:	OVERALL		CONSTRUCTION	
Building Systems	Average Productivity Performances, x (sq. ft./man-day)	Grade	Average Productivity Performances, x (sq. ft./man-day)	Grade
IBS	8.25	B	19.54	A
Conventional	5.27	C	6.96	C

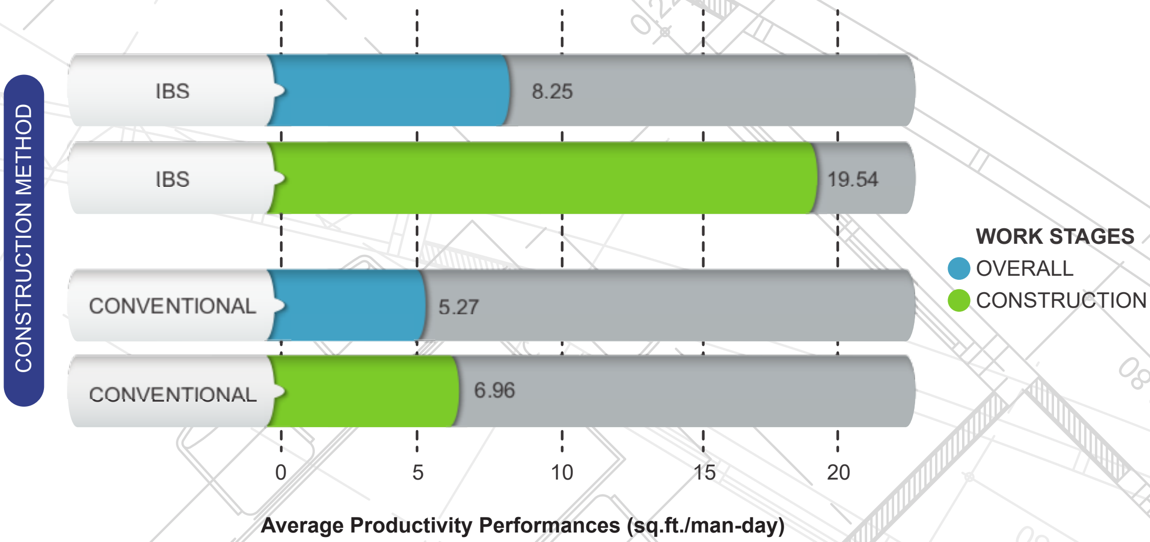


Figure 2: The average productivity performances of IBS and conventional method of construction for overall and construction work stages

Figure 2 visualises the average productivity performances of IBS projects and conventional projects at both stages. Figure 2 shows that IBS projects have an average productivity performance of 8.25 sq. ft./man-day, approximately 1.5 times higher than the average productivity performance of conventional projects (5.27 sq. ft./man-day). However, when the data were analysed only at the construction work stage, the average productivity performance of the IBS project increased significantly to 19.54 sq.ft./man-day. Meanwhile, the average productivity performance of the conventional projects only increased slightly to 6.96 sq. ft./man-day.

From Table 4, the average productivity performance of the IBS construction method achieved grade B at the overall work stage. This grade showed an improvement to grade A when its average productivity performance was only measured at the construction work stage. Meanwhile, although the average productivity performance of the conventional construction method at the construction work stage is higher than that at the overall work stage, its grade did not improve and remained at grade C. This difference shows that the increment is not as significant as that of the IBS construction method.

This research also measured the average productivity performance of 6 types of IBS at the overall work and construction work stages. From 28 IBS projects, 3 projects used precast concrete system, 7 projects used metal framing system, 5 projects used reusable formwork system, 3 projects used blockwork system, 4 projects used timber framing systems, and 6 projects used innovative system.

Figure 3 illustrates the average productivity performances for each type of IBS at the overall and construction work stages. At the overall work stage, the reusable formwork system has the highest average productivity performance of 9.68 sq. ft./man-day, followed by the innovative system with an average productivity performance of 7.98 sq. ft./man-day. The precast concrete system comes in third with an average productivity performance of 7.81 sq. ft./man-day, followed by the metal framing system with an average productivity performance of 6.49 sq. ft./man-day. Next, the timber framing system achieved 5.85 sq. ft./man-day, and the blockwork system achieved the lowest average productivity performance, which is 3.39 sq. ft./man-day.

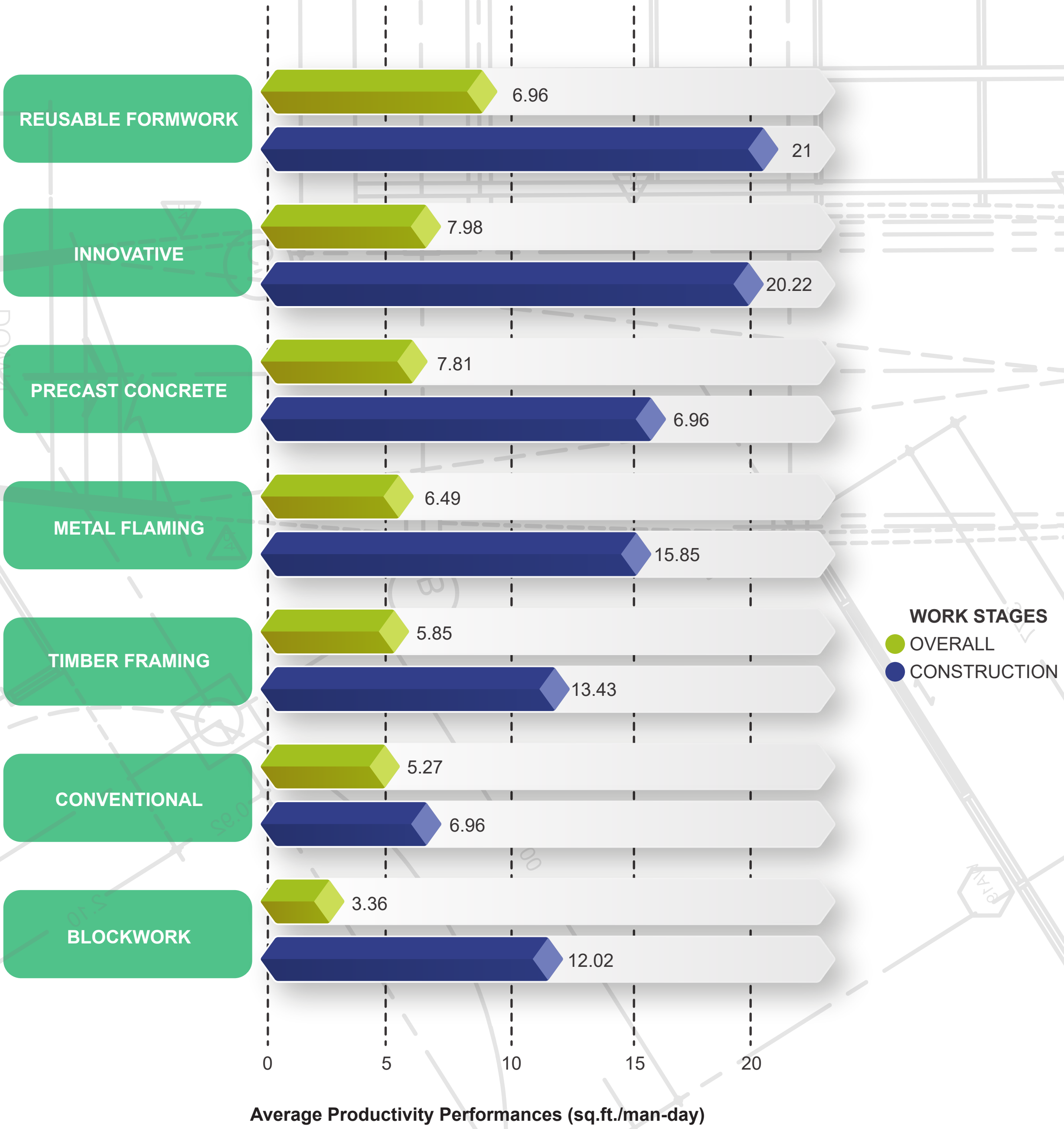


Figure 3: The average productivity performances of different building systems for overall and construction work stages

Figure 3 also demonstrates the comparison between each type of IBS and the conventional construction method. For the overall work stage, only the blockwork system is less productive than the conventional construction method. However, when the average productivity performances were measured at the construction work stage, the average productivity performances of all IBS types grew significantly compared to the conventional construction method. For, reusable formwork system, the average productivity performance increased to 21.56 sq. ft./man-day.

Meanwhile, the innovative system has gained its average productivity performance at the construction work stage to 20.22 sq. ft./man-day, followed by the precast concrete system with an average productivity performance of 16.95 sq. ft./man-day. Likewise, the average productivity performance of the metal framing system increased to 15.85 sq. ft./man-day. The average productivity performance of the timber framing system also improved at the construction work stage, which is 13.43 sq. ft./man-day, as well as the average productivity performance of the blockwork system, which is 12.02 sq.ft./man-day.

Table 5 describes the grades for each type of IBS and conventional building system at the overall work stage and construction work stage. When measured at the overall work stage, none of the IBS projects achieved grade A of the average productivity performance. Only 3 types of IBS have average productivity performances of grade B: precast concrete system, reusable formwork system, and innovative system. Meanwhile, the metal framing system and timber framing system have average productivity performances of grade C. The blockwork system achieved the lowest average productivity performance (grade D), which is lower than that of the conventional construction method (grade C). However, when measured at the construction work stage, the average productivity performances of all types of IBS improved significantly and achieved grade A while the conventional construction method remained at grade C.

Table 5: The average productivity performances of different types of building systems at the overall and construction work stages

WORK STAGES:	OVERALL		CONSTRUCTION	
Building Systems	Average Productivity Performances, x (sq. ft./man-day)	Grade	Average Productivity Performances, x (sq. ft./man-day)	Grade
Precast Concrete	7.81	B	16.95	A
Metal Framing	6.49	C	15.85	A
Reusable Formwork	9.68	B	21.56	A
Blockwork	3.39	D	12.02	A
Timber Framing	5.85	C	13.43	A
Innovative	7.98	B	20.22	A
Conventional	5.27	C	6.96	C

Table 4 and Table 5, as well as Figure 2 and Figure 3 indicate that IBS is a more productive building system compared to the conventional building system. IBS especially gains productivity significantly at the site, compared to the conventional construction method. This is because IBS uses less manpower at the site; thus, construction works can be completed fast (Table 6). Table 6 indicates that the average number of manpower of IBS is less than that of conventional, 68 pax and 75 pax, respectively. IBS also has a shorter average construction period than conventional, which are 10 months and 13 months, respectively. This difference proves the validity of the productivity measuring tool developed, which defines the productivity as GFA constructed per man-day. This means that when man-day is less, i.e. manpower and the construction period are less, to construct a certain size of GFA, the productivity of the project is high.

Table 6: The average no. of manpower and construction period for IBS and conventional construction methods

CONSTRUCTION METHODS	AVERAGE NO. OF MANPOWER (PAX)	AVERAGE CONSTRUCTION PERIOD (MONTH)
IBS	68	10
Conventional	75	13

Table 7 describes the average productivity performances of IBS and conventional projects and their grades based on gross floor area (GFA). IBS projects have higher average productivity performances than conventional projects for every size of gross floor area (GFA) except when GFA is bigger than 1,000,000 sq. ft. When the GFA is less than or equal to 100,000 sq. ft., the average productivity performance of IBS projects is 20.99 sq. ft./man-day, while conventional projects only achieved 3.02 sq. ft./man-day of average productivity performance. When the GFA is between 100,001 sq. ft. and 500,000 sq. ft., IBS projects achieved 19.96 sq. ft./man-day of average productivity performance while conventional projects only achieved 7.07 sq. ft./man-day. Likewise, when the GFA is between 500,001 sq. ft. and 1,000,000 sq. ft., the average productivity performance of IBS projects is higher than the average productivity performance of conventional projects of 21.70 sq. ft./man-day and 7.61 sq. ft./man-day, respectively. However, when the GFA is more than 1,000,000 sq. ft./man-day, conventional projects achieved a higher average productivity performance than IBS projects, which are 31.45 sq. ft./man-day and 21.76 sq. ft./man-day, respectively.

IBS construction method has achieved grade A of average productivity performance for all sizes of GFA whereas conventional construction method only achieved grade D of average productivity performance when the GFA ≤ 100,000 sq. ft., grade C when the GFA is between 100,001 sq. ft. and 500,000 sq. ft., and grade B when the GFA is between 500,001 sq. ft. and 1,000,000 sq. ft. Although both construction methods achieved grade A of average productivity performance, the conventional construction method has a higher average productivity performance than the IBS construction method.

Table 7: The average productivity performances of IBS and conventional projects based on gross floor area

GFA	**GFA ≤ 100,000 sq. ft.**	
Construction Methods	Average Productivity performances, x (sq. ft./man-day)	Grade
IBS	20.99	A
Conventional	3.02	D

GFA	**100,000 > GFA ≤ 500,000 sq. ft.**	
Construction Methods	Average Productivity performances, x (sq. ft./man-day)	Grade
IBS	19.96	A
Conventional	7.07	C

GFA	**500,000 > GFA ≤ 1,000,000 sq. ft.**	
Construction Methods	Average Productivity performances, x (sq. ft./man-day)	Grade
IBS	21.70	A
Conventional	7.61	B

GFA	**GFA ≤ 1,000,000 sq. ft.**	
Construction Methods	Average Productivity performances, x (sq. ft./man-day)	Grade
IBS	21.76	A
Conventional	31.45	A

Table 8 identifies the average productivity performances of IBS projects and their grades according to their IBS Score. For IBS projects that achieved between 50 and 69 IBS Score have an average productivity performance of 6.00 sq. ft./man-day, whereas, for IBS projects that achieved between 70 and 100 IBS Score, the average productivity performance is higher, which is 7.01 sq. ft./man-day. Although both ranges of IBS Score accomplished grade C of average productivity performance, higher IBS Score has higher average productivity performance.

Table 8: Average productivity performances according to IBS Score

Construction Methods	Average Productivity Performances, (sq. ft./man-day)	Grade
50 - 69	6.00	C
70 - 100	7.01	C

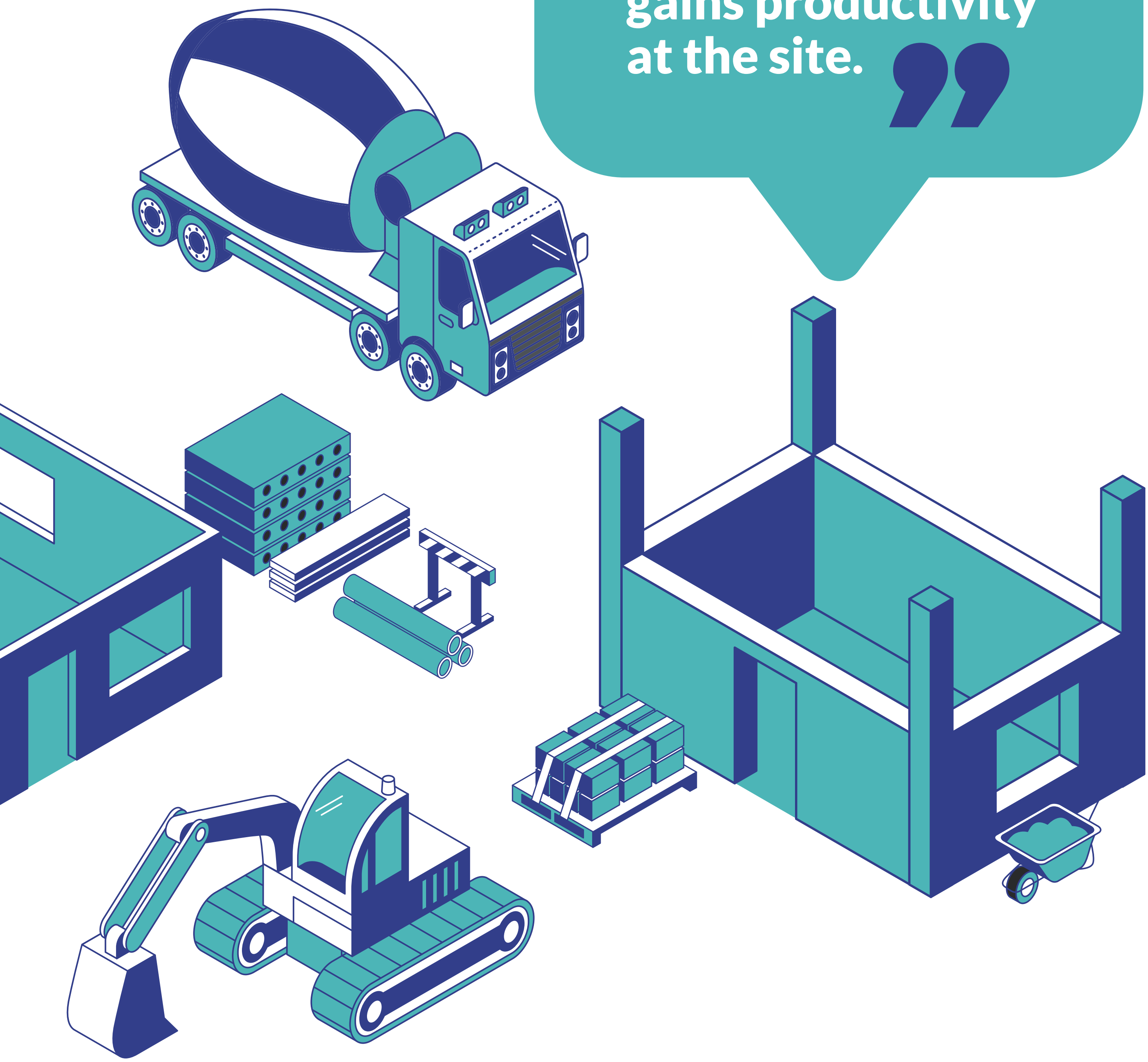
Table 9 indicates the average productivity performances of projects and their grades according to sectors. For the government sector, the average productivity performance of its projects is 13.43 sq. ft./man-day, while building construction projects by the private sector have an average productivity performance of 19.54 sq. ft./man-day. Although both sectors have grade A of average productivity performance, the private sector is marginally more productive than the government sector.

Table 9: The average productivity performances according to sectors

Sectors	Average Productivity Performances, (sq. ft./man-day)	Grade
Government	13.43	A
Private	19.54	A

FOUR
Discussion

> **“IBS is more productive than conventional building system, and IBS especially gains productivity at the site.”**



4 DISCUSSION

This study provides evidence that IBS is more productive than conventional building system, and IBS especially gains productivity at the site. This is because IBS reduces the number of manpower at the site and shortens the construction time. Othuman Mydin et al. (2014) conducted a case study through interviews to identify the strengths and weaknesses of IBS and conventional building system. The case study indicated that IBS could cut down on the overall construction period by saving up to 30% in time compared to the conventional method. The case study respondents agreed that construction works could be completed fast as manufacturing and assembling of precast components have been done earlier in factories. Alaghbari et al. (2015) studied factors affecting the speed of IBS, and the study identified that IBS is significantly faster than conventional because of the high productivity of structural elements and the use of moulds, new techniques as well as technology such as computer and robot in design manufacturing. Additionally, IBS is relatively less labour-intensive at construction sites compared to conventional building system. Conventional building system requires more manpower to complete works such as formwork fabrications and installations, reinforcement bars fabrications and installations, as well as concrete placements (Othuman Mydin et al., 2014). Hanafi, Abdullah, Razak, & Nah (2015) studied the benefits that contractors can gain by implementing IBS at construction sites, and it concluded that the main benefits of IBS implementation are construction site productivity improvement, reduce the time for in-situ concrete mixing activities, and reduce overall construction duration.

When the productivity of a building construction project is measured according to the size of the project, a project with a size of more than 1,000,000 sq. ft. is more productive when the conventional building system is used as the construction method. However, besides IBS, a high-quality construction method, IBS also benefits economic and monetary. (CIDB, 2020) has done a case study to compare residential housing construction cost between IBS and conventional building system. The case study focused on residential construction in Malaysia involving single-storey, double-storey, and apartment units. It was found that the total construction cost for a single storey house using a precast concrete system was lower by 1.6% as compared to the conventional building system. Likewise, the total construction cost for a double-storey and an apartment using a precast concrete system was 3.51% and 1.07% lower than that of the conventional building system.

This study also identified that building construction projects by the private sector is slightly more productive than that of the government sector. This is because the private sector more commonly adopts IBS as compared to the government sector. CIDB Malaysia (2019) has studied the level of IBS adoption in Malaysia for government and private projects. It was found that the private sector has adopted more IBS in its projects than the government sector in 2019, which are 78 projects and 61 projects, respectively.

FIVE

Conclusion and Recommendations

Construction industry should successfully adopt construction technology in construction projects to significantly improve productivity.

5 CONCLUSION AND RECOMMENDATIONS

This study concludes that the nonconventional construction method or IBS is more productive than the conventional construction method. As most of the building components of IBS are prefabricated off-site, IBS simplifies construction works at the site; hence requires less manpower and time to complete the construction project. As defined by PMT, the productivity performance of a construction project depends on the number of manpower involved and the time to complete the construction project. The smaller the number of manpower and time needed to complete a construction project, the more productive the project is.

As IBS is evidently more productive than the conventional method, the industry should successfully adopt construction technology in construction projects to significantly improve productivity. The government needs to play its role to enforce all government and private construction projects to implement construction technology, especially IBS, to help raise the productivity of the construction industry.

By having a productive construction technology such as IBS, the housing crisis in Malaysia, especially the perpetual demand for affordable housing, can be resolved. IBS can supply better housing in a short time, and as it is also cost-effective as compared to the conventional construction method, IBS can also deliver houses to the country that are affordable.

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ROAD TOWARDS PRODUCTIVITY EXCELLENCE:

PRODUCTIVITY OF BUILDING CONSTRUCTION PROJECTS USING INDUSTRIALISED BUILDING SYSTEM (IBS) AND CONVENTIONAL METHOD OF CONSTRUCTION

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