GUIDELINE FOR IBS PRODUCTION TO SUPPORT SUPPLY CHAIN FOR PRECAST CONCRETE SYSTEM

Construction Research Institute of Malaysia
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EXECUTIVE SUMMARY

The adoption of the Industrialised Building System (IBS) in construction projects continues to be promoted in the Malaysian construction industry to assist confront the problems of slow completion, workmanship quality, wastage and over reliance on foreign imported workers. This can be exemplified in the Construction Industry Master Plan (CIMP) 2006-2015 and Construction Industry Transformation Programme (CITP) 2016-2020 that were introduced to reform the industry.

Notwithstanding the issues that continue to persist, the significance of IBS adoption in construction projects is expected to be more profound as the industry progresses into the Industrial Revolution (I.R) 4.0 as highlighted in the Construction 4.0 Strategic Plan 2021-2025 and Dasar Pembinaan Negara 2030. This is because of its capability for integration with Building Information Modelling (BIM), and in facilitating the use of modern construction technologies such as Virtual Reality (VR), Augmented Reality (AR), Autonomous Construction, Big Data Analytics and Cloud Computing.

Despite the efforts expanded to promote the IBS, its adoption in construction projects to date have been slow. Studies undertaken identified several interrelated factors that can contribute to this. This includes inadequacies in the IBS supply chain network, availability of plant and skilled workers needed to assemble the IBS system, procurement system and contracts provisions to suit IBS construction, and inadequate information on the IBS types and their specifications.

This guideline is developed to provide the key information needed for clients, consultants and contractors to assist the selection of the type of IBS for their projects, with special focus and guide on IBS selection and production for precast concrete for new and existing IBS manufacturers. The scope covered are as follows:

1. IBS initiative in the Malaysian construction industry.
2. Requirements for IBS adoption
3. IBS selection guide for precast concrete system
4. IBS production guide for precast concrete system

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SECTION 1: INTRODUCTION

This section is provided to set the context for understanding the Malaysian construction industry. It provides the justification for the initiatives that were introduced to promote IBS adoption and the confronting challenges.

1.1 Definition and characteristics of IBS

The Malaysian construction industry defines Industrialised building system (IBS) as the construction technique where the components are manufactured in a controlled environment, either at site or off site, placed and assembled into construction works. Worldwide, IBS is also known as Prefabricated / Prefab Construction, Modern Method of Construction (MMC) and Off-site Construction.

The unique characteristics of IBS construction systems that differentiates from other construction systems are noted the followings:

1. The production, assembly and fabrication methods and process.
2. Product, system, and technology.
3. Industrialised nature of the production process
4. Transportation and assembly techniques.
5. On-site fabrication.
6. Mass production.
7. Structured planning and standardization.
8. Integrated processes and application of digital construction technology

1.2 Types of IBS

The type of IBS to be chosen for a project is determined by the construction method. Construction methods are the procedures and techniques that are used during the building process. Of the variable construction methods, the fully fabricated construction method best suits the IBS system. This can be fully fabricated on-site or off site. The variable options for choosing the type of IBS are illustrated in Figure 1.

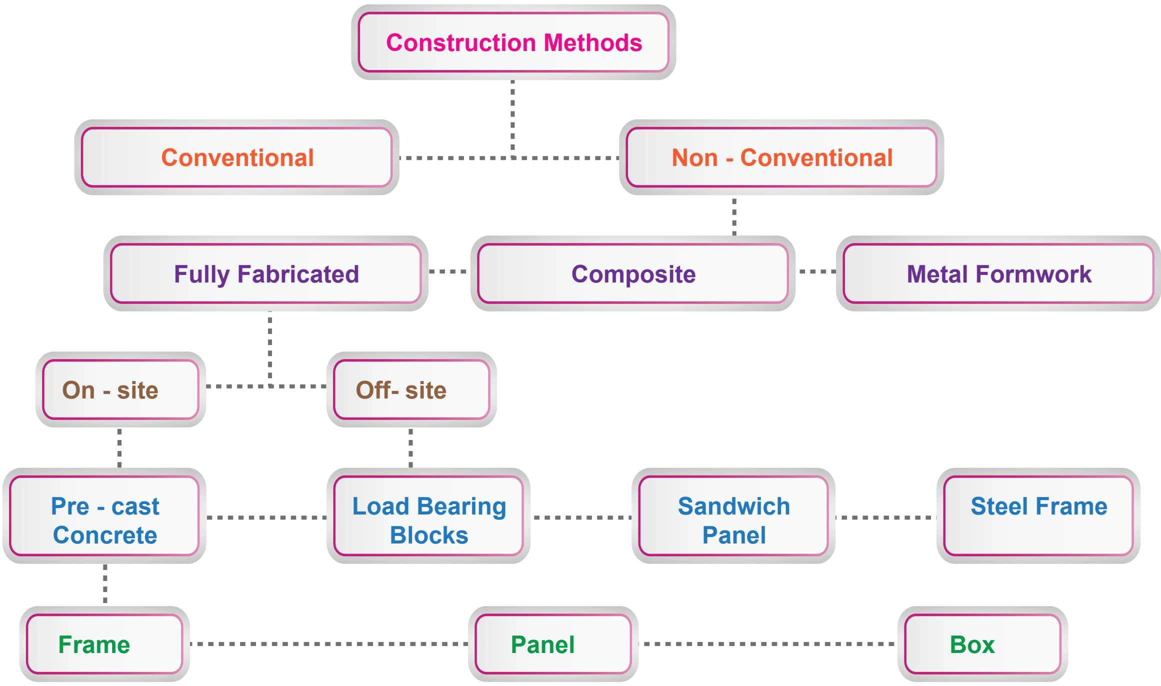

Figure 1: Construction method and choice of IBS

There are six (6) types of IBS system that available for Malaysian construction and there are:

1. Precast concrete
2. Steel framing
3. Steel formwork system
4. Prefabricated roof truss
5. Blockwork system
6. Innovative / hybrid system

In weighing to select the most appropriate method, the advantages that IBS construction promise to consider are:

1. Faster construction
2. Reduce reliance on traditional and imported foreign labour
3. Better quality
4. Safer and healthier construction
5. Minimize waste
6. Improved productivity
7. Lower cost with the right economies of scale
8. Facilitates achieving Quality Standards i.e., ISO 9000

9. Adaptability to open building concepts which permit hybrid applications, adaptable to standardization and modular coordination (MC).
10. Adaptable to Computer Aided design (CAD), Computer Aided Manufacturing (CAM) and Building Information Modelling (BIM)
11. Facilitates application of digitalized construction technologies i.e., Building Information Modelling (BIM), Virtual Reality (VR), Augmented Reality (AR), Autonomous Construction, Big Data Analytics and Cloud Computing.

1.3 Policies to drive IBS adoption

Efforts to promote the adoption of IBS in construction projects started as early as 1999. This was followed with the launch of several initiatives to date. The chronology of the introduction of the key initiatives are:

1. Formation the IBS steering committee in 1999
2. Unveiling of the IBS Strategic Plan 2003
3. Launch of 1st IBS Roadmap 2003-2010
4. Directive issued in 2008 to mandate the use of IBS in government projects valued RM10 million and above, and to achieve 70% minimum IBS score
5. Directive by the Ministry of Local Government and Housing in 2018 to mandate the use of IBS in for private projects valued RM50 million and above, and to achieve 50% minimum IBS score.
6. Introduction of the Construction Industry Master Programme (2006-2015)
7. Launch of 2nd IBS Roadmap 2011-2015
8. Launch of the Construction Industry Transformation Programme 2016-2020.

1.5.1 The IBS Strategic Plan: 1999

The IBS Strategic Plan follows the recommendations of the Colloquium on Industrialised organized by CIDB. The Strategic Plan was meant to be the programme to kick-start the adoption of IBS in Malaysian construction. The plan laid out the objectives, the programmes, and activities to be embarked on, their timelines and deliverables to be achieved.

1.5.2 IBS Roadmap: 2003 – 2010

Following the introduction of the IBS Strategic Plan, a master plan known as 'Industrialised Building Systems (IBS) Roadmap 2003-2010'. This was

developed with input from the inputs from industry stakeholders and an endorsement from the Malaysian cabinet. The roadmap identified the 5-M Strategy, to focus the promotion of IBS within the industry. These are (i) Manpower, (ii) Materials, Components and Machines, (iii) Management, Processes and Methods, (iv) Monetary and (v) Marketing with the target to establish an Industrialised construction industry adopting 'open building' practices by 2010 (CIDB, 2003; CIDB, 2010). It was envisaged that at the end of 2010:

1. The industry will choose IBS, which guarantees better quality, productivity, and safety as these are critical factors for the survival of Malaysian construction players.
2. Modular Coordination (MC) will be enforced through Uniform Building by Laws (UBBL) and this will encourage standardization and subsequently increase the use of IBS components.
3. IBS standard components will be screened to ensure that low-quality products are not marketed in Malaysia.
4. Dependency on wet-trades and on foreign workers will significantly decrease.
5. IBS and MC courses will be offered to the construction building team, i.e., clients, consultants, contractors, IBS manufacturers and IBS fabricators/installers.
6. Tax incentives introduced to manufacturers of IBS components.

1.5.3 International Exhibitions and Seminars on IBS: Beginning from 2001

National and international level IBS seminars were organized to facilitate discussion, showcase, and market BS products and services. Apart from aiding to elevate the awareness of the benefits of IBS adoption (especially among government officers, developers, construction professionals, manufacturers, and researchers), the seminars were intended to serve as the platform for local and global IBS players to exchange ideas and network.

1.5.4 CIDB IBS Centre: 2008

The IBS Centre was established by CIDB in 2008 to serve as a one-stop reference centre for IBS to promote knowledge sharing and cooperation among the industry IBS parties. The activities of the IBS Centre include:

1. Secretariat for IBS Industry planning
2. IBS promotion and marketing
3. IBS technology for research and development (R&D)
4. IBS certification, verification, and testing
5. IBS training

1.5.5 Government Circular on IBS: 2005 & 2008

To support IBS Roadmap 2003-2010, the requirement for all government building projects to have at least 50% IBS content was announced in 2005. To encourage the private sector to follow the same, levy exemption for housing projects that have a minimum IBS Score of 50% was also announced.

1.5.6 Government announcements: 2004 – 2006 and 2015

Realizing the importance of the private construction sector to support IBS adoption, the government announced abolition of CIDB levy (0.125% of project cost) for contractors who achieve a minimum 50% IBS score for their residential construction in 2005. This was to support the construction of the planned 100,000 units of affordable housing using IBS. In addition to this, in 2006, the government also announced that tax incentives will be given through the Acceleration Capital Allowance (ACA) to IBS manufacturers. This would include expenses incurred in the purchase of steel molds used to produce precast concrete components. In 2016, launched a RM500 million promotional fund for developers and Gi_G5 contractors and G1-G5 contractors who adopt IBS in their projects. At the same time, the requirement for private projects to adopt IBS for projects RM50 million and above, and RM10 million and above for government projects.

1.5.7 IBS Scoring System: 2005 & 2010

The IBS Scoring System was introduced to encourage uptake of IBS construction. The scoring system provides a standard and systematic structured assessment system to measure the use of IBS. The first version was introduced in 2005. An improved revised version was introduced in 2010 following recommendations for improvements recommended for the first version to consider the new IBS technologies.

1.5.8 IBS Roadmap: 2011 – 2015

IBS Roadmap: 2003-2010 was reviewed and succeeded by the IBS Roadmap 2011-2015. The revised roadmap was focused to persuade more adoption of IBS by the private sector through the additional provision for:

1. Promoting better quality designs of IBS components through innovations.
2. Faster project completion time.
3. Ensuring a ready pool of competent IBS professionals and workers throughout the entire IBS project lifecycle.
4. Creating a financially sustainable IBS industry that balances user affordability and manufacturer's viability

1.5.9 IBS Manufacturer and Product Registration Programme

IBS Manufacturer & Product Registration Programme is a scheme to assess and certify IBS manufacturers, distributors, suppliers, and agents of IBS products, based on a set of certification requisites. The aim is to produce a list of certified IBS manufacturers for the Malaysian construction industry. There are two certification classifications are:

1. IBS Status Manufacturer
2. IBS Status Distributor / Supplier / Agent

The certified manufacturers are entitled for listing in the 'Certified IBS Manufacturer List'. The list is to facilitate the government and private clients to choose certified quality IBS products and services. Listed manufacturers will be given preference to participate in promotional activities organized by CIDB. This includes listing in IBS web portal, IBS Digest, IBS Centre web, electronic and 'Orange Book' directory.

Despite the efforts expanded with the launch of these initiatives, response for IBS adoption was sluggish and have been unsuccessful in achieving the planned trajectory. This can be exemplified from the study conducted on 500 sample government and private projects carried out in 2019 which found that only 36.1% government projects and 33.1% private projects have adopted IBS. The efforts to continue promoting IBS adoption was continued together the other recently introduced construction industry reform programmes as follows:

1. Construction 4.0 Strategic Plan
2. Dasar Pembinaan Negara 2030

1.6 Limitations and barriers to IBS adoption

IBS is not a construction system suitable for all types of projects. The limitations are:

1. IBS is not suitable for small one-off projects because it is expensive
2. IBS construction is only viable with economies of scale
3. Proximity to the IBS manufacturing locality.
4. Availability of the supply chain i.e., materials, plant and machineries, and fabricators/installers
5. Competency of the contractor
6. Capability of the client and consultant in managing IBS projects
7. Inadequacy in the existing Standard Form of Contracts

While the construction industry is pushing towards more IBS adoption, a key problem is there are few IBS manufacturing plants in Peninsular Malaysia, Sarawak, and Sabah. There are also inherent limitations of IBS which restricts its adoption for small projects. IBS tends to be more suitable for large projects when there are economies of scale for the project to be viable. Suitability of IBS construction is also contingent upon its production capacity, transportation, and storage requirements, site conditions (location, topography, and accessibility), availability of plant and machineries, and skilled fabricators/installers.

Several studies have been undertaken at the industry level to identify other reasons for the low IBS adoption. The findings were culminated and mapped against the IBS promotion ecosystems model shown in Figure 2. The findings identified several missing critical success factors (CSF) within the external ecosystem and internal ecosystem needed to support IBS adoption.

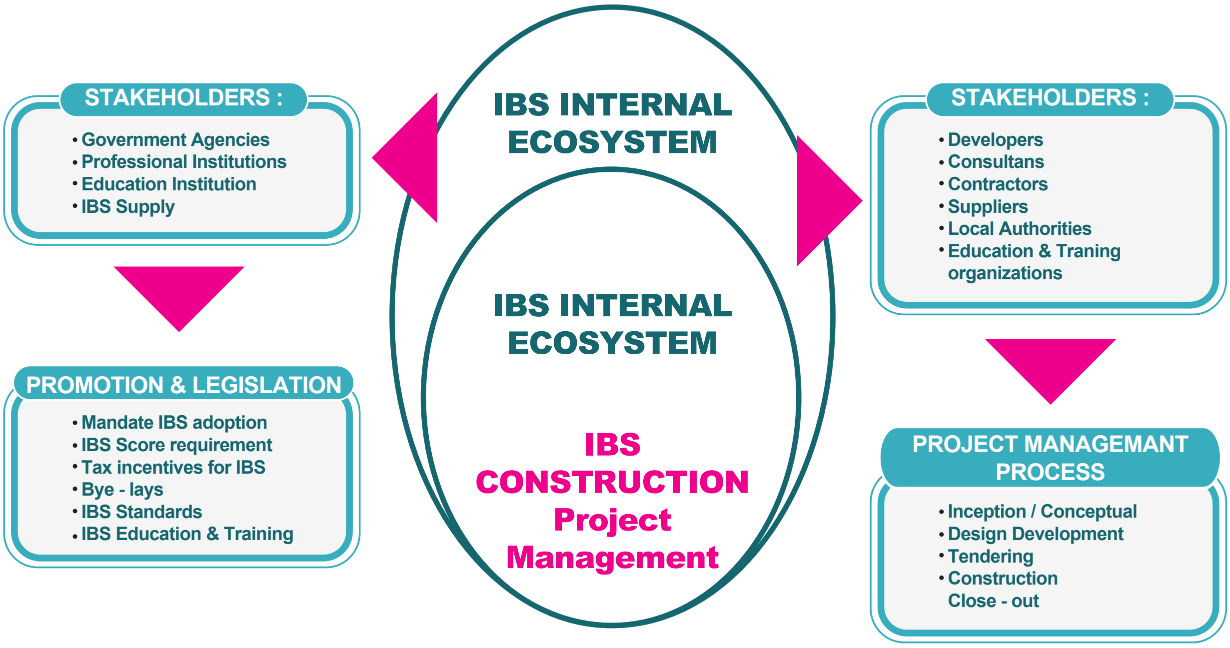

Figure 2: Eco-system for IBS adoption promotion in the Malaysian construction industry (Adapted from Hassan, 2021)

1.6.1 The external ecosystem

Legislation aspect:

1. The lack of interaction and synergy between traditional and IBS approaches towards construction are seen as competing concepts whereas both methods could co-exist.
2. Inadequate effort to enforce the legislation which necessitates IBS adoption in government projects and private projects.
3. Access to information on IBS standards & specifications are limited.
4. Insufficient provisions in existing construction contracts to facilitate adoption of IBS projects.
5. Absence of an integrated IBS education and training especially among the TVET (Technical and Vocational Education and Training) institutions to ensure availability of skilled IBS fabricators and installers needed in IBS projects.
6. Lack of an integrated strategic policy that addresses above issues.
7. Difficult for authorities to change local building regulations and standards to suit IBS as the amendments will consume a lot of effort, time, and cost.

Promotional aspect:

1. Promotion on IBS adoption tends to be focused on IBS manufacturers and contractors, promotion to clients, consultants and authorities approving construction projects are lacking.
2. The medium for promoting IBS tends to be limited to face-to-face promotion and newsletters, online promotion is very lacking
3. Inadequate information is available to assist understand the requirements for implementing IBS projects
4. Support to promote IBS by professional bodies and institutions is very lacking.
5. Promotion for IBS adoption limited to a few central government agencies and developers only
6. Absence of an IBS reference centre or platform for stakeholders (i.e., clients, consultants, contractors project, manufacturers, and authorities) to refer to for any queries.
7. Institutions of higher learning (IHL) are not included in the IBS promotion initiative.
8. Effectiveness of the current IBS training provided for clients, consultants, contractors, and installers.

1.6.2 The internal ecosystem

1. The CSF in the internal ecosystem is related to the project management processes operated by clients, consultants (e.g., and contractors undertaking IBS projects. The factors are:
2. Unfamiliarity and inexperience in IBS construction.
3. Resistance to IBS adoption because of the need to re-learn the IBS project management processes.
4. Inadequate understanding the appropriate procurement system to be chosen to benefit from IBS adoption
5. Consultants and contractors lacking competency in managing IBS construction
6. Absence of learning (education and training) how to manage an IBS construction project.
7. Lack of understanding on the unique characteristics of IBS construction/

SECTION 2: REQUIREMENTS FOR IBS ADOPTION

There is a significant difference between the conventional building construction and IBS building construction to note. This is highlighted in Table 1.

Table 1: Differences between Conventional Construction and IBS Construction (Warzawski, 1999)

No	Conventional Construction	IBS Construction
1	Work dispersed among many temporary locations.	All work performed at once at permanent locations.
2	Little standardization, each project has distinctive features.	High degree of repetition and standardization.
3	Large number of tasks requiring a high degree of manual skill necessary to complete a typical construction project.	A small number of simple repetitive tasks necessary to produce a typical component/product.
4	Each task is performed over a large work area with workers moving from one place to another.	All work performed at ground level in a static workplace.
5	A rugged and harsh working environment.	Workplace carefully adjusted to human needs.
6	High turnover of workers.	Comparatively stable workforce.
7	Authority divided among the client, designer, contractor, and sub-contractors.	Unified decision-making authority for design, decision making and marketing.

2.1 Procurement system considerations

Success of IBS projects is not only limited to managing the construction process but also to management of its procurement and contract. Procurement is the process used to obtain the construction projects. It involves the selection of a contractual framework that clearly identifies the structure of responsibilities and authorities for participants within the construction process. New procurement

systems will continue to be developed to meet new requirements and demands from clients, contactor, and the professions.

However, the type of procurement systems that are commonly used in Malaysia are traditional system, design and build, management contracting and construction management. The common procurement systems available for Malaysian IBS construction are Traditional, Design and Build, Management Contracting and Construction Management. Their features are distinguished as shown in **Appendix.**

Deciding the right procurement system is most important as this will determine how the building team will be selected, how the project will be designed, what the parameters are and how project delivery will be implemented. This is usually made by the client with the advice from his consultants. Deciding the right choice necessitates the evaluation and ranking the project's objects as follows:

1. speed to construct
2. price certainty
3. quality of project
4. level of clients' interference
5. the party who holds responsibility over the project.
6. the contractual relationship, roles and liabilities among parties involved

The procurement system to choose for IBS construction is the option which best:

1. enable the design and construction team working together
2. integrate the design and construction process for faster completion
3. offer the provision for single point responsibility
4. consider design and constructability,
5. facilitate quality, environmental protection, and safety and health.

IBS constructions are known for their advantage in enabling the project to be completed within a shorter time, with cost saving, cleaner site with less wastage and better finish quality. But this necessitates considering the variance in the project's development process as shown in Figure 3.

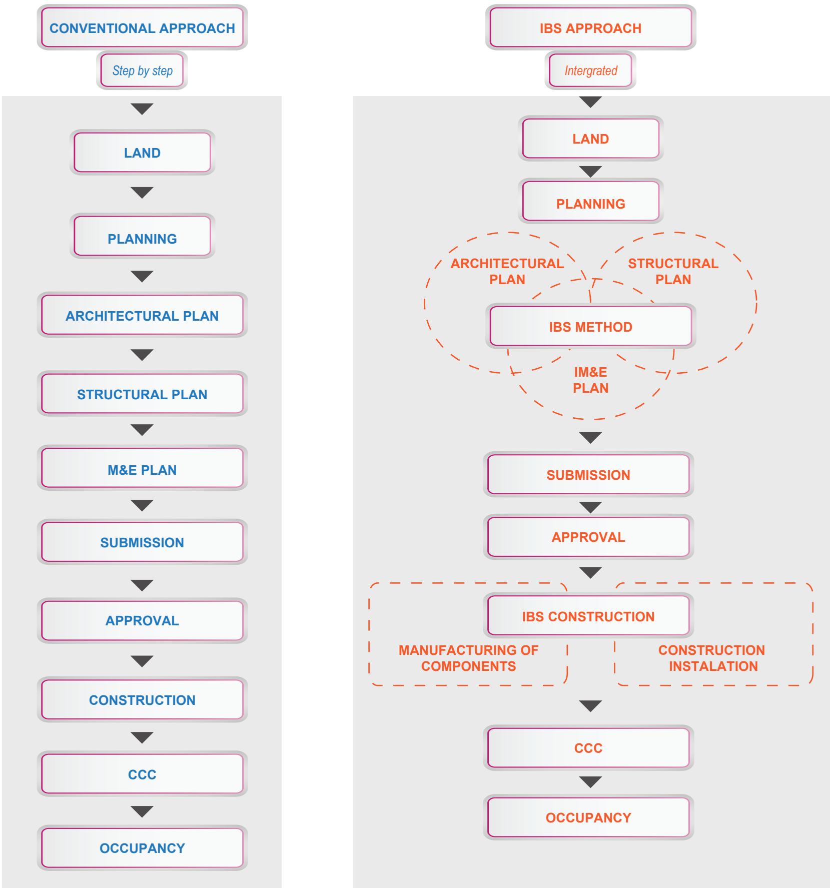

Figure 3: Process flow using conventional and IBS construction (CIDB, 2018)

IBS construction requires close integration of the design and construction activities, thereby making the Design and Build most appropriate of IBS projects. This is based on the better benefits that it can offer, compared to the other procurements as shown in Table 2.

Table 2: Novelty of Design and Build systems (Griffith and Sidwell, 1995)

Simplified contractual arrangements	The contract is between the client and the contractor; single point responsibility; contractor is responsible for all subcontractors and suppliers.
Integrated design and construction	Promotes an integrated design and construction team in the form of the main contractor; encourages the building team (design consultants and contractor) towards the real interest of the client.
Improve communication	Client-contractor single link and integration of design and construction improves communication between the members of the building team.
Increased	Client knows any time who to contact i.e The contractor

operational efficiency	and contractor can respond quickly to client needs.
Shorter project duration	Significant savings in construction time through overlapping design and construction aspects; site mobilization and pre-construction procurement time is greatly reduced; making earlier start possible
Reduced cost	Client knows, within a certain degree of accuracy, the total financial commitment before commencing work on site. More rapid procurement also makes cost savings.
Increased performance	Detailed brief (client's requirements) and the contractor's proposal set out the detail specification for design workmanship, materials, and performance.
Minimal project changes	Detail brief reduces likelihood of changes (variations); the contractor can respond more quickly to any variations.

Control over the overall construction phases is vital in IBS construction. This is to enable the design features to be controlled together with IBS system features and specifications. Therefore, contractors with a complete in-house capacity which include planners, designers, IBS manufacturers and other trades in the supply chain usually have better advantage of securing the project.

2.2 Contract provisions and relevant clauses

The Standard Forms of Contract is a standardized agreement that provides a legal framework regarding right, obligation, and duties of contracting parties in relation to construction work that is to be carried out. A key component of standard forms of contract is the conditions of contract (CoC) that underlines the rights and obligations of the contracting parties. CoCs must be read in concurrence with the project's specification documents, drawings, Bills of Quantities (BQ), activity schedules (including other special conditions which may apply) and the contract clauses. The use of core conditions with option schedules or supplemental provisions is also now common. This also includes recourse or actions that can be taken in the event one of the parties fail to diligently discharge his/her roles, responsibilities, and obligations.

There are several Standard Forms which are designed for both Conventional projects and Design and Build projects for construction projects in Malaysia. Different standard forms of contract offer different ways of pricing, risk transfer, responsibility for performance, and cost certainty. The understanding of the contents of the standard form of contract are important for assisting the parties managing projects aware of their roles and responsibilities in the project. The common standard form of contract available for Malaysian construction are:

1. The Pertubuhan Arkitek Malaysia or PAM Form of Contract (2006):
2. Public Works Department or PWD Form 203/203A (Rev 10/83)
3. Construction Industry Development Board or CIDB Form of Contract for Building Works (2000):
4. FIDIC Form of Contract

The criteria for selecting the standard form of contract for the IBS project are the nature of the work which includes size, the level of complexity, type, and the source of funding of the project. However, in practice the selection is usually done based on the client’s or his agents' familiarity with the forms.

The rights and obligations of the contracting parties are specified by the clauses in the contract. Clauses are specific provisions or sections of the contract that address a specific aspect of the agreement. The purpose of the clauses is to clearly define each party's duties, rights, and privileges under the terms of the contract. There are several different types of clauses, and the ones to use depend on the project needs. The key clauses which have significant bearing IBS projects that must be studied are:

1. Variations
2. Extensions of time and monetary claims
3. Payments and certificates
4. Subcontracting
5. Commencement and completion
6. Determination of the contractor’s employment before completion
7. Dispute resolution methods

2.2.1 Variations

Variations are changes in the contract work and/or conditions under which work is executed. Standard forms of contract provide a clause stating that the employer (or his agent) may require alterations, additions, or omissions to the contract work and that the contractor is bound to carry them out. Without the expressed authority, the employer has no right to instruct any variations in the contract. To be valid, those changes must be authorized by the employer's agent (SO) in writing, usually before execution of the work but the changes may be sanctioned in writing subsequently (up to the issue of the final certificate).

2.2.2 Extensions of time and monetary claims

Provisions for the making and settlement of the monetary claims and the granting of extensions of time (there is not any necessary link between the two). The expression "claims" will be taken to mean a claim by the contractor for additional payment more than the original contract price. Any contractual claim must be provided by the terms of the contract. This includes the contractor's obligation to complete the works on or before the completion date. The standard forms provide for the employers' agent to extend the time for a variety of reasons. The granting of an extension of time relieves the contractor from his liability to pay liquidated damages from the date stated in the contract. Direct loss and/or expenses identify those financial losses or expenditures incurred by the contractor as a result of material disturbance of the regular progress of the works by specified causes, which he may want to claim from the employer.

2.2.3 Payments and certificates

The employer's obligation in a construction contract is to pay the contractor. Payment is made to the contractor in instalments as the works progress. Standard forms provide for the employer's agent to issue certificates as a condition precedent to payments. Types of payments are:

1. Interim payments (made at agreed intervals or stages; occur throughout the contract construction period)
2. Final payment.

The payments are determined by valuation of the work executed during the period. The progress payments generally include for value of the work properly executed, materials and goods delivered to the site for use in the works, claims, fluctuations (if any), and deduction for sums retained and amounts previously paid.

2.2.4 Subcontracting

It is common for a contractor to sublet parts of the work, particularly those that call for specialist attention, to subcontractors. Standard Forms of Contract generally allow subletting but that the contractor shall not sublet the whole of the works. Usually, the written consent of the employer must be obtained prior to subletting. Subcontracting does not relieve the contractor of any of his obligations under the contract; he is as responsible for the subcontracted work as if he had carried it out himself. Standard forms provide for arrangements relating to the appointment of 'domestic sub-contractors' (DSC) and 'nominated subcontractors' (NSC). In both cases, the Contractor remains responsible for all operations on the site and subcontractors must look to him for instructions and payment.

2.2.5 Commencement and completion

The date by which the site for the works should be made available to the contractor to commence construction is referred to as the 'date of possession'. On this date the contractor shall be given possession of the site and shall begin the works, proceeding with diligence to completion on or before the completion date. If the date of possession is not specified, the law will simply imply a term that the client will give possession of the site to the contractor in sufficient time to allow completion by an agreed date for completion. Completion is when the contract works are finished. In building contracts, completion is when in the opinion of the employer's agent, the building is ready for immediate occupation even though some minor work may be outstanding (the works are complete for all practical purposes and can fulfil their intended functions reasonably). This condition is described as 'practical completion' in the building contracts and 'substantial completion' in the engineering contract. On the date of the achievement, the employer's agent will issue a certificate of practical completion, and this marks the start of the defect liability or maintenance period.

2.2.6 Determination of the Contractor's Employment before Completion

Determination is the ending of a contract where one of the parties elects either to exercise a contractual right or to treat a fundamental breach by the other as a repudiation. Standard forms give the employer and the

contractor a right to determine the contractor's employment in specified circumstances. It should be noted that the contractual right is to determine the employment of the contractor and not the contract. Thus, the terms of the contract which govern the rights of the parties after such determination will continue in effect.

2.2.7 Dispute resolution methods

Contractual disputes tend to occur when a claim by one party to the contract is rejected by the other. In other words, they have a grievance. There are several types of options for Dispute Resolution, and these are negotiation, mediation (or conciliation), arbitration and litigation.

2.3 Conditions of Contract (CoC) concerns

Despite the provisions in CoCs to ensure equity of risk distribution between the client and contractor, several ambiguities in the CoCs which exist and need to be noted when negotiating for IBS projects. Efforts are mooted to address the deficiencies by designing a Standard Form of Contract tailored for IBS projects. However, below are findings from research culminated to highlight the shortcomings.

2.3.1 Security of payment

Most IBS manufacturers would require the contractor to pay between 10-15% of the contract sum upfront to confirm the IBS supply before manufacture and delivery to the project site. Most contractors do not have the financial capability to undertake this big initial commitment to start the project. Apart from the provision available in some JKR Standard Forms for advance payment be paid to contractors upon award of the project, there are no similar provisions in the other Standard Forms. Even when provided, the advance payment provision is limited only to Bumiputera contractors only. This requirement veers to discourage contractors who do not possess the financial strength and close working relationship with the manufacturers from participating in IBS projects.

2.3.2 Progress payments

Compounding the problem for contractors is the condition in existing

standard forms of contract which progress payment to be made based on work done on-site. This is unfavorable for the contractors as in IBS projects most of the activities are done off-site. To circumvent, most contractors would need to have strong financial assistance.

2.3.3 PWD 203A standard form of contract

(No studies are available to assess other standard forms of contract, therefore only observations noted in the PWD 203A Standard Form of Contract are highlighted in this section). There are 81 clauses in the PWD 203A Standard Form of Contract and not the clauses are appropriate for IBS construction, but this report is able to identify six (6) clauses (drawn from Ashraf, 2018) which are significant to be noted. These are:

1. Clause 1: Definition of unfixed material and goods.
2. Clause 2: Evaluation of interim payment.
3. Clause 3: Inspection, testing of material, goods, and equipment.
4. Clause 4: Insurance/Bond.
5. Clause 5: Submission of the supervision report.
6. Clause 6: Extension of time (relevant events).

Examples of the ambiguities in the clauses which were that can impact IBS are highlighted as follows:

Clause 1: Definition of Unfixed Material and Goods

The clause states that all unfixed material and goods need to be on or adjacent to the site; the contractor is fully responsible for the loss or damages to the unfixed material and goods; the material and goods need to be delivered to the site in accordance with the project progress; it cannot be delivered ‘premature’ to avoid any unwanted circumstances (site congested, material damages or lost); and when the payment has been made by the client, the unfixed material and goods will be the client’s responsibilities.

This contradicts as in IBS construction as most of the unfixed material and goods are not being delivered to the site; all of the unfixed material and goods are being stored/used off-site.

Clause 2: Evaluation of Interim Payment

The clause states that the client needs to evaluate at least once a month on the progress of work done; the value of the interim payment will be based on two (2) components i.e., (i) the progress of work done that fulfills the specification and (ii) the material that has been delivered on-site according to the project progress.

The client needs to issue the interim payment certificate within 14 days of the evaluation of the site and the payment needs to be done by 30 days upon the interim payment certificate issued.

However, in IBS construction both components for calculating the value of the interim payment cannot be applicable, as most of the activities in IBS construction are done off-site. This will not enable them to claim for off-site works.

Clause 3: Inspection, testing of material, goods, and equipment

The clause requires the contractor to carry out the inspection and test as required in the contract; this covers inspection and testing of material, goods, and equipment regardless of whether the work is already incorporated in the works or not.

The contractor from time to time also needs to provide such assistance such as instruments or machines that are required for inspection and testing. This includes supplying samples before incorporation in the works.

A problem may arise if the client wants to get the opinion on the IBS system's inspection, testing of material, goods, and equipment from other parties in the industry. The party selected from the industry might not be on the 'same page' and this might result in the contractor incurring additional cost to conduct an inspection and test for the works that are not incorporated in the works (off-site).

Clause 4: Insurance/Bond

The clause requires the contractor to take insurance in joint names with the client; the insurance will cover against loss, damages, lightning, explosion, storm, flood and many more; the coverage protects all work

executed and all unfixed material/goods that are delivered on or adjacent to the site (on-site only).

The provision in the clause only allows only for materials onsite to be covered by the insurance, whereas in IBS construction most of the activities are offsite, this would significantly disadvantage the IBS contractor.

Clause 5: Submission of the Supervision Report

There is no clause In PWD 203A Standard Form of Contract for the contractor to submit a Supervision Report to the client; on the other hand, the variant Standard Form of Contract of Design and Build project (PWD Form for DB, Rev. 1/2010) require the contractor to submit a report on-site activity which include works properly done, progress of works, test was done and safety measures on-site.

This clause is good for IBS construction, if there is a requirement for the submission of the Supervision Report. However, the scope should be extended to include off site activities since most of the activities for IBS work is undertaken offsite.

Clause 6: Extension of Time (Relevant Events)

The clause stipulates the rules, procedures, and events that the contractor can refer to enable the extension of time. In brief, the contractor should write to the client reporting the causes and supplemented with calculation to determine the length of delay; and this must be supported with the relevant documents.

However, ‘all of the relevant events’ stated in the clause focus on the site activities only. This will be unfair to IBS construction and off-site manufacturing activities must also be considered.

SECTION 3: IBS SELECTION GUIDE FOR PRECAST CONCRETE SYSTEM

For the purpose of the section, a summary of the considerations for IBS precast concrete selection are highlighted.

3.1 Component specifications

Unlike the design of cast in-situ concrete, which is based on optimising architectural and structural dimensions and form, and the design of structural steelwork, where standard serial sizes are available and connection details are often resolved by the contractor, precast design solutions are greatly depending on specific manufacturing and construction methods. The wide variety of specifications would prove to become a point during its implementation. Competition is also key towards innovation and ensuring the best practices and guidelines are realized. Nevertheless, the crux of the issue remains to be balancing out policies and ensuring steady competition within the industry. With this, an analysis of literature is done to organize the main components for IBS Construction. It can be concluded that certain components for IBS can be categorized into the following:

1. Structural Components
2. Non-Structural Components
3. Connections
4. Other design considerations
5. Mechanical & Electrical Services

3.1.1 Structural components

Structural Components are the main components that make up the core foundation towards IBS construction. The common basic structural form for IBS is the skeletal frame system. A precast skeletal frame system is a structural system that consists of precast concrete slabs, beams, columns, walls, and staircases. Precast concrete is of the highest possible quality, in terms of strength and durability. Concrete is delivered to a shape mould, ensuring zero segregation, honey-combing and minimal vibration. Using materials that have passed strict quality control procedures, rapid hardening cement is mixed with excellent quality aggregates of known source and purity, often in computer-controlled batching and mixing plants to produce concrete of specified workability and strength. In addition to components and connections, structural calculations also include (all these factors are also taken into account upon design and manufacturing of the structural components):

1. Design against progressive collapse and measures taken to avoid accidental loading, this is provided either by the steel mesh and site placed bars in the structural topping, or by additional tie bars in the joints between floor slabs and perimeter and internal beams, in addition to vertical suspension ties in the columns and/or walls
2. Positions and provisions for expansion or construction joints to cater for thermal movement and residual shrinkage after installation.
3. Horizontal floor diaphragm action satisfied either by the same structural topping or horizontal tie bars defined in bullet point 1 in combination with the interface action between discrete precast floor units.
4. Structural stability against horizontal wind pressure and/or notional sway/drift loads (note the Eurocode is additive, whereas other codes are replacement).
5. Temporary stability of the framework and floor diaphragm.
6. Foundation loads, moments, and shear forces.

3.1.2 Non-structural elements

Components that are not pre casted but are not specified as structural elements are counted as Non-Structural Elements. These elements compose components such as non-load bearing walls and staircases. Based on CIDB's Catalogue, the requirements needed for non-load bearing walls are minimal, requiring standard dimensions., fire resistance and connection detail. However, for staircase, additional specification on loading is mandatory alongside the usual method statement and drawings.

3.1.3 Connections

The design and construction of connections are key components in ensuring that structural components for IBS are rigid and uniform. Their purpose is to transmit forces between structural members and provide

stability. The strength of RC connections plays a remarkable function in the durability of the structure while insufficient joints, which have ineligible joint transverse reinforcement and incompetent anchorage of the beam bottom reinforcement, were the main reason of the observed damages in the structures over the years.

The most important aspect to consider in precast concrete structures is the design and construction of joints and connections. There are several different ways of achieving a satisfactory connection, such as bolting, welding, or grouting. Beams and columns are connected to form an integrated frame system before the floor slabs are placed. Hence, structural connectors are required to connect all the structural components of beams, columns, and slabs. The major structural connections include beam to column, column to column and column to base, and are either structurally pinned or rigid. The complete precast frame must be designed in compliance with the required strength, stiffness, ductility, and reliability. Analysis on moment-rotation.

The preferred method of making beam-to-column connections in skeletal frames is to attach the end of the beam to the column face via a concrete corbel, steel billet or stiffened steel angle. When precast floor slabs and tie bars are included, the connection possesses flexural strength and stiffness to resist imposed gravity and wind loads. With this there have been several types of testing conducted by research and authority to determine what kind of analysis is best to determine the effectiveness of precast connections. Based on literature the general guideline is to ensure that analyses cover structural integrity according to BS8110.

3.1.4 Mechanical and electrical services

Mechanical & Electrical services are not to be disregarded. In the precast concrete construction system, pre-planning, and pre-determining almost all mechanical and electrical (M&E) services inside individual precast panels are necessary. This requirement changes the standard working practice, which can be overwhelming for contractors who are not accustomed to it or lack the necessary resources. However, such pre planning can prevent errors in M&E services, improve quality and reduce delays and costs. M&E services can either be embedded or exposed depending on the building requirements. The key takeaways are to ensure that installation and maintenance of M&E services are well planned and established to during the conception and design of the building. This is to ensure smooth communication, integration, and coordination.

3.2 Other considerations

There are various considerations that have been proposed by multiple literatures. The section summarizes the overall operational consideration that would create a best practices guideline for IBS Precast Construction.

3.2.1 Logistics

Logistical consideration for IBS can be summarised into 3 factors, planning, transportation, and delivery. Logistics are particularly important when planning construction workflows for a project as a cycle and flow process. As such, logistics planning must be a cross-divisional and interactive process conducted during work preparation. In addition to providing the right production equipment and site infrastructure for proper construction production, logistics planning as part of WPP also focuses on supply, disposal, transportation, storage, and turnaround activities on the construction site. Logistics links and supplies the stakeholders on a construction site with a smooth flow of information, materials, energy, and construction work. The aim of logistics is to save resources and optimize costs.

The problems associated with this weak performance of billable items usually arise as a result of unproductive activities, such as:

1. Clearing materials up and out of the way as they are hindering work
2. Searching for materials
3. Transporting materials long distances between the warehouse and the location of
4. installation
5. Disruptions and interruptions caused by missing materials and tools

Transportation in logistics is another crucial consideration. The success of a construction site is due in no small part to central logistics management as part of the work preparation/site management, which bundles all project- relevant information in digital form, calculates the quantities of required materials, submits orders that take account of lead times, calls them up from the dealer/manufacturer just in time, coordinates the transport activities, and hands the materials over to the responsible person on the construction site, or delivers them to a predefined storage area. This enables material, transport and circulation costs to be reduced, and deliveries to be coordinated just in time.

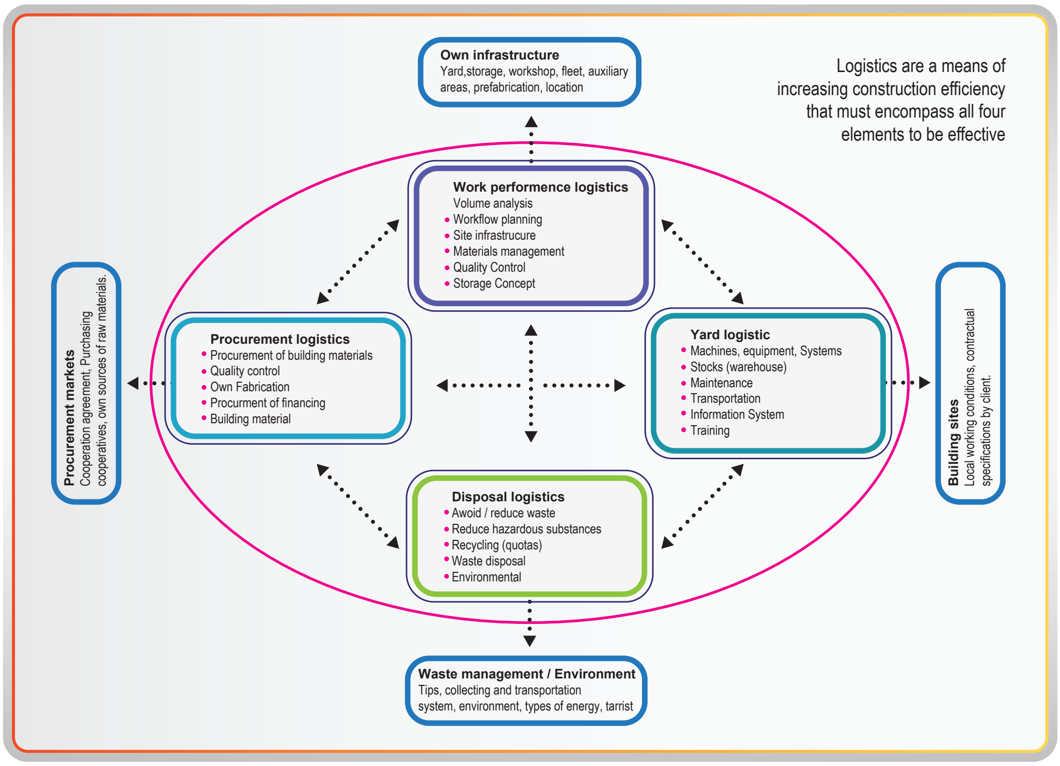

Figure 4: Logistics Concept

Transport efficiency on a construction site is dependent on the following criteria:

1. Location of the material sources and the construction site
2. Existing infrastructure
3. Local conditions on the construction site; owner's specifications
4. Quantities and properties of materials in transit (gas, fluids, parcels, bulk)
5. Size, location, and state of the lay-down areas for possible interim storage
6. Timing specifications derived from the project workflow

Building on this, work preparation for a cycle and flow process must develop the following basic specifications for a logistics concept:

1. Delivery areas and handover points must be easy to reach
2. Transportation means and equipment on the construction site must match
3. Route planning and area utilization outside and inside the building
4. Traffic safety and site access rules

This all produces a huge need for coordination and communication to reduce space and timing constraints when ordering materials. Transport reports with quantities and tours, site access rules, and storage area signage all must be developed and coordinated. Even before leaving, or while still en route, vehicles should radio through to the coordinator in order to avoid unnecessary waiting times when unloading. The results of implementing these concepts are:

1. The construction site is supplied with the necessary materials as required during the construction process
2. Bottlenecks in material deliveries can be identified and avoided
3. Early coordination of material transportation and storage across all trades
4. Overview of all material storage locations and quantities through barcodes with
5. central registration of material flows.

Construction site logistics can be broken down into planning the storage areas, and planning site transports. When planning the material flow on a construction site, the material units must be specified, the means of transport selected, transport chains developed, and material storage areas defined at the location of use. One fundamental principle should always be observed: Wherever possible, store materials right where they are going to be installed to avoid additional wage costs for moving them. Since this is, however, not always possible, given the space constraints and the changeability of the project timing/spacing, transportation means and chains must be planned, together with the associated equipment and storage areas. Logistics planning as part of WPP is a process that flanks

construction and which should be planned and adjusted on the construction site, given the prevailing conditions there. Open or fully encased pallets, crates and containers are suitable as means of transport. For reasons of work safety and work efficiency, materials must be stored on pallets and encased in foil to prevent them falling during transportation.

Delivering the required material to the specified storage or work area is crucial for guaranteeing proper material supply. Barcodes attached to the loading units are ideal for this. They store the data that matter in material flows, such as content, quantity, and execution sections, where the material is ultimately to be delivered. The use of hand-held registration devices enables identification of the loading units at any time on the construction site, as well as the exact purpose/destination, and registration of the consumption and relocation to the installation site, with ultimate daily transfer back to the central logistics computer to determine the overall balance. Planning the transport chain includes material turnover on the construction site, vertical transportation of the materials to the individual floors, and horizontal distribution of the materials throughout the floors of the structure. The following principles must be observed:

1. Transport materials on the shortest route
2. Avoid manual transport; use technical means of transport
3. Try to set up small material storage areas close by the production site
4. Select reasonable transportation units
5. Ensure the storage areas are kept in good order and set up cross-trade logistics on each floor

Suitable unloading equipment must be available to ensure smooth unloading of materials being turned over on the construction site. Call-up, transport registration and early distribution of the materials in suitable units ensure that whoever is responsible is ready to accept deliveries at any time. If trucks are not fitted with their own unloading equipment, the materials can be unloaded using the forklifts, wheel loaders, truck or tower cranes provided by the logistics coordinator. Depending on the available space and provided suitable openings and mobile floor loading platforms are provided, materials should be delivered directly to the floors, if suitable

cranes are available on the site or the truck's own unloading equipment has sufficient reach. As such, WPP and logistics planning should ensure sufficiently large openings in the facade for the respective periods. Wheel loaders and forklifts can move the materials to the vertical transport equipment. Lists of available equipment and transport units simplify transport chain planning and equipment selection".

A hoist or crane with floor platforms can be used to vertically transport materials. The material must be delivered to a location on the site installation plan from where, for example, the crane can move it to the storage areas. Depending on local conditions, the material may have to be temporarily stored, or is directly lifted up to the floors for processing. The same applies when delivering raw materials, storage close by the processing equipment and vertical transportation via hoists, elevators, or cranes. The best way to horizontally distribute material on the floors is by forklift, lift truck, and so on, depending on the materials properties and distance of travel. The units of materials should be taken on unpacked by the vertical transport equipment and moved to the storage areas. The traffic routes and storage areas must be sufficiently large.

3.2.2 Storage Management

Material stores form the buffer between irregular material deliveries and fluctuating consumption during production. This poses the following requirements in terms of storage space management as follows:

1. Coordination meetings and agreement with all trades
2. Provision of required building materials in the requisite quantities in the window needed for the relevant construction phase by matching supply to requirements through just in time delivery
3. Dividing storage areas up into spaces for different materials
4. Assigning storage areas on the floors of the building in the various time windows as construction progresses without the actors getting in each other's way
5. Entering the delivery location and storage areas, together with the construction roads and location of the equipment for the individual construction phases on the site installation plan
6. Shortening travel routes
7. Storage areas that are decentralized, and close to the workplace on

the floors and/or locations of installation, for example, strive for vertical distribution immediately upon delivery of the materials at the handover points.

This is all guaranteed by developing floor logistics concepts for the respective construction phase, which should incorporate the following principles:

1. Plan transport routes and lay-down areas for each construction phase Avoid moving materials from one storage place to another
2. Make sure the interior finishes trades working in parallel do not get in each other's way
3. Safeguard materials and completed construction works against damage
4. Keep the building site clean
5. Enhance health and safety
6. Reduce storage space requirements on the construction site
7. Keep the routes clear (supply and disposal)
8. Reduce lay-down space requirements by coordinating storage.

The interior finishes schedule forms the basis for planning floor logistics. The area must be divided up into work areas and storage based on the workflow sequence. The storage space requirement is determined based on the work to be performed by each trade during the relevant construction phase, the space needed to execute the work, and the necessary transport routes. Depending on the construction phase, the storage and work areas, and the transport routes needed for horizontal material distributions are marked on the storage plan for each floor.

3.2.3 Disposal logistics

Disposal logistics is responsible for ensuring proper disposal of all materials left over after completion of construction production. The cost efficiency of cleverly designed disposal logistics concepts is secured by separating waste properly for recycling or final disposal.

3.2.4 Fire Rating

The structural components must comply with fire rating requirements as specified in the relevant standard and local authority requirements. It is also important to ensure that any changes implemented by CIDB and BOMBA are to be taken notice not just by the project team and contractor, but also manufacturers of IBS Components.

3.3 Application considerations

There are two applications in IBS selection for precast concrete; on-site and off-site manufacturing.

3.3.1 On-Site Considerations

The significant difference between permanent and mobile precast manufacturing is the mobility of the precast manufacturing plant. The main structure of a permanent precast manufacturing plant is a permanent building, while a mobile precast manufacturing unit has a temporary structure, with only as much cover as needed. A detailed example comparison of permanent and mobile precast manufacturing plants is provided below.

Table 3: Permanent & Mobile Manufacturing Comparison

Description	Permanent Manufacturing	Mobile Manufacturing
Annual Project	Above RM100 million	Below RM100 million
Capital	High	Low
Technology	Prefabricated, semi-automatic, automatic	Prefabricated
Maintenance	High	Low
Land capacity	Minimum of 15 acres	Can start with 5 acres
Mould	Flexible size	Flexible size
Roof of IBS Manufacturing Unit	Permanent (protected from rain)	Mobile (Portable roofing to protect the concrete)

Manpower	200 to maximum of 500 workers (automatic) Specific task High payment	25 workers Multi-tasking Low payment
Production capacity (min)	100,000m2 / year	37,500m2 / year
Crane	Permanent	Permanent or mobile
Concrete	Required batching plant	Outsource or new setup of batching plant

A research conducted by Azman et al (2017) found that IBS manufacturers were concerned with the value of return possible from the project before setting up a manufacturing plant. The thumb rule for the profit margin for IBS projects is around 10%. Usually, a big and established manufacturer will target a minimum production value of RM100 million annually, while a new one will target a minimum project value of at least RM10 million annually. New manufacturers will preferably choose a mobile manufacturing plant that requires lower initial capital, with the average initial cost for setting up the plant being around RM1 million. Big IBS players have the capacity to set up a permanent manufacturing plant, but the initial capital cost is about RM15 million to RM25 million, which is 15 to 25 times more than the cost of setting up a mobile IBS manufacturing plant.

IBS manufacturers require high capital investment in purchasing the machinery such as crane and trailer for handling the heavy components. Foremost, a permanent manufacturing plant will have the following: a fully covered factory, mould, a semi-auto, or fully automatic machine running the movement of IBS components, a batching plant, a permanent crane, a boiling steam oven and high usage of electricity. Although permanent manufacturing plants require high initial capital investment, their capability of producing concrete is high. A permanent manufacturing plant has the capacity to produce 100,000 m2/year of concrete with the support of 350 workers. Whereas the mobile manufacturing plant has a capacity of producing 37,500 m2/year of concrete with a workforce of 25 workers. A comparison between permanent and mobile manufacturing shows that the production capacity of a permanent manufacturing plant is almost triple that of a mobile manufacturing plant.

3.3.2 Off-Site Considerations

A mobile manufacturing plant will have moulds, and a mobile or permanent crane to erect the IBS components and batching plant. If the size of the capital for setting up the mobile manufacturing is limited, they can outsource the concrete. Thus, a mobile plant manufacturer will not work on the inspection of the concrete as it is cast into the mould. Moreover, a mobile manufacturing plant is uncovered. It has the advantage of the sun for natural curing and will save cost. However, the Malaysian heavy rainy season could affect the manufacturing process. The creativity of the manufacturers to overcome this challenge has been proved by their designing a portable roofing system that protects the concrete from the rain. After the casting of concrete into the mould, it is covered with a canvas and the portable roofing is moved along for the next concrete work. Figure 8 shows the portable roofing that moves along the casting yard.

The workflow of mobile IBS manufacturing starts with the preparation of the mould for casting and installing the required steel bar in the mould. The concrete is then poured into the mould. If it rains during natural curing, then portable roofing will cover the casting yard. After the curing process and achieving the required concrete strength, the crane will lift the IBS components from the mould and erect them in the component yard. The quality is checked and labelled according to the design specification. If the IBS component fails to meet the standard, it is repaired. After the inspection, the IBS components are delivered to the construction site using trailers.

3.3 Certifications

There are many certifications that can be obtained. Local certifications in Malaysia are as follows.

3.3.1 CIDB IMPACT Certification

IBS Manufacturer & Product Assessment & Certification – IMPACT program involves application process, assessment procedure, application approval and certification before being recognized as a manufacturer of IBS components registered with CIDB Malaysia. This certification was made based on CIDB Act 520-1994. The objectives of this standard are to create a common standard for IBS products for key stakeholders to implement.

The benefits of registering with CIDB Impact is that it provides a product guarantee as well as adding value towards the IBS products. This is in line with policies made by CIDB to enhance quality of products within the Construction Industry. Manufacturers, Contractors and Consultants would have a standard guideline and process as reference for IBS products that will indirectly provide a good platform to create awareness and market good quality products and services within the Malaysian Construction Industry.

3.3.2 SIRIM IBS IMPACT Certification

The IMPACT scheme is a comprehensive system that encompasses testing, inspection and certification of Industrialised Building System (IBS) products based on requirements of the Construction Industry Development Board Malaysia (CIDB). These requirements serve to raise awareness among industry players to ensure the quality of IBS products and components in a methodical manner. The system ensures high-quality and affordable products while maintaining a systematic, cost-efficient, and orderly construction site. This standard is a collaboration between CIDB and SIRIM to ensure uniformity between governing bodies with regards to standards.

SIRIM QAS International provides high-end equipped facilities and professional business solutions to meet the growing demands of the industry by offering a full range of expert evaluation and testing on products and materials to manufacturers, developers, and contractors. The advantages of this SIRIM IBS Impact Certification are:

1. It provides an independent assurance that the product is manufactured under an effective system of testing, supervision, and control.
2. Purchasers or consumers need not carry out further tests, as the products are already certified to follow the standards.
3. Certified products provide the user an assurance for safety and reliability.

4. Certified products enjoy the benefits of protection against competition from substandard products and misrepresentation.
5. The Product Certification Mark on a product is an excellent marketing tool.
6. It enhances the reputation of the manufacturer and thus, extends the market.
7. It improves efficiency in production and reduces wastage and rejects.

3.3.3 Product Certification

Product certification and testing services are proof that the materials sold in the market are of superior quality.

Since concrete is an important material in the precast concrete system, testing and product certification scheme services for Ready-Mix Concrete (RMC) is required by CIDB Malaysia. This is to ensure the concrete materials comply with mandatory product safety requirements through a conformity assessment of the concrete through Ready-Mixed Concrete Certification Scheme by SIRIM QAS International.

Local engineers, consultants, contractors, and suppliers of RMC are recommended to adopt the latest standards of MS EN 206 and CIS 21 in order to ensure the quality of the concrete.

SECTION 4: IBS PRODUCTION GUIDE FOR PRECAST CONCRETE SYSTEM

This section focuses on production criteria in establishing an IBS production setup including the typical space requirements needed adopting function-based approach to provide concise definition and guidance through checklists.

4.1 Best Practices for IBS Production for Precast Concrete System

Figure 5 shows the flow chart of best practices for IBS production for precast concrete systems where a production line-up setup comprises a batching plant system to produce concrete and production system for reinforcement preparation. The end products are then stored in a stockyard. Figure 6 further illustrates the flow chart of the business model for IBS production.

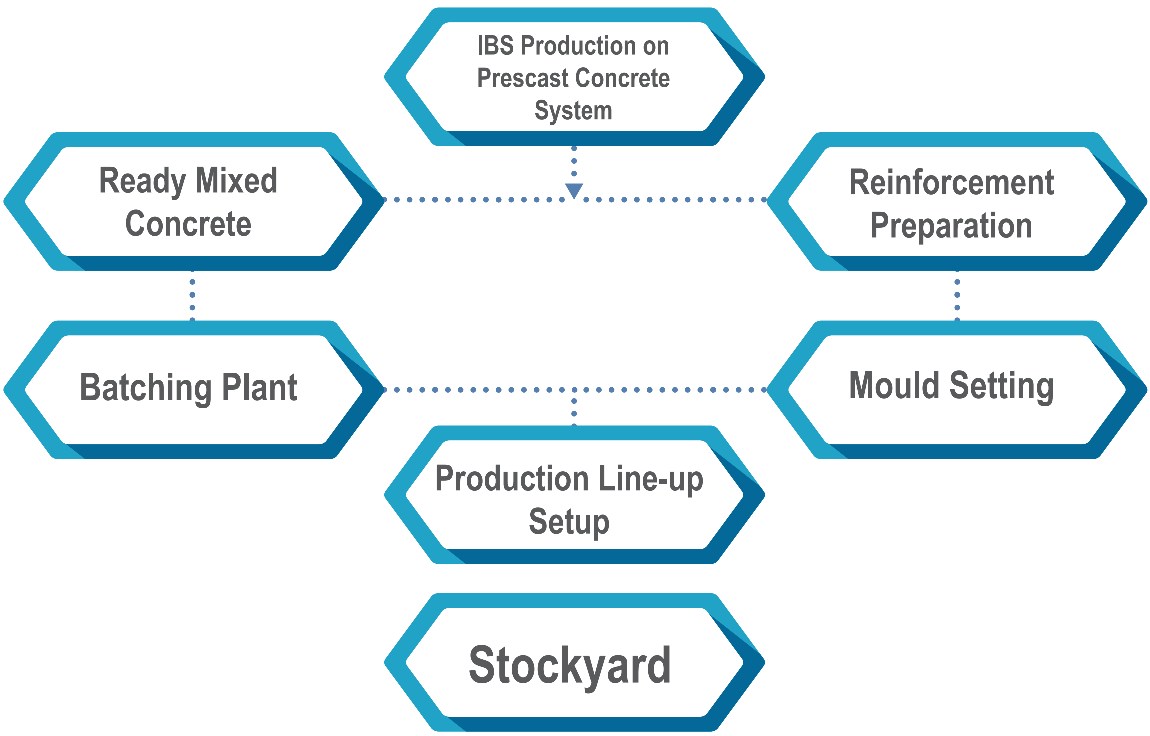

Figure 5: Flow Chart of Best Practices for IBS Production for Precast Concrete System (CREAM, 2020)

Figure 6: Flow Chart of the IBS Production Business Model (CREAM, 2020)

4.2 IBS Production Criteria (Precast Concrete System)

Prior to the IBS production activities, several aspects shall be taken into consideration which are not exhaustively as follows:

1. Determine cost of the project, production capacity and continuity.
2. Set permanent or on-site factory.
3. Determine precast components to be produced.
4. Develop a business model that considers the supply chain components such as planning, sourcing, logistics, sales & marketing and others.

Table 4: Checklist for IBS Production (Precast Concrete System)

Item	Criteria	Function	Checklist
1	Precast component	1. Establish component	☐ Wall ☐ Column ☐ Beam ☐ Slab ☐ Others:
2	Precast operation	1. Plan resources 2. Setup machines	☐ **Semi-auto** ☐ Manual

		3. Hire workers	☐ Others:
3	Production line	1. Facilitate production activities 2. House machines and equipment 3. Facilitate movement 4. Cure concrete	☐ **Covered casting area** ☐ Open yard casting ☐ Others:
4	Production system	1. Store steel 2. Mould steel 3. Control quality 4. Manage waste	☐ **Steel mould** ☐ Non-Automated pallet with fixed mould ☐ Automated pallet with fixed mould ☐ Others:
5	Batching plant system	1. Mix raw materials 2. Produce concrete 3. Supply concrete 4. Control quality 5. Manage waste	☐ **Dry Plant** ☐ Wet Plant ☐ Others: ☐ **Fully automated** ☐ Semi-automated ☐ Manual ☐ Others:
6	Stockyard	1. Store products / stocks 2. Segregate products / stocks	☐ **Open** ☐ Factory ☐ Others:
7	Storage system	1. Organise finished products / stocks	☐ **Rack system** ☐ Fish-bone system ☐ Others:
8	Concrete specification	1. Comply to requirements 2. Meet demands 3. Meet project requirements	☐ 30 N/mm2 ☐ 40 N/mm2 ☐ 45 N/mm2 ☐ 50 N/mm2 ☐ 60 N/mm2 ☐ Others:

9	Concrete supply	1. Supply concrete	☐ **Mixer truck** ☐ Flying bucket ☐ Others:
10	Machineries & equipment	1. Facilitate production output	On-Site ☐ **Crawler crane (50 tonne)** ☐ Gantry crane (12.5 tonne + 25%) ☐ Others: Permanent ☐ **Overhead crane** ☐ Others:

1. The production criteria is non-exhaustive and other criteria have to be considered on a case-to-case basis.
2. The ones that are highlighted in bold format are considered as commonly used by the existing IBS manufacturers (CREAM, 2020).
3. All of the production criteria shall comply with the authorities requirements, labour policies, testing and certifications, etc.

4.3 Space Requirements for IBS Production (Precast Concrete System)

In order to construct an IBS production setup, several aspects have to be looked into details including:

1. Area / Site Planning.
2. Preliminary investigation (access road & basic infrastructure).
3. Available supply of utilities.
4. Compliance to planning submission and building codes.

For example, a project that consists of 500 units of housing for 2 years is recommended to have about 5-10 acres for the required spaces, depending on the complexity and repetitions.

Table 5: Checklist for Space Requirements for IBS Production (Precast Concrete System)

Item	Space	Function	Ideal	Required
Production Capacity				
Essential				
1	Casting	1. House batching plant 2. House production system 3. Facilitate movement	40-100m2 area per daily production capacity	
2	Stockyard	1. Store End Product	80-90m2 area per daily production capacity	
3	Storage	1. Store Raw Materials 2. Protect Raw Materials	30%-50% of the stockyard area	
Supporting				
1	Transportation area	1. Facilitate logistics activities	Depending on the production capacity	
2	Office	1. Facilitate business operation 2. House office equipment	Depending on the business operation	
3	Staff Quarter	1. Accommodate staff	Depending on the number of workers	

1. The concrete volume for residential is assumed at 30-40m3/single storey unit and 60-70m3/double storey unit.
2. The precast concrete product is assumed to be stored at the stockyard for 10 days.

CONCLUSION

While the construction industry is pushing towards more IBS adoption, a key problem is there are few IBS manufacturing plants in Malaysia. Suitability of IBS construction is also contingent upon its production capacity, transportation, and storage requirements, site conditions (location, topography, and accessibility), availability of plant and machineries, and skilled fabricators/installers.

There are two applications in IBS selection for precast concrete; on-site and off-site manufacturing. The significant difference between permanent and mobile precast manufacturing is the mobility of the precast manufacturing plant. The main structure of a permanent precast manufacturing plant is a permanent building, while a mobile precast manufacturing unit has a temporary structure.

As such, a standard flow chart on best practices and business model for IBS production for precast concrete systems was established by CREAM with a production line-up setup comprising a batching plant system to produce concrete and a production system for reinforcement preparation while the end products are then stored in a stockyard.

Practical checklists using function-based definition are established so as to guide new and the existing IBS manufacturers on IBS selection and production for precast concrete including typical space requirements needed. The lists are non-exhaustive and flexible to be used as a reference for IBS production for precast concrete systems to support the supply chain network.

Apart from the importance of having an adequate IBS supply chain network, other considerations have to be taken into account in adopting IBS such as suitability of the procurement system and incorporating relevant provisions to facilitate the applications of contracts for IBS projects. The practicality of the IBS certification process to suit the industrial practices also possibly influences the participation of new IBS manufacturers in the market whilst providing quality assurance to the products. These considerations are pertinent in addressing the micro and macro-ecosystem gaps of IBS adoption in the industry.

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Features of the different Procurement Systems

	Traditional	Design & Build	Management Contracting	Construction Management
Concept	• The client appoints an architect to prepare a brief, a scheme outline and working drawings • The architect may also, with the client's approval, appoint other members of the consultant team such as quantity surveyor and structural engineers. • Tenders are invited to select contractors, usually based on competitive tendering • The contractor, who has no responsibility for the design, and is only responsible for executing the construction works • The design team work independently from the contractor	• A contractor undertakes the responsibilities and risks for both the design and construction. • There may be various levels of employer involvement in the design • The client engages a building contractor who is then responsible both for the design and the construction. • Clients may engage outside consultants to advise on the preparation of requirements and to evaluate and select tenders etc. • The main contractual link is between client and the contractor and the client's agent, or representative has only a limited role. • The contractor might also have a contractual link with his own design consultants, and with subcontractors and suppliers. • As the contractor is wholly responsible for their performance, both in terms of design and construction, there might be less need for collateral agreements between them and the client.	• The management contractor provides the management and buildability expertise in return for a fee. • The contractor does not participate to profit from construction work itself and does not directly employ any of the labour and plant, • Because the contractor is employed on a fee basis, the appointment can take place early during the design stage. • The contractor is therefore able to provide substantial input into the practical aspects of the building technology process. • Each trade required for the project is tendered independently by the subcontractor, either upon the basis of the measured work packages or a lump sum. • This should therefore result in the lowest cost for each trade and thus for the construction work as a whole. • The management contractor assumes full responsibility for the control of the work on site.	• The construction manager is responsibility for the overall control of the design team and the various trade contractors, throughout both the design phase and the construction phase of the project • The construction manager is appointed after a careful selection process and is paid a management fee. • There is no general contractor; instead, there is a series of direct contractual links between the client and the trade contractors • This makes the role of the construction management more like a consultant than a contractor. • The arrangement is used particularly by experienced clients on projects with short lead-times

Contractual Relationship	• The client is in a direct contractual relationship with the consultants on the one hand and the contractor on the other. • Any contractual links for only where they clients make nominations is it advisable to recommend collateral agreements to protect his interests in respect of any matters which might lie outside the building contract • Architect is the lead designer to coordinate with Engineers on the part of M & E works. • Architects are also to ensure that the design complies with the local authority requirements. Besides that, • Architects manage the whole project and supervise the works. • Contractors to execute and complete the building works based on the design and specifications in the contracts. • Contractors are to coordinate with the nominated Sub-contractors (NSC) on specialist works.	• The contractor is directly responsible for all-in design and construction services. • It may also be necessary and desirable to employ independent professional advisers to monitor the progress and quality of the contractor's work and to agree the value of the interim certificate for payment purposes. • Clients state his requirements through his consultants who prepare the 'Employer's Requirement' or conceptual design. • D & B Contractor prepares the detailed design and prepares the cost proposals to the client. • The successful D & B assume 'Single-Point Responsibility' for designing, planning, organizing, constructing, and controlling the whole project. • The scope of the design obligation needs to be set out as clearly as possible.	• The contract is between the client and the management contractor • All works contractors are in direct relationship with the management contractor. • It may also be desirable to establish a contractual relationship between the client and each work contactors by means of a collateral agreement. • In construction management the contractual relationship is between the client and the construction manager, with all trades contractors in direct relationship with the former	• Trade contracts are arranged and administered by the construction manager • The construction manager is a coordinator, and usually cannot guarantee that the project will be finished to time or cost. • The clients direct the project, and the client is also likely to carry the greatest burden of risk.
Advantages	• Quality of work is controlled by Client. • Can achieve the best price through competitive tendering. • Clients can easily request any variation of the works. • Client's interest is protected by the Consultants who serve as advisors and independent certifiers in the building contracts.	• Ease of communication-Client only needs to liaise with one party i.e., D&B Contractor, it is direct contact with the client. • Saving in time and cost of construction. • The contractor's experience with the project from inception. • The option for contractors is to include their constructing capability in the proposed design.	• Early appointment of contractor as a member of the design team to provide management skill. • Better coordination & control of projects through improved management qualities. • Shorter project period because increase speed of design and construction	• Independent management function. • Reduction in project durations and costs. • Design team is able to concentrate on design. • No conflict of interest between design and production.

Disadvan-tages	• From inception to completion the project needs a relatively longer period. • The communication channel among various consultants may be incompetent. • Clients may find it too difficult to coordinate with the various consultants.	• Design possibilities are not explored in full and tend to be restricted by the D & B Contractor's standard design and construction method. • Quality of materials may be compromised in view of the D & B Contractor's profit. • Clients are discouraged to order any variations of works. • Client must select only D & B Contractor with a good reputation and track record.	• Pressures on the design team in preparation of various tender documentation and tender evaluation.	• Additional management cost. • Erosion of Architect's power and responsibilities which may affect design.