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# Buildability Attributes at Design Phase in Malaysian Building Construction

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## ABSTRACT

In Malaysian construction industry, construction problem is a common occurrence that hinders the project to run smoothly, notably in traditional contracting system where the design and construction process are separated. Previous research revealed that buildability is able to minimise these problems as it link the design and construction. This study outlines the buildability attributes in building design. Extensive reviews have been carried out on previous researches on buildability concepts, attributes, principles and other areas related to, and contributing to buildability mainly in the design phase. The term 'buildability attribute' has been selected in this study to describe those characteristics which directly or indirectly optimize integration of construction knowledge in the building process and balancing the various project and environment constraints to maximize project goals and building performance. Close examinations of available references revealed that altogether there are 19 buildability attributes that can be implemented during the design phase. The results of survey conducted in the study show that Malaysian construction industry practitioners rate the attributes Provide Clear and Complete Design Information and Less Work Below Ground as the most important and least important buildability attributes respectively. The client, consultant and contractor share the same opinion regarding the level of importance of the identified buildability attributes. Out of 19 attributes, 11 attributes have significantly high mean values indicating that these buildability attributes have to be considered in future building design. This study has successfully measured the level of importance of design buildability attributes for building construction in Malaysia

***Keywords:*** *Buildability Attribute, Design Phase*

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## 1.0 INTRODUCTION

There are a lot of problems occurred during construction where buildings or facilities could not be built as designed or could not be constructed efficiently. Particularly in traditional contracting system, the design and construction are separated. Nevertheless, buildability is seen to be able to solve some of the problems in the construction industry. It is a concept that has been extensively being developed and applied in various countries such as the USA, UK and later in Australia, where their studies have demonstrated that improved buildability has lead to significant savings in both cost and time required for completing construction projects [1-4].

Buildability, as known in the U.K., is the extent to which the design of a building facilitates ease of construction subject to the overall requirements for the completed building [5]. In the U.S., it is known as constructability, is defined as the optimum use of construction knowledge and experience in planning, engineering, procurement and field operations to achieve overall project objectives [6].

Designers, together with other project participants involved in the design stage, should stay alert to the impact of building designs on the downstream activities. The integration of good buildability into good overall design is the responsibility of the design team. The processes are executed by altering the attributes of the design, such as structure layout or the element size, that contribute to constructability problems based on construction aspects such as dimensional tolerances, rebar congestion etc. Buildability attribute is the term used in this study to describe buildability characteristic in optimising integration of construction knowledge in the building process. Proper and timely consideration of buildabilty will ensure that the final design outcome will meet all the performance criteria that have been set.

New developments in the construction industry highlight the importance and continued relevance of buildability. If adequate considerations are made during the design stage in buildability aspects, it would help save wasteful efforts throughout the whole process of building development and increase efficiency. [7] stated that the early efforts of buildability implementation can oblige the engineer to make the best efforts at each stage of the project. However, in Malaysia construction industry, research into buildability is still relatively not well developed. There is lack of available sources and reliable documentation that detail those buildability concepts and guide their application. Hence, Malaysian engineers have a disadvantage by not knowing what, when and how they should enhance the project buildability compared with the engineers in more developed countries [3]. Besides, the concepts for improving buildability of projects vary between one country to the other where it depends on the nature of the construction industry.

This study has been carried out with the following objectives:

i. To identify buildability attributes in building design phase for Malaysian construction industry; and
ii. To measure the level of importance the buildability attributes in building design phase among Malaysian construction practitioner

## 2.0 BACKGROUND OF THE STUDY

### *2.1 Buildability in Building Construction*

Buildings constructed with the least variation to design are known to give satisfaction to all the major parties of a building project - client, design team and construction team. It is believed that the use of experienced construction knowledge from the outset to the completion of a project that integrate the methods of construction in to the design process, providing benefits and solutions to achieve the design intent in a cost effective and timely manner. In the construction process it is used to drive out waste and enhance cost and program certainty, through properly planning the works and construction logistics and using modern construction techniques.

Buildability is increasingly becoming a major requirement in building construction practice. The aim of buildability is to improve efficiency of the overall building process by developing construction sensitive designs [8]. The expected results from implementing constructability are efficient and effective construction of a building, with an economical project cost and at agreed quality specified by the clients. [9] highlighted that buildability must be considered from the first notional idea suggested by the client, and is quite simply a prerequisite throughout what may be considered to be a staged process (see Figure 1).

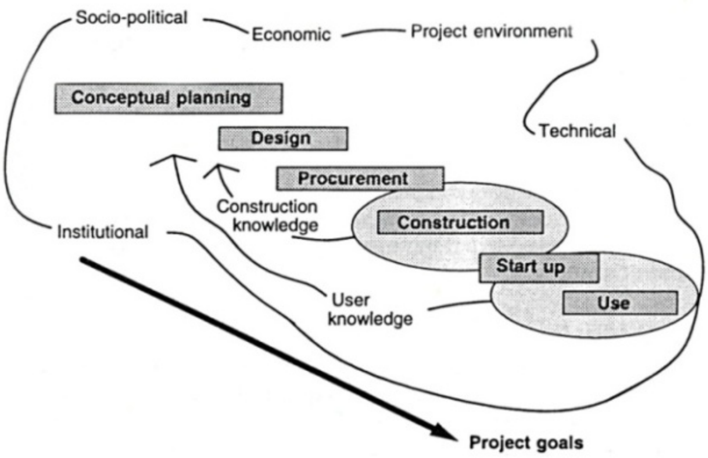



**Figure 1:** The wider framework of buildability [10]

It is essential to consider buildability at an early stage in the total construction process, because the ability to influence project cost, and so value for money from the client's viewpoint, diminishes as the project progresses in time. During the project lifecycle, buildability consideration should focus on the buildability attributes for each stage throughout the project lifecycle.

### 2.2 *Buildability Attributes in Design Phase*

This study outlines the discussion on buildability concepts in design phase. For this purpose, extensive reviews have been carried out on previous researches on buildability concepts, attributes, principles and other areas related to, and contributing to buildability mainly in the design phase. Even though different terms have been used to describe the so called buildability characteristics, generally the term 'buildability attribute' has been selected in this study to describe those characteristics which directly or indirectly optimize integration of construction knowledge in the building process and balancing the various project and environment constraints to maximize project goals and building performance.

The studies of buildability and constructability in different countries have demonstrated their different focuses of interest. For example in Singapore the government has enforced the law to require minimum buildability of submitted building plans before granting approval. In UK, researchers emphasised the integration of design and construction, introducing construction experts into the design phase as well as developing procurement structures to achieve improvement of buildability. In Hong Kong, where most construction sites are congested with restrictive surrounding conditions in busy urban areas, buildability becomes critical in ensuring smooth projects delivery. So, there is a real and immediate need for local construction industry to improve its overall buildability performance. In US and Australia, more practical approaches were adopted. The CII United State (US) and the CII Australia published guidelines for implementing the concepts of constructability. [11], [3] and [12] summarized most of the studies on buildability attributes for the whole project lifecycles.

Close examinations of available references revealed that altogether there are 19 buildability attributes that can be implemented during the design phase. Table 1 shows the summary of buildability attributes as identified by researchers in different countries.

**Table 1:** Buildability attributes identified by researchers in different countries

| **No.** | **Buildability Attribute** | **CIRIA [5]** | **Tatum et al [13]** | **Adam [26]** | **Ferguson [23]** | **CII [6]** | **CII [14]** | **Hon [8]** | **CII Australia [10]** | **BCA (BDAS) [15]** | **CIRC Report [16]** | **Rosli Mohamad Zin [9]** | **Tam [4]** | **Ganah [25]** | **Nima [11]** | **Lam et al . [12]** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BA1 | Consider Innovative/efficient Construction Methods | | | | | √ | √ | √ | | | | | | | | |
| BA2 | Provide Clear and Complete Design Information | | | | | | | | | | | | | | | √ |
| BA3 | Maximise Prefabrication | | | | | | √ | | | √ | √ | | √ | | | |
| BA4 | Maximise Standardization | √ | | √ | | | √ | √ | | √ | √ | | | | | √ |
| BA5 | Less Work Below Ground | | | √ | √ | | | | | | | √ | | | | |
| BA6 | Simple Detailing | | | √ | √ | | | √ | | | | | | | | |
| BA7 | Allow Flexibility | | √ | | | | √ | √ | | | | | | | | |
| BA8 | Simple Installation | √ | √ | | √ | | √ | √ | | √ | √ | | | | | |
| BA9 | Employ Visualization Tools | | | | | | | | | | | √ | | √ | | |
| BA10 | Optimise Labour/Skills Usage | | | √ | √ | | √ | √ | √ | | | | | | | |
| BA11 | Optimise Materials Usage | √ | | √ | √ | | √ | √ | √ | | | | | | | |
| BA12 | Optimise Plant and Equipment Usage | | | √ | √ | | √ | | √ | | | | | | | |
| BA13 | Effective Site Layout | | | √ | | | | | | | | | | | √ | √ |
| BA14 | Minimise/Avoid Return Visit | | | √ | | | | | | | | √ | | | | |
| BA15 | Consider Construction Sequence | √ | | √ | √ | | √ | | | | | | | | | √ |
| BA16 | Sufficient Tolerance | √ | | √ | | | | √ | | | | | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BA17 | Consider Impact of Weather | | | √ | | | √ | | | | | | | | | |
| BA18 | Consider Safety | | | | | | | | | | | √ | | | | √ |
| BA19 | Encourage Sustainable Construction | | | | | | | | | | | | √ | | | |

In order to provide a more clear representation of buildability for ease of understanding by practitioners, the identified buildability attributes listed in Table 1 is further explored and described as follows (also as in Table 2):

**BA1 - Consider Innovative/efficient Construction Methods**
The design solution encourages the usage of efficient and innovative construction methods. Iterating design approaches with the construction method can improve the project quality and safety performances [17]. Suggestions for non-obligatory construction methods for contractor are considered in this attribute.

**BA2 - Provide Clear and Complete Design Information**
This attribute consider the co-ordinating of drawings and specifications and updating specifications and removing ambiguities or misunderstandings. Information related to site-specific such as site conditions and terrain characteristics should also be accurate and readily available during the design process. The underlying premise for this aspect is that every construction site is unique and special attention needs to be devoted to the design to facilitate construction.

**BA3 - Maximise Prefabrication**
Precast or prefabricated self-contained bathrooms and kitchens, etc. reduce the amount of wet trade activities on site. Since building elements are then made under the controlled factory environment, messy and polluting works vulnerable to adverse weather conditions are eliminated. When standardisation and prefabrication are used together, facilitating a better management [18].

**BA4 - Maximise Standardization**
Standardization can be manifested through the repetition of grids, sizes of components and connection details. It enhanced ease of construction by increasing project performance and reduction of the project cost [17, 19-21]. Site personnel find it easier to acquaint themselves with the repeated working logistics, as it reduces learning time [22]. Standard size components, e.g. columns, doors and construction details, also allow saving of time and efforts because of less variation in formwork based on common dimensions.

**BA5 - Less Work below Ground**
In condition where the ground is hazardous, poor or wet, it will slow down the speed and flow of the project [3]. It is crucial to obtain a clear understanding of the conditions likely to be met beforehand. The designer must always bear in mind that work below ground is always difficult to carry out They must have knowledge on various design alternatives to suit the condition on site. Previous experience in design and supervision on works below ground such as foundation and excavation works will definitely assist the designers.

**BA6 - Simple Detailing**
Details should be kept as simple where possible to reduce the learning curve effect of site tradesmen. Reasonable tolerances should be specified [22-23]. In the case of

innovative details or combinations of materials, which are being used for the first time, it is beneficial to have mock-up models or prototypes erected to study the installation process and iron out possible problems before full scale production.

**BA7 - Allow Flexibility**

The high adaptability of building elements help save resources and increase the flexibility for change according to actual site conditions being encountered. Interchangeable components, e.g. optional left/right orientation of cabinets, sanitary ware or universal assemblies that can be fitted in positions other than the designated ones shown on drawings, should be adopted.

**BA8 - Simple Installation**

Irregular shapes, complex geometrical profiles, complicated installation details and multi-disciplinary designs could burden contractors with additional resources for co-ordination and site assembly. As such, building designs with simple configurations enable works to be executed in a straightforward manner and facilitate ease of construction [18]. However, this aspect must be balanced with the aesthetic requirements of clients and artistic aspiration of designers. If complexity is necessarily required, the design process should be coordinated properly to ensure that minimum cross-referencing of documents is required, otherwise expensive errors are prone to occur on site.

**BA9 - Employ Visualization Tools**

The rapid development of information technology has enabled advanced software to be used for preparing design that integrates visualization features [24]. Visualisation has been cited improve the collaboration between site and design teams in solving buildailty problems that may arise during construction [3]. It irons out difficulties that may occur before construction commences on site. Common buildability problems that can be solved by employing visualisation tools are interfaces between components and difficult assembly [25].

**BA10 - Optimise Labour/Skills Usage**

[26] pointed out that any design is only good as skills available to execute it, either off-site or on-site. Labour and skills requirements vary between one project to another, between one locality to another. Design must include a realistic assessment of the level of skill likely to be available from appropriately chosen contractors and specialists.

**BA11 - Optimise Materials Usage**

Products and materials to be specified during design should be selected with care, particularly, any which have not long been established and accepted within the industry. It is recommended that only products and materials, which have been proven suitable to be used are selected. At the same time more economical benefit can be gained if local materials are used as in many cases materials produced locally are cheaper and easy to get.

**BA12 - Optimise Plant and Equipment Usage**

Designing for optimum use of plant and equipment and having the knowledge of them, also designing for temporary plant and equipment anchorage in permanent structures are some important issues which are discussed here.

**BA13 - Effective Site Layout**

The environment around the construction site has significant influence on the whole development process [11, 26-27]. Confined sites possess characteristics concerning the imposed restrictions which substantially hinder the construction process. The smoothness of construction is susceptible to nearby traffic conditions, especially when exits and ingress often encroach upon pedestrian pavements and vehicular routes.

**BA14 - Minimise/Avoid Return Visit**

This attribute will optimise the usage of certain trade by enabling the trade to work with as few return visits as possible. [26] presented an example related to this attribute. In this design, the gable end structure was design using similar materials as with other intermediate steel frame structures instead of gable wall simply because to ensure the steel workers complete the whole work with minimum interruption. The benefit is gained from material saving through gable wall design did not outweigh the cost of erecting steel gable end.

**BA15 - Consider Construction Sequence**

The sequence of installation should not be dictated in design document but left for the contractor to decide on the sequence for the entire works. For example, ground floor slabs can be constructed before or after superstructure construction to allow flexibility in the timing of underground drainage works.

**BA16 - Sufficient Tolerance**

The tolerances which are normally achievable in site conditions should be properly considered in the design especially interfacing between different building components such as different products, methods of construction, materials and method of manufacture. For example sufficient tolerance needs to be specified to allow window frame to be fixed onto window opening without having to do any adjustment or modification.

**BA17 - Consider Impact of Weather**

Considering possible timing to avoid carrying out structural work, external finishes, etc., during rainy days, typhoon seasons for high rise buildings is an important issue.

**BA18 - Consider Safety**

In high rise building, allowing safe sequence of trades is an issue. Designers should look into the impact of the design solution on safety of manpower during handling of materials and components or wherever requirement for access is necessary. [3] added the design should be arranged so as to facilitate safe working in area prone to accidents such as underground and high elevation works.

**BA19 - Encourage Sustainable Construction**

With heightened awareness of environmental pollution, natural resource depletion and accompanying social problems, sustainable development and sustainable construction have become a growing concern throughout the world [28]. Buildings are one of the heaviest consumers of natural resources and account for a significant portion of the greenhouse gas emissions. Conventional on-site construction methods have long been criticized for low productivity, poor quality and safety records, long construction time, and large quantities of waste in the industry.

**Table 2:** The considerations in enhancing design buildability

| Buildability Attribute | Considerations |
|---|---|
| BA1 | • Use of Industrialised Building System (IBS)<br>• Less in-situ works |
| BA2 | • Coordination of drawings and specifications<br>• Avoidance of missing information |
| BA3 | • Allowing offsite work for typical floor buildings and for non-typical floor buildings<br>• Enabling the adoption of single integrated elements (e.g., whole toilet completed with sanitary ware, piping & finishes) at the discretion of contractor<br>• Optimising the mix of offsite work (e.g., precasting) and onsite work (e.g., final levelling) |
| BA4 | • Allowing modular layout of components<br>• Allowing a high degree of standardisation and repetition for floor buildings<br>• Allowing use of standard details with lots of repetitions |
| BA5 | • Designing for minimum construction time below ground<br>• Designing for safe construction below ground<br>• Considering effects of below ground work on surrounding buildings, e.g., destabilising foundations |
| BA6 | • Designing to aid visualisation of finished work<br>• Referring to typical/standard details for repetitive items<br>• Using blow up details to examine possible clashes in the design, e.g., building services clashing with reinforcements. |
| BA7 | • Using interchangeable components, e.g. optional left/right orientation of cabinets, sanitary ware or universal assemblies |
| BA8 | • Allowing adaptation (e.g. piping around obstacles instead of penetrations) by contractor on site without extensive re-work<br>• Allowing flexibility in erection/trade sequences (e.g. G/F slab laid after all upper floors)<br>• Allowing for early removal of temporary support to leave clear working space |
| BA9 | • Enabling design requirements to be easily visualized and ordinated by site staff |
| BA10 | • Allowing use of know-how and labour skills available locally<br>• Allowing economical use of labour (e.g. balancing between labour and plant use d)<br>• Avoiding as far as possible multiple handling and visits by different trades |
| BA11 | • Allowing use of wide range of materials to fulfil required performance<br>• Giving rise to lower cutting wastages (e.g. tiles, rebars) |
| BA12 | • Designing for optimum use of plant and equipment<br>• Designing with knowledge of plant and equipment capacities<br>• Allowing use of local plant and equipment available |
| BA13 | • Allowing sufficient working space for labour and plant<br>• Causing less environmental nuisance (e.g. noise, vibration, waste water, |

| | |
|---|---|
| | chemical waste and dust) to surroundings for urban sites<br>• Allowing for early enclosures from weather for high rise buildings<br>• Allowing for construction traffic on permanent structure early after erection (e.g. left-in steel decking on structural steel) |
| BA14 | • Avoiding as far as possible multiple visits by different trades |
| BA15 | • Letting Contractor decide on the sequence for the entire works. |
| BA16 | • Specifying tolerances for as many items as possible<br>• Co-ordinating tolerances specifications for interfacing items (e.g. window frame vis-à-vis window opening) |
| BA17 | • Considering possible timing to avoid carrying out structural work, external finishes, etc., during rainy/typhoon season for high rise buildings |
| BA18 | • Allowing safe sequence of trades (e.g. heavy M&E plant hoisted into position before building is fully enclosed) for high rise buildings<br>• Sizes and weights of materials and components are safe for workers to handle using commonly available plant for high rise buildings |
| BA19 | • Design for sustainable material in the project<br>• Design for method of construction that preserves the environment. |

## 3.0 METHODOLOGY

Figure 2 illustrates the schematic of research methodology that has been adopted.

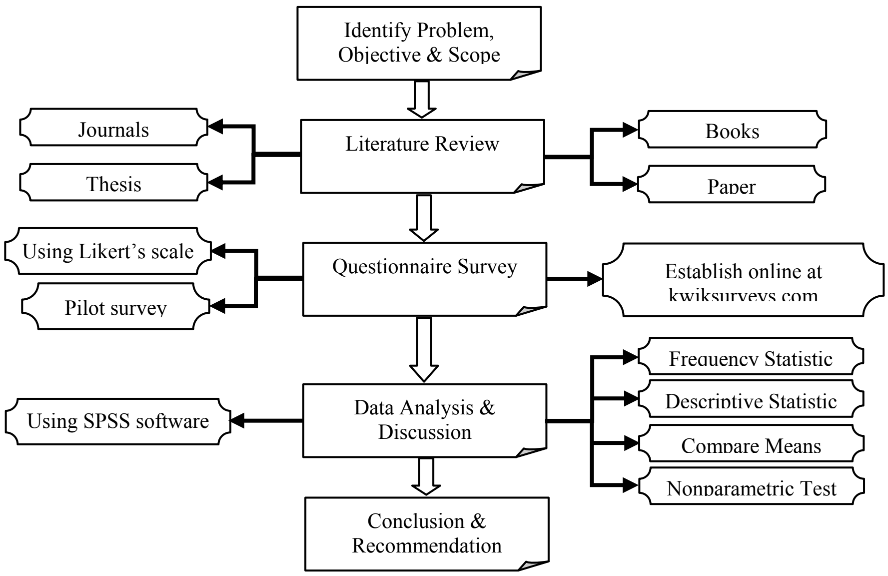



**Figure 2:** Schematic of the research methodology

To achieve the objectives of the study, the methodologies adopted were through literature review and online questionnaire surveys. At the beginning, the study involved extensive review on design-phase buildability concepts. The literature search enables the buildability attributes in design stage to be identified. After the buildability attributes were extracted, the questionnaire was constructed. A brief meeting was conducted to ensure that the questionnaire is applicable before posting it online. The online surveys were conducted for about 3 months. The questionnaire was targeted to professionals who worked with the clients, contractor, consultant or other organisations; and have direct involvement in building project construction. Various organisation had been contacted personally to invite them participating in the survey.

In order to determine the degree of importance of the buildability attributes considered in this study, the classification of the rating scales had been used. The responses to the questionnaire are based on Likert scale of five ordinal measures which is from one to five according to the level of effects of variation orders attributed to the question. Likert scale is a widely used instrument in measuring opinions, beliefs and attitudes. The classifications of the rating scales are as follows:

5 = Most Important
4 = Important
3 = Moderately Important
2 = Little Important
1 = Least Important

For the purpose of data analysis collected through questionnaire survey, the Statistical Package for Social Science (SPSS) software version 18.0 was adopted. The data from questionnaires were extracted into the SPSS software. With the aid of the SPSS, the following statistical methods have been used;

(a) Frequency Statistic - for obtaining summaries of individual data variables;
(b) Descriptive Statistic - for obtaining summary comparisons of approximately normally distributed scale data variables and for easily identifying unusual cases across those data variables by computing z score;
(c) Compare Means - to characterize the central tendency and dispersion of data variable. It tests for differences between group means using one-way ANOVA. The one-way ANOVA in Means provides with linearity tests and association measures to help understand the structure and strength of the relationship between the groups and their means.
(d) Nonparametric Test (Kruskall-Wallis Test) - for determining whether or not the values of a particular data variable differ between two or more groups. This study has multiple independent samples; hence the Kruskal-Wallis test is adopted. It tests the null hypothesis that multiple independent samples come from the same population. The Kruskal-Wallis statistic measures how much the group ranks differ from the average rank of all groups but it does not tell how the groups are different, only that some difference is present.

## 4.0 RESULTS AND DISCUSSION

### 4.1 Demographic of Respondent

Section A of the questionnaire is related to demographic of respondent. Table 3 shows the type of company or organization that participated in the survey with a total number of 201 respondents. They are client, consultant, contractor and also higher institution (university). From Figure 3, it illustrates that the client dominate the survey with 87 out of 203. Then, it is followed by the consultant with 72 respondents, the contractor with 42 respondents and lastly 2 respondents from the higher institution. Based on the huge respond, it shows that the practitioners in Malaysian construction industry are open for improvement in their future project especially from the client.

**Table 3:** The type of company or organisation involved in the survey

| Company | Frequency | Percent |
|---|---|---|
| Client | 85 | 42.3 |
| Consultant | 72 | 35.8 |
| Contractor | 42 | 20.9 |
| Institution | 2 | 1.0 |
| Total | 201 | 100.0 |

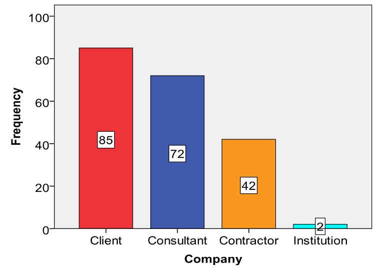



**Figure 3:** The type of company or organisation involved in the survey

In Table 4, it tabulates the role of respondent in their company or organisation. They comprise of architect, engineer, lecturer, project manager, quantity surveyor and site supervisor. Figure 4 demonstrates the result in percentage value. It clearly can be seen that the major involvement are from the engineer with 79.3%. The second highest are project manager with 12.8%. The architect and the quantity surveyor share the same percentage with 3.0% and; also the lecturer and supervisor with 1.0%.

**Table 4:** The role of respondent in their company or organisation

| Roles | Frequency | Percent |
|---|---|---|
| Architect | 6 | 3.0 |
| Engineer | 160 | 79.6 |
| Lecturer | 2 | 1.0 |
| Project Manager | 25 | 12.4 |
| Quantity Surveyor | 6 | 3.0 |
| Site Supervisor | 2 | 1.0 |
| Total | 201 | 100.0 |

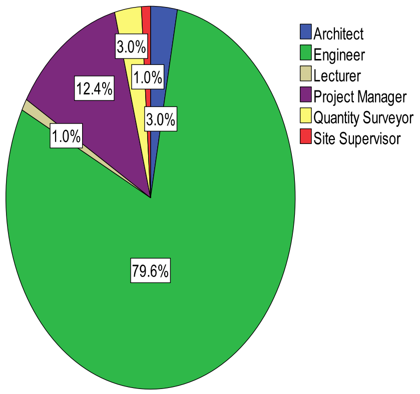



**Figure 4:** The role of respondent in their company or organisation

The year of experience in construction work for the respondents are tabulated and exhibited in Table 5 and Figure 5. Meanwhile, the year of experience in design work of the respondents are shown in Table 6 and Figure 6. Majority of the respondent have less than 4 years of experience in construction work and also in design, with percentage 39.3% and 66.7% respectively.

**Table 5:** The respondent's years of experiences in construction work

| Years of Experience | Frequency | Percent |
|---|---|---|
| Less than 4 Years | 79 | 39.3 |
| 5-9 Years | 51 | 25.4 |
| 10-14 Years | 24 | 11.9 |
| 15-19 Years | 17 | 8.5 |
| 20 Years and above | 30 | 14.9 |
| Total | 201 | 100.0 |

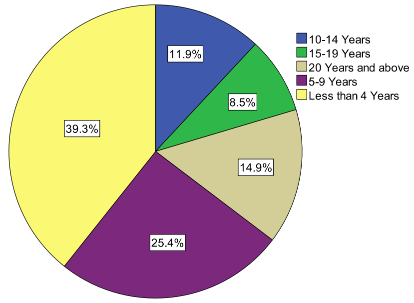



**Figure 5:** The respondent's years of experience in construction work

**Table 6:** The respondent's years of experiences in design work

| Years of Experience | Frequency | Percent |
|---|---|---|
| Less than 4 Years | 134 | 66.7 |
| 5-9 Years | 33 | 16.4 |
| 10-14 Years | 18 | 9.0 |
| 15-19 Years | 11 | 5.5 |
| 20 Years and above | 5 | 2.5 |
| Total | 201 | 100.0 |

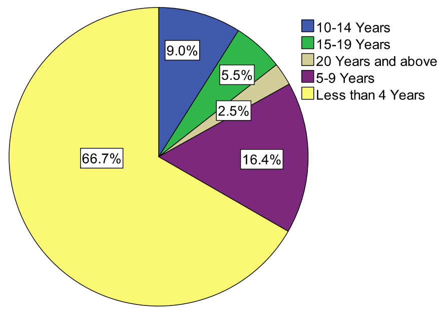



**Figure 6:** The respondent's years of experience in design work

Table 7 and Figure 7 demonstrate the distribution of respondent's company location. Nine states took part in the survey. Four major states involved are Pulau Pinang, Selangor, Kelantan and Johor with each hold more than 20% of respondent, which means more than 40 respondents participated in the survey. The minor states are Perak, Negeri Sembilan, Pahang, Perlis and Kedah.

**Table 7:** The distribution of respondents according to states

| State | Frequency | Percent |
|---|---|---|
| Johor | 44 | 21.9 |
| Kedah | 1 | .5 |
| Kelantan | 45 | 22.4 |
| Negeri Sembilan | 2 | 1.0 |
| Pahang | 2 | 1.0 |
| Perak | 3 | 1.5 |
| Perlis | 1 | .5 |
| Pulau Pinang | 54 | 26.9 |
| Selangor | 49 | 24.4 |
| Total | 201 | 100.0 |

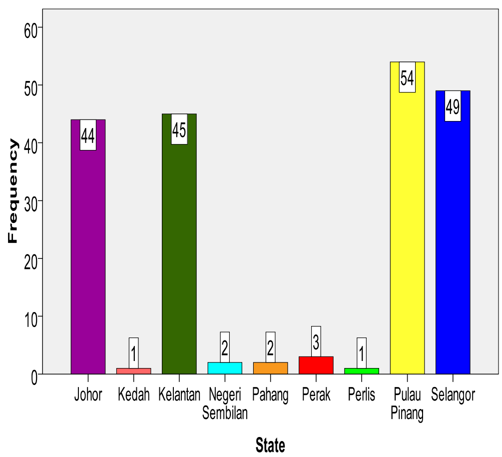



**Figure 7:** The distribution of respondents according to states

## 4.2 The Level of Importance of Buildability Attributes in Malaysian Construction Industry

Section B of the questionnaire focused on to determine the degree of importance of the buildability attributes in design phase among practitioner in the Malaysian construction industry. For each of the attributes, their mean values are obtained by using SPSS software and then the attributes are ranked based on this value. The higher the mean value indicates that the buildadbility attribute must be considered in design stage.

Based on the survey results, the attribute with the highest mean is Provide Clear and Complete Design Information, 4.56 (see Table 8). Thus, it means this attribute is very important to be considered during the design stage. This attribute enables a smooth and success construction project, which is by co-ordinating of drawings and specifications and updating specifications and removing ambiguities or misunderstandings.

**Table 8:** The rank of buildability attributes in building design based on mean value

| Buildability Attributes | Mean | Std. Deviation | Skewness |
|---|---|---|---|
| Provide Clear and Complete Design Information | 4.56 | .638 | -1.284 |
| Consider Safety | 4.34 | .810 | -.934 |
| Encourage Sustainable Construction | 4.23 | .740 | -.768 |
| Effective Site Layout | 4.22 | .724 | -.767 |
| Consider Innovative/efficient Construction Methods | 4.20 | .700 | -.384 |
| Consider Construction Sequence | 4.18 | .756 | -.320 |
| Optimise Materials Usage | 4.17 | .696 | -.430 |
| Maximise Standardization | 4.12 | .732 | -.731 |
| Simple Installation | 4.10 | .771 | -.446 |
| Optimise Plant and Equipment Usage | 4.10 | .703 | -.497 |
| Optimise Labour/Skills Usage | 4.08 | .724 | -.281 |
| Allow Flexibility | 3.96 | .826 | -.775 |
| Sufficient Tolerance | 3.91 | .729 | -.017 |
| Maximise Prefabrication | 3.87 | .773 | -.026 |
| Employ Visualization Tools | 3.87 | .753 | -.412 |
| Simple Detailing | 3.86 | .900 | -.884 |
| Consider Impact of Weather | 3.86 | .784 | -.055 |
| Minimise/Avoid Return Visit | 3.70 | .895 | -.305 |
| Less Work Below Ground | 3.60 | .917 | -.462 |

By referring to Figure 8, there are 10 other buildability attributes with mean value above 4.00 and 8 attributes with mean values below 4.00. The lowest is Less Work Below Ground with 3.60 mean value. Most of the respondent point out that this attribute is less important to be considered during the design stage.

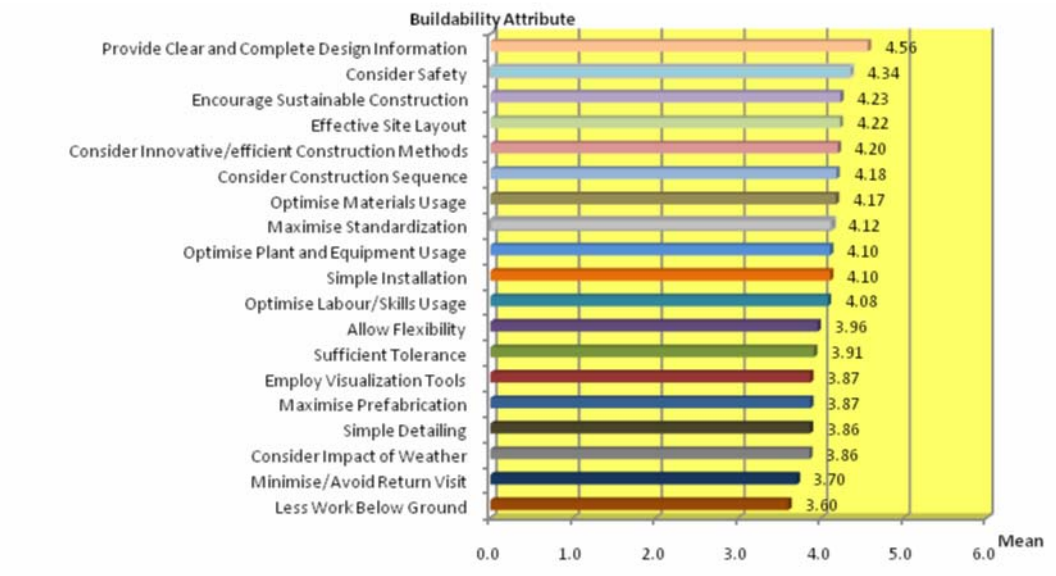



**Figure 8:** The rank of buildability attributes in building design based on mean value

Table 9 show the Chi-square values and significance levels for each buildability attributes, yield from analysing mean value by using Kruskall-Wallis test. The test checks whether the distribution of means among the company has significance difference or otherwise. With significance level of 0.05, there are only two attributes has significance value less than 0.05. Those attributes are Consider Construction Sequence and Consider Safety, with value 0.027 and 0.049 respectively. This suggests that there is no significance difference of ratings on the degree of importance of buildability attributes among the company or organisation.

**Table 9:** The significance difference of buildability attributes between company or organisation (Kruskall-Wallis H-test)

| Buildability Attributes | Chi-square | Asymptotic Sigfinicance |
|---|---|---|
| Consider Innovative/efficient Construction Methods | 2.736 | 0.434 |
| Provide Clear and Complete Design Information | 1.151 | 0.765 |
| Maximise Prefabrication | 5.556 | 0.135 |
| Maximise Standardization | 1.827 | 0.609 |
| Less Work Below Ground | 2.128 | 0.546 |
| Simple Detailing | 7.192 | 0.066 |
| Allow Flexibility | 4.487 | 0.213 |
| Simple Installation | 3.764 | 0.288 |
| Employ Visualization Tools | 1.470 | 0.689 |
| Optimise Labour/Skills Usage | 4.715 | 0.194 |
| Optimise Materials Usage | 0.745 | 0.862 |
| Optimise Plant and Equipment Usage | 0.820 | 0.845 |
| Effective Site Layout | 4.023 | 0.259 |
| Minimise/Avoid Return Visit | 0.326 | 0.955 |
| Consider Construction Sequence | 9.184 | 0.027 |
| Sufficient Tolerance | 3.373 | 0.338 |
| Consider Impact of Weather | 3.030 | 0.387 |
| Consider Safety | 7.871 | 0.049 |
| Encourage Sustainable Construction | 2.379 | 0.498 |

### 4.2.1 The importance level of buildability attributes from client's view

The result presented in Table 9 only shows the overall analysis of buildability attributes among 201 respondents. Since for each organisation, different opinion towards the level of importance of buildability attributes may exist, therefore, detail analysis for each types of organisation has been carried out. Table 10 tabulates the rank of buildability attributes in four organisations involved, which are the client, consultant, contractor and higher institution. The attributes in the table are organised from BA1 to BA19, not according to its mean value.

**Table 10:** The rank of buildability attributes in building design between the companies respectively

| Bui},ladbilitty Attribute | Mean Value | | | |
|---|---|---|---|---|
| | Client | Consultant | Contractor | Institution |
| Consider Innovative/efficient Construction Methods | 4.27 | 4.19 | 4.05 | 4.50 |
| Provide Clear and Complete Design Information | 4.56 | 4.61 | 4.48 | 4.50 |
| Maximise Prefabrication | 3.92 | 3.72 | 3.98 | 4.50 |

| | | | | |
|---|---|---|---|---|
| Maximise Standardization | 4.15 | 4.11 | 4.05 | 4.50 |
| Less Work Below Ground | 3.51 | 3.64 | 3.71 | 4.00 |
| Simple Detailing | 3.67 | 3.99 | 4.02 | 4.00 |
| Allow Flexibility | 3.84 | 4.06 | 4.02 | 4.00 |
| Simple Installation | 4.02 | 4.24 | 4.05 | 4.00 |
| Employ Visualization Tools | 3.89 | 3.89 | 3.79 | 3.50 |
| Optimise Labour/Skills Usage | 4.13 | 4.03 | 4.02 | 5.00 |
| Optimise Materials Usage | 4.20 | 4.17 | 4.12 | 4.50 |
| Optimise Plant and Equipment Usage | 4.09 | 4.14 | 4.05 | 4.50 |
| Effective Site Layout | 4.27 | 4.25 | 4.07 | 4.50 |
| Minimise/Avoid Return Visit | 3.66 | 3.72 | 3.76 | 3.50 |
| Consider Construction Sequence | 4.02 | 4.36 | 4.19 | 4.50 |
| Sufficient Tolerance | 3.80 | 4.00 | 3.98 | 4.00 |
| Consider Impact of Weather | 3.86 | 3.78 | 4.00 | 3.50 |
| Consider Safety | 4.34 | 4.50 | 4.07 | 4.50 |
| Encourage Sustainable Construction | 4.29 | 4.24 | 4.10 | 4.00 |

Figure 9 is the ranking of buildability attributes from the clients' perspective. The clients rated attribute Provide Clear and Complete Design Information (BA2) as the most important attribute to be considered in design stage with 4.56 mean value. Meanwhile, the attribute Less Work Below Ground has the smallest mean value (3.51), thus considered as less important buildability attribute in design stage. Out of 19 attributes, only 8 attributes have mean values less than 4.00.

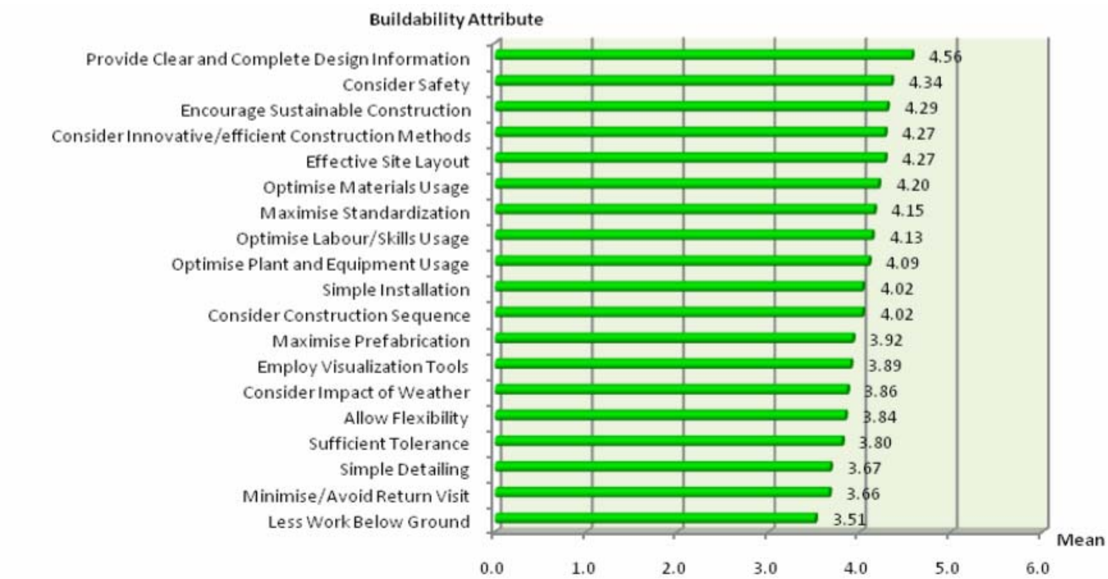



**Figure 9:** The rank of buildability attributes in building design among the client

### 4.2.2 The importance level of buildability attributes from consultant's view

From consultant's view, the most important attribute is Provide Clear and Complete Design Information and the less important is Less Work Below Ground (see Figure 10). By comparing the results between the client and consultant, the ranking for the first, second and nineteenth ranked attributes are quite similar. However, from the third until seventeenth ranked attributes the ranking show significant difference. Out of nineteen attributes, only six have mean values below 4.00.

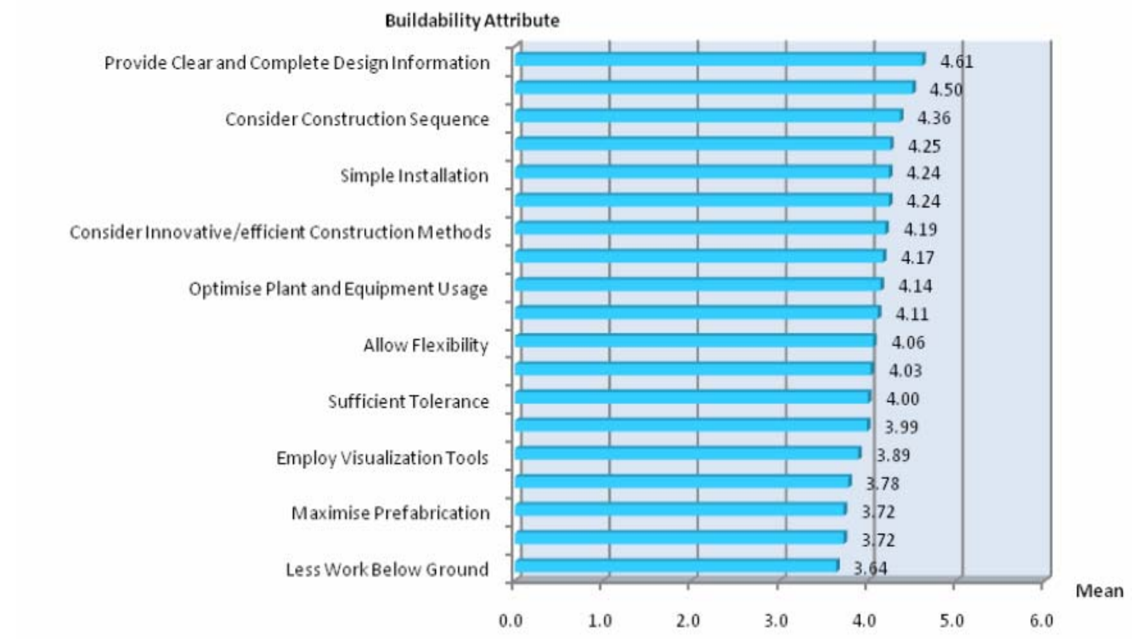



**Figure 10:** The rank of buildability attributes in building design among the consultant

### 4.2.3 The importance level of buildability attributes from contractor's view

By referring to Figure 11, it demonstrates that the contractor seems to be in agreement with the client and the consultant opinion for the highest and lowest rank buildability attributes in design stage. The highest is 4.48 mean value for Provide Clear and Complete Design Information and the lowest is 3.71 mean value for Less Work Below Ground. Out of nineteen attributes, only five have less than 4.00 mean values.

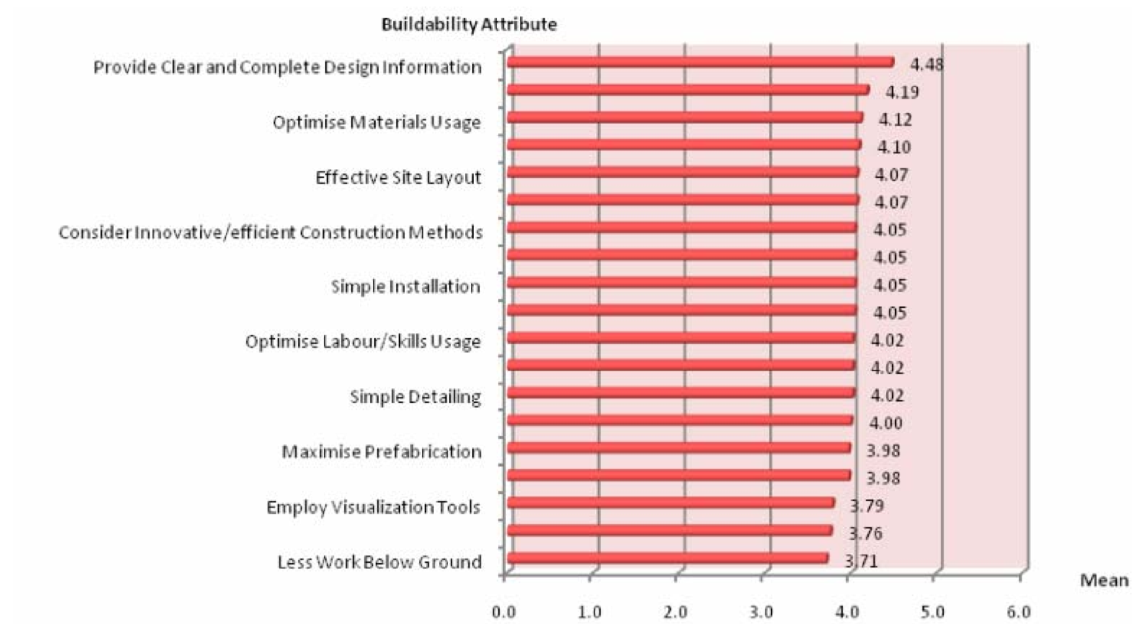



**Figure 11:** The rank of buildability attributes in building design among the contractor

### 4.2.4 The importance level of buildability attributes from institution's view

For higher institution, there were only two respondents involved. Thus, the buildability attributes' ranking is unique from other organisations. The highest mean value attribute is Optimise Labour/Skill Usage, 5.00, while the lowest mean is Employ Visualisation Tools, 3.50 (see Figure 12).

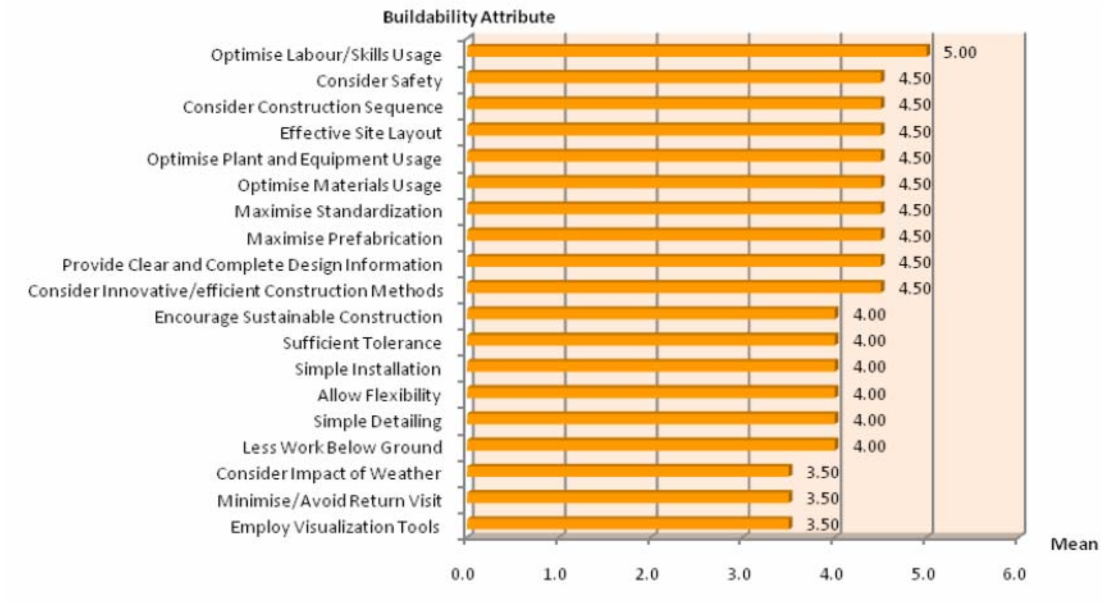



**Figure 12:** The rank of buildability attributes in building design among the institution

### 4.3 Buildability in Construction Method

Section C of the questionnaire seeks the repondent opinion regarding the influence of construction method towards buildabilty. Figure13 indicates the result of the importance level of considering building construction method at design stage. Meanwhile, Figure 14a and 14b show the respondent's opinion regarding the influence of construction method towards project cost and duration respectively.

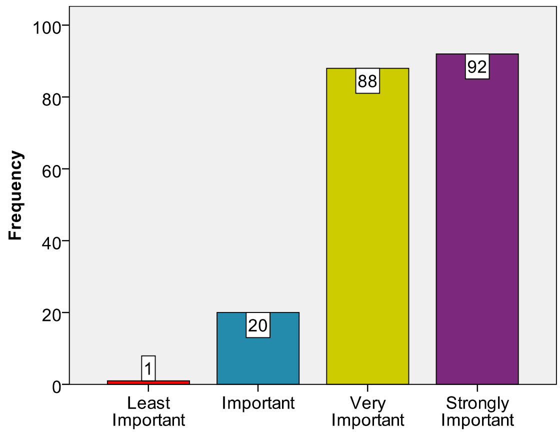
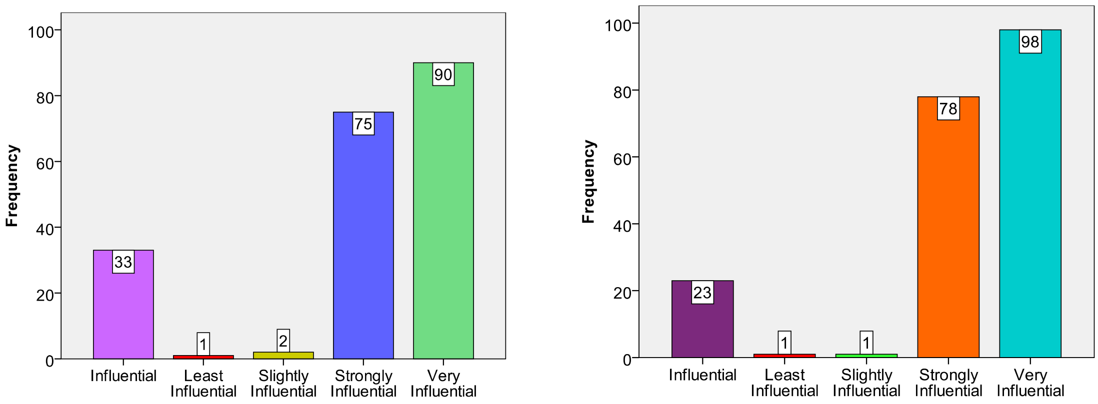



**Figure 13:** The consideration of building construction method at design stage

Based on the bar chart above, 92 respondents pointed out that building construction method is strongly important to be considered at design stage. Only one respondent mentioned it as least important. From Figure 14, 90 respondents highlighted that construction method is very influential towards project cost while 98 of respondents emphasized that it is very influential toward project duration. Also, only one respondent singled out construction method as least influential toward both project cost and duration.




a) b)

**Figure 14:** a) The influential of construction method toward project cost, and b) The influential of construction method toward project duration

## 5.0 CONCLUSION

This study has identified 19 buildability attributes in building design phase for Malaysian construction industry. From the results of survey, the attribute Provide Clear and Complete Design Information, with mean value of 4.56 is considered as the most important while Less Work Below Ground, with mean value of 3.60, is considered as the least important attribute. The client, consultant and contractor share the same opinion regarding the most important and the least important attributes, only higher institution's view is slightly different. From Kruskall-Wallis test, only the attributes of Consider Construction Sequence and Consider Safety have significance value less than 0.05, but the rest show no significance difference of ratings on the degree of importance of buildability attributes among the company or organisation. The study has successfully assessed the importance level of buildability attributes among Malaysian construction practitioner.

## 6.0 REFERENCES

[1] Russell, J., Gugel, J., and Radke, M. W. (1992). *Benefits of Constructability: Four Case Studies*. The Construction Industry Institute, Austin, Texas.

[2] Jergeas, G., and Van der Put, J. (2001). Benefits of Constructability on Construction Projects. *Journal of Construction Engineering and Management*. 127(4): 281–290.

[3] Rosli Mohamad Zin. ( 2004). *Constructability Assessment of Project at Design Phase*. Faculty of Civil Engineering, Universiti Teknologi Malaysia: PhD. Thesis, Unpublished.

[4] Tam V.W.Y., Tam C.M. and Ng W.C.Y. (2007). On prefabrication implementation for different project types and procurement methods in Hong Kong. *Journal of Engineering, Design and Technology*. 5(1): 68-80.

[5] CIRIA. (1983). *Buildability: An Assessment.* Special Publication 26: Construction Industry Research and Information Association.

[6] CII. (1986). *Constructability – A Primer*. Publication 3-1. Austin, Texas: Construction Industry Institute.

[7] Trigunarsyah, B., Bakti, E.S. and Majid, M.Z.A. (2011). Constructability Innovation in Piperack Design for Refinery Project. In Hughes, Will, Eds. *Proceedings Construction Management and Economics*. Reading, UK.

[8] Hon, S.L., Gairns, D.A. and Wilson, O.D. (1988). *Buildability: A Review of Research and Practice.* Australian Institute of Building Papers: 3.

[9] Griffith A. and Sidwell A.C. (1997). Development of constructability concepts, principles and practices. *Engineering, Construction and Architectural Management*, 4(4), 295-310.

[10] CII, Australia. (1993). *Constructability Principles File*. University of South Australia, Adelaide, Australia: Construction Industry Institute.

[11] Nima, M.A. (2001). *Constructability Factors in the Malaysian Construction Industry*. Universiti Putra Malaysia: Ph.D. Thesis.

[12] Lam P.T.I., Wong F.W.H. and Chan A.P.C. (2006). Contributions of Designers to Improving Buildability and Constructability. *Journal of Design Studies*. 27(4): 457-479.

[13] Tatum, C.B., Vanegas, J.A., and Williams, J.M. (1985). *Constructability Improvement Using Prefabricated, Preassembly, and Modularisation*. Technical Report No. 297. Dept. of Civil Engineering, University of Stanford, Stanford, CA.

[14] CII (1987). *Constructability Concepts File*. Publication 3-3. Austin, Texas: ConstructionIndustry Institute.

[15] BCA. (2005). *Code of Practice on Buildable Design*. Singapore: Building and Construction Authority.

[16] CIRC. (2001). *Construct for Excellence: Report of the Construction Industry Review Committee*. Hong Kong, China: Construction Industry Review Committee.

[17] Trigunarsyah, B. (2007). Project Designers' Role in Improving Constructability of Indonesian Construction Projects. *Construction Management and Economics*. 25(2): 207–215.

[18] Wong F.W.H., Lam P.T.I., Chan A.P.C., and Chan E.H.W. (2006). A Review of Buildability Performance in Hong Kong and Strategies for Improvement. *Surveying and Built Environment*. 17(2): 37-48.

[19] Griffith, A and Sidwell, T. (1995). *Constructability in Building and Engineering Projects*. Mac Millan Press. Ltd., London.

[20] Low S.P. and Abeyegoonasekera B. (2001). Integrating buildability in ISO 9000 quality management systems: case study of a condominium project. *Building and Environment*, 36(3), 299-312.

[21] Egan J. (1998). *Rethinking Construction: the Report of the Construction Task Force to the Deputy Prime Minister, John Prescott, on the Scope for Improving the Quality and Efficiency of UK Construction*. Dept. of the Environment, Transport and the Regions, London.

[22] Griffith, A. (1984). *A Critical Investigation of Factors Influencing Buildability and Constructability.* Heriot-Watt University, UK: Ph.D. Thesis.

[23] Ferguson, I. (1989). *Buildability in Practice*. Mitchell's Professional Library, 1st. Edition, London.

[24] Mahalingam, A., Kashyap, R. and Mahajan, C. (2010). An evaluation of the applicability of 4D CAD on construction projects. *Automation in Construction* 19: 148–159.

[25] Ganah, A., Anumba, C. and Bouchlaghem, N. (2000). The Use of Visualisation to Communicate Information to Construction Sites. *ARCOM 16th. Annual Conference.* 6-8 September. Glasgow Caledonian University, UK: 833-842.

[26] Adams, S. (1989). *Practical Buildability*. The Construction Industry Research and Information Association, London.

[27] Ballal T.M.A. and Sher W.D. (2003). Artificial Neural Network for the selection of buildable structural systems. *Engineering, Construction and Architectural Management*, 10(4), 263-271.

[28] Pulaski, M.H., Horman, M.J. and Riley, D.R. (2006). Constructability Practices to Manage Sustainable Building Knowledge. *Journal of Architectural Engineering.* 12(2): 83-92.