# Constructability Practices among Construction Contractors in Indonesia

Bambang Trigunarsyah, M.ASCE[1]

**Abstract:** The concept of constructability in the United States or buildability in the United Kingdom emerged in the late 1970s, which evolved from studies into how improvement can be achieved to increase cost efficiency and quality in the construction industry. It is an approach that links the design and construction processes. The studies in the Unites States, United Kingdom, and Australia have demonstrated that improved constructability has lead to significant savings in both cost and time required for completing construction projects. However, in implementing constructability improvement, it is important to consider the uniqueness of the construction industry in a specific country. This paper presents the study performed on the construction contractors in Indonesia with regard to their current constructability practices and its impact on the project performance. The study shows that many contractors in Indonesia have been implementing part of the constructability concept in their projects. The concepts that usually applied during the construction stage as part of the overall construction plan were planning the sequence of field tasks and analyzing layout, access, and temporary facilities

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## Introduction

### Construction Industry in Indonesia

In the summary of its report on the construction industry in developing countries, the World Bank (1984) stated that the construction industry is an essential contributor to the process of development. It influences most, if not all, sectors of economy. Roads, dams, irrigation work, houses, schools and other construction works are the physical foundations on which development efforts and improved living standards are established. To most developing countries, improving construction capacity and capabilities is important that include improving the efficiency, timeliness, and quality of construction works. In Indonesia, the construction industry has grown significantly since the early 1970s. Its contribution to the gross domestic product (GDP) has increased from 3.86% in 1973 to just above 8% in 1997. It constitutes about 60% of the gross fixed capital formation. The annual growth of the manpower employed by the construction industry is about 13.1%.

More than 50% of the construction works in Indonesia have been in heavy engineering construction, which provides the infrastructure, i.e., roads, ports, irrigation, power generations, and distribution, gas and water distribution, and telecommunication. Building construction constitutes about 35%. The remaining works are shared by residential and industrial construction.

Most public work projects, including any construction projects under government authority or under state owned companies, are awarded on a competitive basis using the traditional approach. Professional designers and constructors are engaged in separate contracts. The contractors usually would not be involved until the designs have been completed. Many private sector projects have also been using the similar approach.

The separation of design from production in the construction process has led to a certain amount of isolation of the professionals from technical development in construction industry (Wells 1986). This division has also been suggested as being responsible for the lack of constructability of the construction projects (Griffith 1984), which was cited as a reason for projects exceeding budgets and schedule deadlines (Construction Industry Institute Australia 1992). By separating construction from design function the project stakeholders are ignoring opportunities of significant savings in both project cost and completion time resulting from the careful interaction of planning, design, and engineering with construction (Tatum et al. 1986).

### Constructability Defined

The concept of constructability in the United States or buildability in the United Kingdom emerged in the late 1970s, which evolved from studies into how improvement can be achieved to increase cost efficiency and quality in the construction industry. It is an approach that links the design and construction processes. In this paper the constructability is defined as "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve the overall project objectives" (Construction Industry Institute 1986).

[1]Deputy Head of Department and Course Coordinator—Project Management, Civil Engineering Dept., Univ. of Indonesia, Kampus UI Depok, Depok 16424, Indonesia.

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### *Prior Research*

Early research work in the United Kingdom has focused attention upon only one genuine aspect, that of design rationalization. The primary aim of the research was to identify those factors in the design of a construction project that have an impact on site construction techniques (Griffith 1984). As a result of the research work done in 1979, the Construction Industry Research Information Association (CIRIA) (CIRIA 1983) provided seven "Guidelines for Buildability," which was later expanded into 16 "Design Principles" for practical buildability (Adams 1989).

In contrast to the United Kingdom approach, constructability researchers in the United States have placed emphasis on the management systems and involvement of owners and contractors. Constructability improvement has been considered as an integrated part of the whole project life cycle. The Construction Industry Institute (CII) (Construction Industry Institute 1987) has 14 developed constructability concepts, which were later appended with three additional concepts (Russell et al. 1992).

In Australia, the Construction Industry Institute Australia (CIIA) has also developed 12 principles of constructability based on the CII constructability concepts, which were tailored to the Australian construction industry.

## Constructability Improvement in Indonesia

There has not been a particular study in Indonesia regarding the impact of the separation of responsibility between design and construction. However, the study by Wells (1986) in several developing countries indicated that this separation has led to a certain amount of isolation of the professional from technical developments, which is reinforced by the rigid compartmentalization of training. Furthermore, the separation also means that the designer (architects/engineers) is isolated from knowledge of actual construction costs and the costs of construction based upon alternative designs. Wells argued that as long as design is divorced from the responsibility for building, the builder has practically no say in the opportunities or occasions for introducing, or making use of, innovations except to some extent in the technical organization of the actual building process.

As suggested by the research findings in Australia, implementation of constructability improvement has to consider the uniqueness of the construction industry in a specific country. Therefore, in order to improve constructability in Indonesian construction projects, it is important to assess the existing constructability practices.

**Table 1.** Type of Projects and Their Ownership

| Type of project | Type of owner: Public | Private | Total |
|---|---|---|---|
| Heavy engineering | 23 | 1 | 24 |
| Industrial | 7 | 13 | 20 |
| Buildings | 7 | 23 | 30 |
| Residential | 1 | 2 | 3 |
| Total | 38 | 39 | 77 |

### *Constructability Survey*

This paper assesses the current constructability practices among the construction project stakeholders in Indonesia. The scope of study was limited to the current constructability practices among the construction contractors particularly in their involvement in the early stages of the project life cycle and its influence in the project performance. The study was done using questionnaire surveys, which have been developed based on previous surveys and research done in the United States. As the concept of constructability has been developed in the United States, it is assumed that this concept was not known by most of the respondents. A brief explanation of the terminology and the basic concept of constructability have been included in the questionnaire survey.

Roles of contractors prior the construction stage of a project will be limited by the contractual approach implemented by the owner. In the traditional approach, for example, the contractor will not be involved until all designs have been completed. In this condition, the development and utilization of innovative construction methods can measure contractors' effort in constructability improvement. Innovative construction methods will refer to methods of deploying various construction resources that are not generally considered common practices across the construction industry and are generally creative solutions responsive to field challenges (O'Connor and Davis 1988).

From 88 responses that were received from the construction contractors, only 77 responses were included in the analysis. The main reason not to include some of the responses is mainly due to the incomplete nature of the responses. Table 1 summarizes the different types of project that the respondents constructed and the type of project ownership. Three respondents categorized their projects as others. However, as they subcontracted works for the building or heavy engineering projects, in the analysis their responses are included in the building projects or the heavy engineering projects.

Table 2 summarizes the different type contractual approaches

**Table 2.** Contractual Approaches Selected by Different Type of Owner in Different Type of Projects

| Contractual approach | Type of owner: Public | Private | Total | Type of project: Heavy eng. | Industrial | Building | Residential |
|---|---|---|---|---|---|---|---|
| Traditional | 17 | 14 | 31 | 15 | 5 | 2 | 2 |
| Owner–builder | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| Design–construct | 10 | 17 | 27 | 5 | 13 | 8 | 1 |
| Design–manage | 2 | 0 | 2 | 2 | 0 | 0 | 0 |
| Construction management | 6 | 3 | 9 | 2 | 1 | 6 | 0 |
| General contractor as construction management | 2 | 5 | 7 | 0 | 1 | 6 | 0 |
| Total | 38 | 39 | 77 | 24 | 20 | 23 | 3 |



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**Table 3.** Contractor Involvement During the Preconstruction Phases

| Involvement | No | Yes |
|---|---|---|
| C1. Contractor involvement in the conceptual phase | 50 | 27 |
| a. Advice owner in setting the project goals and objectives | | 41% |
| b. Feasibility studies and advice in site selection | | 15% |
| c. Advice owner in the contracting strategy | | 48% |
| d. Suggest structural systems | | 67% |
| e. Selection of major construction methods and materials | | 67% |
| f. Preparation of schedule, estimates, and budget | | 67% |
| g. Others | | 11% |
| C2. Contractor involvement in the design-procurement phases[a] | 46 | 31 |
| a. Analyzed design to enable efficient construction | | 61% |
| b. Review and advice accessibility of personnel, material, and equipment | | 77% |
| c. Analyzed/revised specification to allow easy construction | | 71% |
| d. Advice on source of materials and engineered equipment | | 58% |
| e. Analyzed/promoted design that facilitate construction under adverse weather condition | | 26% |
| f. Preparation of schedule, estimates and budget | | 61% |
| g. Others | | 6% |

[a]As % of the number that involved in this phase.

that were selected by the different type of owners in the different type of projects. It can be seen in this table that the heavy engineering projects are more likely to be delivered using the traditional approach, whereas the industrial projects are more likely to be delivered using the design–construct approach. In the building projects, the delivery approaches selected by the owner vary. However, it is important to note that in the construction management (CM) approach and the general contractor (GC) as the construction manager approach, the roles of the CM or the GC are usually limited to the construction phase.

## Early Contractor Involvement

The questionnaires that were given to the respondents consist of four parts (Appendix). In the first part, the respondents were asked whether they were involved in the preconstruction phases or not. It is important to understand that contractors' involvement prior to the construction stage of projects depends upon the contractual approach implemented by the project owners. Only 27 respondents (35.1%) were engaged in the project as early as the conceptual planning stage and 31 respondents (40.2%) started to be involved in the project in the design–procurement phase. Table 3 presents the list of activities that the contractors are involved in these project phases.

In the conceptual planning phase the most common activities that the contractors were involved in are: providing advice/suggestions to the project owners regarding structural systems (C1d); selecting major construction methods and materials (C1e); and preparing project schedule, estimate, and budget (C1f). As their involvement is limited by the scope of the contract, the survey results suggest that it is because of their expertise and experience in those areas that the owners require the contractors' services. The least common activity that the contractors were involved in is conducting the feasibility studies and the selection of site (C1b). The reason for this could be attributed to the preference of the owner to perform the studies by themselves or by engaging a consultant firm. Another activity that the respondents were engaged to is to develop project basic designs (C1g).

In the design-procurement stage the most common activities that the respondents were involved in include the activities: to review and provide advice regarding accessibility for personnel, materials, and equipment (C2b) and to analyze and revise specifications to allow easy construction (C2c). As in their involvement in the conceptual planning phase, it is their expertise and experience in conducting these services that is required by the owner and/or the designer in order to improve the constructability of the project. The least common activity that the respondents were involved in is the analysis and promotion of design that facilitates constructions under adverse weather. It is not surprising as Indonesian weather is relatively stable throughout the year and does not vary much in different areas except for some areas with high precipitation.

The design–construct and the design–manage approaches are

**Table 4.** Types of Project Delivery Approach Used to Engage Contractor Personnel in Preconstruction Phases

| | Conceptual planning | | | Design procurement | |
|---|---|---|---|---|---|
| Project delivery approaches | *Yes* | *No* | Total | *Yes* | *No* |
| Traditional | 31 | 0 | 31 | 31 | 0 |
| Owner–builder | 0 | 1 | 1 | 0 | 1 |
| Design–construct | 7 | 20 | 27 | 4 | 23 |
| Design–manage | 0 | 2 | 2 | 0 | 2 |
| Construction management | 6 | 3 | 9 | 5 | 4 |
| General conductor as construction management | 6 | 1 | 7 | 6 | 1 |
| Total | 50 | 27 | 77 | 46 | 31 |



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**Table 5.** Early Contractor Involvement (% Against Those Involved)

| When involved in the pre-construction phases the contractor: | No.(%) | Yes (%) | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| C3. Assigned appropriate construction personnel | 19.4 | 3.2 | — | 22.6 | 29.0 | 25.8 |
| C4. Locate the construction personnel in/close to design team office | 25.8 | 9.7 | 19.4 | 25.8 | 12.9 | 6.5 |
| C5. Proactively involved in developing project plan | 9.7 | — | 3.2 | 29.0 | 29.0 | 29.0 |
| C6. Use preconstruction plans as a basis for input to design | 6.5 | — | 19.4 | 22.6 | 25.8 | 25.8 |
| C7. Study construction method that may improve constructability | 9.7 | — | 6.5 | 12.9 | 38.7 | 32.3 |
| C8. Review and select constructability issues | 12.9 | 16.1 | 6.5 | 35.5 | 22.6 | 6.5 |
| C9. Provide a means to monitor constructability improvement activities | 16.1 | 3.2 | 22.6 | 35.5 | 19.4 | 3.2 |
| C10. Make timely input to design | 6.5 | — | 3.2 | 38.7 | 32.3 | 19.4 |



most likely to facilitate early contractor involvement, as can be seen on Table 4. Although early contractor involvement can be implemented in the CM approach, more owners tend to utilize the CM services mainly during the construction phase. When the GC acts as the construction manager, it is more likely that the contractor would not be involved in the preconstruction phases, particularly in the building projects. It is a logical consequence, as this approach is similar to the traditional approach where the design and the construction contracts are let separately.

The respondents were also asked if they were involved in those phases in regard to improving the constructability of the project. If the response is ('Yes'), the respondents were asked to rank the degree of their involvement from 1 (very low) to 5 (very high). Their responses are summarized in Table 5.

Most of the respondents stated that they had provided a timely input to the designer (C10) using a preconstruction plan as the base for their input (C6). These results suggest that for the contractor input to have a positive impact on constructability of the project, the input should be given in time. And a preconstruction plan is the best reference on when is the best time to incorporate the input. Attaching the construction personnel (representatives) to or locating them in close physical proximity to the design team (C4) was the least common method that the respondents had performed during those stages. One possible reason could be the use of regular project meetings using the preconstruction plan as the basis to facilitate construction input to design.

From the 31 respondents that were involved in the preconstruction phases, seven are state-owned construction companies (BUMN), 13 are private (national) construction companies, and 11 are multinational enterprises. There is no significant difference in the degree of involvement among the different types of contractor except for assigning appropriate construction personnel (C3), as presented on Table 6. The mean rank comparison from the Kruskal–Wallis test suggests that the involvement of the private contractors in assigning appropriate construction personnel is higher compared to the BUMN or multinational contractors.

However, the same table shows that there are some significant differences in the degree of involvement in some activities among the contractors in the different types of project. Those activities are: assigning appropriate construction personnel (C3), involved in developing project plan (C5), studying construction method that may improve constructability (C7), and providing a means to monitor constructability improvement (C9). The degree of involvement of the industrial project contractors is more likely to be the highest among the contractors building the different types of projects. The involvement of the heavy engineering contractors, on the other hand, is the lowest. The response from the respondent who builds residential projects is not included in this particular analysis because there is only one response received.

**Table 6.** Kruskal–Wallis Test Results: Early Contractor Involvement

| Activity | Type of contractors | | Type of project | |
|---|---|---|---|---|
| | Chi square | *p* value | Chi square | *p* value |
| C3 | 11.328 | 0.003 | 7.465 | 0.024 |
| C4 | 0.809 | 0.667 | 2.413 | 0.299 |
| C5 | 3.415 | 0.181 | 11.332 | 0.003 |
| C6 | 0.988 | 0.610 | 3.484 | 0.175 |
| C7 | 4.353 | 0.113 | 6.184 | 0.045 |
| C8 | 1.098 | 0.578 | 5.082 | 0.079 |
| C9 | 0.636 | 0.728 | 8.941 | 0.011 |
| C10 | 3.334 | 0.189 | 4.704 | 0.095 |
| D11 | 1.784 | 0.410 | 2.515 | 0.284 |
| D12 | 0.093 | 0.955 | 0.922 | 0.631 |
| D13 | 3.819 | 0.148 | 2.226 | 0.329 |
| D14 | 2.004 | 0.367 | 0.418 | 0.811 |
| D15 | 2.553 | 0.279 | 1.199 | 0.549 |
| D16 | 1.952 | 0.377 | 1.123 | 0.570 |



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**Table 7.** Constructability during Field Operations

| In the construction phase the contractor | No. (%) | Yes (%) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| D11. Carefully analyzed layout, access and temporary facilities | 2.6 | 1.3 | — | 9.2 | 35.5 | 51.3 |
| D12. Plan the sequence of field tasks to improve productivity | — | — | 1.3 | 10.4 | 24.7 | 63.6 |
| D13. Use hand tools that reduce labor activities, increase mobility, accessibility, safety or reliability | 11.7 | — | — | 22.1 | 31.2 | 63.6 |
| D14. Customize or upgrade construction equipment to improve productivity | 14.3 | 2.6 | 2.6 | 27.3 | 29.9 | 23.4 |
| D15. Use innovative construction equipment | 11.7 | 5.2 | 7.8 | 46.8 | 10.4 | 18.2 |
| D16. Use modularization/pre-assembly work | 19.5 | 3.9 | 6.5 | 32.5 | 22.1 | 15.6 |
| D17. Others | 90.9 | | | 9.1 | | |

### Constructability Improvement during Field Operations

In the second part of the questionnaires, the respondents were asked about their roles in the construction stage related to constructability improvement effort. As the involvement of the contractors in the early stages of projects is very dependent upon the owners and owners' selection of a contractual approach, it is then important to assess the roles of the contractor in improving constructability during the construction phase. Although decisions related to field operation constructability tend to be relatively low leverage decisions, CII (1987) suggested that collectively they offer substantial benefits. The concept recommended by CII to improve constructability during field operation is a development and utilization of innovative construction methods, which can simplify construction effort and reduce project cost.

Table 7 summarizes the contractor activities during the construction phase related to constructability improvement. The most common activities that were performed by the respondents are preparing an effective sequence of field tasks (D12) and carefully analyzing site layout, access and temporary facilities to improve productivity (D11). Good construction planning is the basis for effective and efficient construction activities that can be monitored and controlled to achieve project objectives (ASCE 1990). Hence, it would be a logical priority for the contractors to achieve optimum project results. In addition to that an efficient layout, access, and temporary facilities can have the effect of reducing labor intensity, reducing the likelihood of delays in providing for utilities, or improving the work environment (O'Connor and Davis 1988). The least common activity that was performed by the respondents is the use of a modularization/preassembly work (D16). The other activities that some of the respondents performed in regard to improving the constructability of their projects include the activities to conduct value engineering and to improve site transportation system for materials and labors.

The Kruskal–Wallis test is performed to assess how these activities were performed by the different types of contractor and in the different types of project. Table 8 summarizes the chi-square values and the related $p$ values results of that analysis. It can be seen in this table that there is no significant difference among the different type of contractors in their role in improving constructability during the construction phase. Similarly, there is no significant difference in how those activities are performed by contractors in the different types of project.

### Typical Constructability Problems

In order to assess the influence of the early contractors' involvement on the constructability of the project, in part three of the questionnaires the respondents were asked about typical problems that they faced during the construction period. For each problem they encountered, the respondents were asked to rank the degree of the problem from 1 (very low) to 5 (very high). Table 9 summarizes the common constructability problems faced by the 'contractor' respondents during the construction period.

The most common problems that were encountered by the respondents are related to construction tolerance (E19) and specifications (E18). The less common problems are related to unrealistic schedule (E22), weather (E21), and physical interference (E20). There are other problems (E23) that the respondents face during the construction phase. Those problems include the problems with design changes/revisions, late decisions in some detailed design, unclear scope of works and inaccurate geotechnical data. Some respondents also have problems regarding access to project sites due to conflicts in land acquisition, permit from local community and availability of heavy equipment. The other problems include coordination among different contractors in the case of multiple contracts, client or main contractor late supply of materials/equipment and selection of nominated contractor.

Table 10 summarizes $Z$ values and their related $p$ values from the Mann–Whitney U test on the typical problems against the type of owner. This table also presents the Kruskal–Wallis test

**Table 8.** Differences in Constructability Improvement during Construction Phase

| Constructability improvement activities | Type of contractors: Chi square | Type of contractors: $p$ value | Type of project: Chi square | Type of project: $p$ value |
|---|---|---|---|---|
| D11 | 1.784 | 0.410 | 2.515 | 0.284 |
| D12 | 0.093 | 0.955 | 0.922 | 0.631 |
| D13 | 3.819 | 0.148 | 2.226 | 0.329 |
| D14 | 2.004 | 0.367 | 0.418 | 0.811 |
| D15 | 2.553 | 0.279 | 1.199 | 0.549 |
| D16 | 1.952 | 0.377 | 1.123 | 0.570 |



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**Table 9.** Typical Constructability Problems

| Typical problems encountered by the contractor during the construction phase | No. (%) | Yes (%) | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| E18. Specification problems | 18.2 | 6.5 | 36.4 | 23.4 | 10.4 | 5.2 |
| E19. Tolerance problems | 16.9 | 11.7 | 22.1 | 36.4 | 7.8 | 5.2 |
| E20. Problems with physical interference | 31.6 | 18.4 | 19.7 | 21.1 | 5.3 | 3.9 |
| E21. Weather related problems that could be avoided during design phase | 30.3 | 17.1 | 13.2 | 25.0 | 9.2 | 5.3 |
| E22. Unrealistic schedule | 29.9 | 10.4 | 19.5 | 24.7 | 7.8 | 7.8 |
| E23. Others | 77.9 | | | 22.1 | | |



results on the typical problems against the type of designer, the type of project and the type of project delivery. These analyses are performed to assess the difference in the occurrence of those typical problems in the different types of owner, designer, project and project delivery.

It can be seen in Table 10 that there is no significant difference in the degree of the problems between the two types of project owner. Similarly, there is also no significant difference in the degree of the problems among the projects designed by the different types of project designer or among the different types of project. However, there are some significant differences in the degree of the problems among the projects in the different types of delivery/contractual system. Those problems are specification problem (E18), tolerance problem (E19), and unrealistic schedule (E22). The mean rank comparison from the Kruskal–Wallis test indicates that the degree of those problems are more likely to be lower when the projects are delivered using the design–construct or design–manage approach compared with the projects delivered using the other types of contractual approaches. It is also found that the degree of those problems tends to be high when the projects are delivered using the traditional approach.

### Impact of Early Contractor Involvement in Reducing Constructability Problems

The Mann–Whitney U tests and correlation analyses are used to assess the impact of early contractor involvement on project performances. The project performances in this case are the typical problems that the contractors encountered during the construction phase as presented in Table 9. Table 11 presents the $Z$ values and the related $p$ values of the Mann–Whitney U test, which is used to analyze the differences in the degree of the typical constructability problems due to the involvement of contractors in the preconstruction phases. Table 12 summarizes the nonparametric correlation coefficients between the typical constructability problems and how the contractors were involved in the early stages of the project.

It can be seen in Table 11 that when the contractors are involved in the conceptual planning phase, this results in a lower degree of problems in construction tolerances (E19), specifications (E18) and weather related problems (E21). Similarly, the contractor involvement in the design–procurement phase could lead to a lower degree of problems in construction tolerance (E19) and specifications (E18).

Negative correlation coefficients on Table 12 suggest that early contractor involvement could reduce the problems during the construction period. The two problems that are influenced the most by the contractor involvement in the preconstruction phases are the problems related to construction tolerances (E19) and specifications (E19). It is not a coincidence that the highest influence occurs against the two most common problems that contractors encountered during this period. As a logical consequence of having the knowledge and experience of facing these problems the contractors would concentrate their early involvement in avoiding or reducing the occurrence of these problems in the construction phase.

Table 13 summarizes the respondents' responses on the questions related to early contractor involvement. It can be seen in this table that most of the respondents (97%) agree that their involvement in the early phases of the projects can avoid those problems and produce better constructable projects. They also agree that during the early phases of projects, construction should be included as another specialty like architectural, structural, mechanical, electrical etc.

### Project Performances

In the last part of the questionnaire, the contractors were asked to assess the overall performances of the projects that they had constructed in terms of project cost, time, quality, and safety. For project time and cost performances, the respondents were asked to describe their project performances as behind schedule/ exceeding budget, within schedule/budget, or ahead of schedule/ less than budget. If the response was "behind" schedule or "exceed" budget, it was scored 1–4. If the response was "within" schedule/budget, it was scored 5. If the answer was "ahead of" schedule or "less than" budget, it was scored 6–8. For project

**Table 10.** Difference in Occurrence of Typical Constructability Problems

| Typical problems | Type of owner | | Type of designer | | Type of project | | Project delivery | |
|---|---|---|---|---|---|---|---|---|
| | $Z$ values | $p$ value | Chi square | $p$ value | Chi square | $p$ value | Chi square | $p$ value |
| E18 | −0.519 | 0.604 | 1.775 | 0.412 | 1.949 | 0.377 | 6.599 | 0.037 |
| E19 | −0.062 | 0.951 | 1.145 | 0.564 | 0.347 | 0.841 | 7.101 | 0.029 |
| E20 | −0.142 | 0.887 | 1.134 | 0.567 | 0.581 | 0.748 | 0.108 | 0.947 |
| E21 | −1.321 | 0.187 | 0.001 | 1.000 | 4.295 | 0.117 | 3.931 | 0.140 |
| E22 | −0.200 | 0.842 | 5.036 | 0.081 | 1.593 | 0.451 | 6.023 | 0.049 |



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**Table 11.** Differences in Occurrence of Typical Problems due to Early Contractor Involvement

| Typical constructability problems | Contractors involved in: Conceptual planning | | Design and procurement | |
|---|---|---|---|---|
| | $Z$ value | $p$ value | $Z$ value | $p$ value |
| E18. Specification | −2.389 | 0.017 | −2.346 | 0.019 |
| E19. Tolerance | −2.071 | 0.038 | -−2.515 | 0.012 |
| E20. Physical interference | −0.888 | 0.375 | −1.006 | 0.315 |
| E21. Weather related | −2.106 | 0.035 | −1.449 | 0.147 |
| E22. Unrealistic schedule | −1.052 | 0.293 | −1.104 | 0.270 |

**Table 13.** Responses on Early Construction Involvement to Avoid Constructability Problems

| The respondents agreed that | No. (%) | Yes (%) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| E24. Early contractor involvement could avoid the constructability problems | 2.6 | — | 3.9 | 10.4 | 35.1 | 48.1 |
| E25. Construction should be included as another discipline | 3.9 | 1.3 | 1.3 | 23.4 | 35.1 | 35.1 |



quality and safety performances, the owners were asked to score their project from 1 (poor) to 6 (good). Their responses are summarized in Table 14.

Seventy three of the 77 contractors responded to the question on project cost. Of these, 30% of them stated that their projects were completed within the budget, 34% completed their projects less than the budget, and the remaining 36% stated that their project exceeded the budget. Seventy four of the contractors answered the question on time schedules. Of these, 47% stated that their projects were completed within the schedule, 15% of them completed their projects ahead of schedule, and 38% of them stated that their projects were completed behind schedule. Seventy six of the contractors answered the questions on project quality. Of these, 33% of the respondents assessed their project quality as "average" (score 3 or 4) and the other 67% assessed their project quality as "good" (score 5 or 6). Seventy four of the contractors answered the question on project safety performance. Of these, 34% graded their projects "average" and the other 66% of the respondents graded their project "good."

The Kruskal–Wallis test was used to determine whether there were any differences on project performances for the different types of contractor, the different types of project and the different types of project delivery approach. The results of this test (Table 15) show that there was no significant difference on the overall project performances among the different project delivery approaches. The only significant difference in the project performances among the different types of contractor and among the different types of project was for project cost performance. The mean rank comparison from the Kruskal–Wallis test suggests that the overall cost performance of the projects built by the private-national contractors is better than the state-owned (BUMN) contractors and multinational contractors. It is interesting to note that the overall cost performance of the project built by multinational contractors was the lowest of the three. The mean rank comparison also suggests that the overall cost performance of industrial construction projects is better than the cost performance of the other types of project. The overall project cost performance of heavy engineering construction projects was the poorest of the four types of project.

Nonparametric correlation analysis was performed to assess the influence of the different variables, i.e., C3–E23, on the project performances. Table 16 summarizes the correlation coefficients and the related $p$ values of the different variables against project performances. For variables C3–C10, only the contractors who were involved in the preconstruction stages were included in the analysis.

A significant positive correlation between was found between variable C10 (make a timely input to design) and project cost performance. It was also found that some of the current constructability practices performed in the construction stage have significant correlation with the project performances. Good planning of sequences of field tasks (D12), for example, may lead to better project quality and project safety.

This table also shows that some of the constructability problems that occur during the construction phase negatively influence the project performance. As might be expected, problems related to physical interference (E20), weather related problems that could be avoided by appropriate attention during the design phase (E21), and some other problems categorized in variable E23 negatively influence the project cost performance. As might also be expected, problems relating to construction tolerance lead to lower performances in regards to project time and project quality.

## Conclusions

### *Current Constructability Practices among Construction Contractors in Indonesia*

The concept of constructability was developed in the United States. However, a constructability survey conducted among con-

**Table 12.** Correlation Coefficients: Typical Constructability Problems

| | E18 Coefficient | E18 $p$ value | E19 Coefficient | E19 $p$ value | E20 Coeffcient | E20 $p$ value | E21 Coeffcient | E21 $p$ value | E22 Coefficient | E22 $p$ value |
|---|---|---|---|---|---|---|---|---|---|---|
| C3 | −0.262[a] | 0.022 | −0.335[a] | 0.003 | 0.011 | 0.928 | −0.197 | 0.089 | −0.137 | 0.236 |
| C4 | −0.194[a] | 0.091 | −0.259[a] | 0.023 | 0.013 | 0.910 | −0.179 | 0.122 | −0.093 | 0.422 |
| C5 | −0.286[a] | 0.012 | −0.357[a] | 0.002 | −0.012 | 0.919 | −0.240 | 0.038 | −0.204 | 0.078 |
| C6 | −0.295[a] | 0.009 | −0.309[a] | 0.006 | 0.088 | 0.448 | −0.146 | 0.207 | −0.208 | 0.069 |
| C7 | −0.311[a] | 0.006 | −0.379[a] | 0.001 | −0.033 | 0.779 | −0.248[a] | 0.030 | −0.198 | 0.084 |
| C8 | −0.220 | 0.055 | −0.264[a] | 0.020 | 0.039 | 0.741 | −0.152 | 0.191 | −0.188 | 0.101 |
| C9 | −0.233[a] | 0.042 | −0.321[a] | 0.004 | −0.014 | 0.903 | −0.189 | 0.102 | −0.216 | 0.059 |
| C10 | −0.268[a] | 0.018 | −0.300[a] | 0.008 | 0.013 | 0.910 | −0.171 | 0.139 | −0.207 | 0.071 |

[a]Correlation is significant at the 0.05 level.



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**Table 14.** Project Performances

| Project performance relating to project | Mean | Median |
|---|---|---|
| Time (F26) | 4.8 | 5.0 |
| Cost (F27) | 4.2 | 5.0 |
| Quality (F28) | 5.0 | 5.0 |
| Safety (F29) | 4.9 | 5.0 |

**Table 15.** Differences on Project Performances

| | Type of contractor | | Type of project | | Project delivery | |
|---|---|---|---|---|---|---|
| Project performances | Chi square | *p* value | Chi square | *p* value | Chi square | *p* value |
| E26 = cost | 7.783 | 0.020 | 8.381 | 0.039 | 2.783 | 0.426 |
| E27 = time | 1.289 | 0.525 | 3.211 | 0.360 | 3.964 | 0.265 |
| E28 = quality | 3.155 | 0.206 | 0.871 | 0.832 | 4.871 | 0.182 |
| E29 = Safety | 2.069 | 0.355 | 0.975 | 0.807 | 3.752 | 0.290 |

**Table 16.** Nonparametric correlation

| | E26 | | E27 | | E28 | | E29 | |
|---|---|---|---|---|---|---|---|---|
| Activity | Coefficient | *p* value | Coefficient | *p* value | Coefficient | *p* value | Coefficient | *p* value |
| C3 | 0.259 | 0.183 | 0.023 | 0.909 | 0.051 | 0.788 | 0.65 | 0.743 |
| C4 | −0.018 | 0.927 | −0.095 | 0.632 | −0.202 | 0.285 | −0.198 | 0.313 |
| C5 | 0.286 | 0.140 | −0.129 | 0.515 | −0.016 | 0.933 | −0.058 | 0.771 |
| C6 | −0.019 | 0.922 | −0.121 | 0.541 | −0.221 | 0.241 | −0.084 | 0.669 |
| C7 | 0.313 | 0.104 | 0.006 | 0.977 | 0.186 | 0.325 | 0.235 | 0.229 |
| C8 | 0.057 | 0.771 | 0.123 | 0.534 | −0.175 | 0354 | −0.102 | 0.605 |
| C9 | 0.251 | 0.198 | 0.099 | 0.615 | 0.105 | 0.581 | −0.140 | 0.478 |
| C10 | 0.510[a] | 0.006 | 0.005 | 0.979 | 0.71 | 0.367 | 0.261 | 0.180 |
| D11 | −0.073 | 0.541 | 0.024 | 0.839 | 0.085 | 0.468 | 0.046 | 0.698 |
| D12 | 0.003 | 0.981 | 0.130 | 0.268 | 0.357 | 0.002 | 0.374 | 0.001 |
| D13 | −0.025 | 0.836 | 0.042 | 0.722 | 0.238 | 0.039 | 0.153 | 0.193 |
| D14 | −0.042 | 0.723 | −0.116 | 0.326 | 0.080 | 0.493 | 0.129 | 0.273 |
| D15 | −0.082 | 0.489 | −0.099 | 0.404 | −0.036 | 0.759 | 0.021 | 0.861 |
| D16 | −0.008 | 0.946 | 0.007 | 0.954 | −0.022 | 0.853 | 0.016 | 0.895 |
| D17 | −0.082 | 0.490 | −0.042 | 0.724 | 0.030 | 0.799 | −0.175 | 0.135 |
| E18 | −0.066 | 0.577 | −0.143 | 0.226 | −0.156 | 0.179 | −0.158 | 0.179 |
| E19 | −0.137 | 0.247 | −0.357* | 0.002 | −0.226* | 0.050 | −0.176 | 0.134 |
| E20 | −0.286[a] | 0.015 | −0.196 | 0.097 | −0.141 | 0.228 | −0.115 | 0.333 |
| E21 | −0.274[a] | 0.020 | −0.039 | 0.746 | −0.148 | 0.206 | −0.141 | 0.235 |
| E22 | −0.147 | 0.214 | −0.171 | 0.145 | 0.023 | 0.847 | −0.090 | 0.444 |
| E23 | −0.278[a] | 0.017 | −0.169 | 0.151 | −0.059 | 0.611 | −0.154 | 0.192 |

[a]Correlation is significant at the 0.05 level.

struction contractors suggested that, with limitations, many contractors in Indonesia have been implementing part of the concept in their projects. The concepts that usually applied during the construction stage as part of the overall construction plan were planning the sequence of field tasks and analyzing layout, access, and temporary facilities.

Contractor involvement in preconstruction phases would depend on the owner and owner selections of project delivery systems. When engaged early in the project life cycle, contractors in Indonesia have also shown some implementation of the constructability concept. In the conceptual phase of the project, the main activities performed by contractors were providing advice/suggestions to the project owner regarding structural systems, selection of major construction methods and material, and preparation of schedule, estimate, and budget. In the design–procurement stage, the most common activities contractors involved with were reviewing and providing advice regarding accessibility for personnel, materials and equipment; and analyzing and revising specification to allow easy construction. The most common activities or services that contractors were involved with were in line with their expertise and experience as constructors of projects.

Contractor early involvement in the project life cycle could lead to a better project performance in terms of less problem occurrences. The survey results point to the fact that contractor involvement in preconstruction phases could reduce the problems during field operation. The survey results also suggested that it is important for the contractors to provide a timely input to design using a preconstruction plan as the basis of their input.

## Further Studies

Constructability improvement required contribution from all project stakeholders. It is then important to conduct a similar constructability survey against the other main construction project stakeholders, i.e., owner and designer.

The next step would be case studies for in-depth investigation of the constructability practices in the Indonesian construction industry in implementing the CII's constructability concepts. As suggested by the Australian CII (Francis and Sidwell 1996) it is important to consider the uniqueness of the construction industry in a specific country in implementing constructability improvement.

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**APPENDIX: Questionnaire form**

**Part A. Company Details**

**Name of Company/Organisation:**________________________________

**Address :** ____________________________________________

**Phone No.** : ______________ **Fax No.:** ______________

**Name of Respondent (Optional):** ________________________________

**Title or Position of Respondent:** ________________________________

**Type of ownership of your organisation/company**

- State owned company (BUMN/BUMD) ..................................... 1 ☐
- Private company (National) .................................................... 2 ☐
- Multi-national ............................................................... 3 ☐

**What best described your type of organisation**

- General Contractor ........................................................... 1 ☐
- Design-Construction Contractor ............................................. 2 ☐
- Subcontractor ................................................................. 3 ☐
- Others (please specify: __________________________) ............. 4 ☐

**Typical type of project your company work on**

- Heavy engineering (infrastructure) (*)....................................... 1 ☐
- Industrial engineering (**)...................................................... 2 ☐
- Buildings (***) ...................................................................3 ☐
- Housing .......................................................................... 4 ☐
- Others (.......................................................................) 5 ☐

(*) *include structures for power generation and distribution, flood control, irrigation, bridges, transportation structures, pipeline, water distribution system, treatment and disposal systems, and communication networks*

(**) *include petroleum refineries & petrochemical plants, mine developments, steel mills, large heavy-manufacturing plants, and other facilities essential to our utilities and basic industries*

(***) *include architectural, structural, mechanical & electrical works*

**Your annual volume of works: Rp./ US$** ________________________

**Part B. Project Details**

**Name of the Project :** ____________________________________

**Project Owner :** ____________________________________________

**Type of organisation/company of the Project Owner:**

- Government institution (dept.) ............................................. 1 ☐
- State owned company (BUMN/BUMD) ..................................... 2 ☐
- Private company (National) .................................................. 3 ☐
- Multi-national ............................................................... 4 ☐





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**Type of project:**

| | | |
|---|---|---|
| Heavy engineering (infrastructure) | 1 | ☐ |
| Industrial engineering | 2 | ☐ |
| Buildings | 3 | ☐ |
| Housing | 4 | ☐ |
| Others ( ________ ) | 5 | ☐ |

**Project Location** : ____________________

____________________

**Project Values : Rp./US$** ____________________

**Project Duration** : ____________________

**Contractual approach to this project**

| | | |
|---|---|---|
| Traditional (separate designer and single general contractor) | 1 | ☐ |
| Design-construct | 2 | ☐ |
| Design-manage | 3 | ☐ |
| Construction manager | 4 | ☐ |
| General contractor as a construction manager | 5 | ☐ |
| Other (please specify: ________ ) | 6 | ☐ |

**Your company scope of works on this project**

| | | |
|---|---|---|
| General Contractor | 1 | ☐ |
| Subcontractor | 2 | ☐ |
| Design-construct | 3 | ☐ |
| Construction Management | 4 | ☐ |
| Others (please speciy: ________ ) | 5 | ☐ |

**Design Consultant :** ____________________

| | | |
|---|---|---|
| State owned company (BUMN/BUMD) | 1 | ☐ |
| Private company (National) | 2 | ☐ |
| Multi-national | 3 | ☐ |

Address : ____________________

Number of years of experience in similar projects : ________ years





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## Part C. Early Construction Involvement

I-1. Did your organisation participated in the conceptual phase of this project:

- ☐ No
- ☐ Yes, in the following activities: (check all that apply)
  - ☐ Advice owner in the establishment of the project goals and objectives
  - ☐ Execution of feasibility studies and advice in selection of site
  - ☐ Advice owner in the contracting strategy
  - ☐ Suggest structural systems
  - ☐ Selection of major construction method and materials
  - ☐ Preparation of schedule, estimates and budget
  - ☐ Others (specify: ________________________________)

I-2. Did your organization participated in the design-procurement phase of the project:

- ☐ No
- ☐ Yes, in the following activities: (check all that apply)
  - ☐ Analysed the design to enable efficient construction
  - ☐ Review and advice accessibility of personnel, material and equipment
  - ☐ Analysed/revised specifications to allow easy construction
  - ☐ Advice design team about sources of materials and engineered equipment
  - ☐ Analysed/promote designs that facilitate construction under adverse weather conditions
  - ☐ Preparation of schedule, estimates and budget
  - ☐ Others (specify: ________________________________)





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**If you answer 'Yes' for question no. 1 and/or 2 please answer the following questions. If you answer 'No' for both questions please go to question no. 11**

| ***When you involved in the conceptual phase and/or the design-procurement phase of this project, do you:*** | **Yes** | | | | | **No** |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | |
| 3. carefully assign appropriate construction personnel who has the required experience and team approach to the project team | | | | | | |
| 4. attach the construction personnel (representatives) to or locate them in close physical proximity to the design team | | | | | | |
| 5. pro-actively involved in developing project plans | | | | | | |
| 6. use pre-construction plans as a basis for input to design | | | | | | |
| 7. study construction method that may improve constructability of the project | | | | | | |
| 8. review and select constructability issues which are most important to the project including the need for special studies | | | | | | |
| 9. provide a means to monitor constructability improvement activities | | | | | | |
| 10. make timely input to design to avoid the need for changes | | | | | | |

## Part D. Constructability Improvement during Field Operations

| ***During the construction phase of the project do you:*** | **Yes** | | | | | **No** |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | |
| 11. carefully analysed the layout, access, and temporary facilities to improve productivity | | | | | | |
| 12. plan the sequence of field tasks to improve productivity | | | | | | |
| 13. use hand tools that reduce labour activities, increase mobility, accessibility, safety or reliability | | | | | | |
| 14. customise or upgrade your construction equipment to improve productivity | | | | | | |
| 15. use innovative construction equipment | | | | | | |
| 16. use modularisation/pre-assembly works | | | | | | |

I-17. Please specify other innovative methods (if any) that you use during field construction works that improved productivity:

________________________________________

________________________________________



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## Part E. Constructability Problems

| *During the construction phase of the project do you encounter the following difficulties:* | Yes | | | | | No |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| 18. specification problems | | | | | | |
| 19. tolerance problems | | | | | | |
| 20. problems with physical interference | | | | | | |
| 21. weather related problems that could be avoided during design phase | | | | | | |
| 22. unrealistic schedule | | | | | | |
| 23. other problems that could be avoided during design phase (specify: ____________________ ) | | | | | | |

I-24. Do you agree that participation of contractors during the early phases of the project (conceptual planning and detailed design) could avoid these problems and produce better constructable project?

| Yes | | | | | No |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | |
| | | | | | |

I-25. Do you think construction should be included as another specialty during the early phases (conceptual planning and detailed design) of the project such as architectural, structural, mechanical, electrical, etc.?

| Yes | | | | | No |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | |
| | | | | | |





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## Part F. Project Performance

**I-26. Project Costs**

| Less than Original Budget | | | Within Budget | Bigger than Original Budget | | | |
|---|---|---|---|---|---|---|---|
| >10% | 5-10% | 0-5% | | 0-5% | 5-10% | 10-15% | >15% |
| | | | | | | | |

State the main reason (briefly) : ______________________________

______________________________

______________________________

**I-27. Project Time (Schedule)**

| Ahead of schedule | | | Within Schedule | Exceeded schedule | | | |
|---|---|---|---|---|---|---|---|
| >10% | 5-10% | 0-5% | | 0-5% | 5-10% | 10-15% | >15% |
| | | | | | | | |

State the main reason (briefly) : ______________________________

______________________________

______________________________

| | Poor 1 | 2 | 3 | 4 | 5 | Good 6 |
|---|---|---|---|---|---|---|
| **28. Project Quality** | | | | | | |
| **29. Project Safety** | | | | | | |

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