Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.8, No.3, 2016

Constructability Concepts and Enhancement Capabilities of Construction Site Team Members in Obafemi Awolowo University, Ile-Ife, Nigeria

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Abstract
The application of constructability principles is as important as the principles themselves, and the construction site is where the application can be carried out. The integrated efforts required to improve constructability on construction sites can be derived from project members' team work. Constructability is a team effort making it imperative to have the team collectively define constructability challenges, opportunities and solutions; owing to the need to share construction innovations within and across site team members. In spite of this, few researches have been done related to constructability enhancement at the construction stage by the construction site team members. To address this, a total of 60 questionnaire were administered to site team members on construction sites in Obafemi Awolowo University with a response rate of 70%. Percentage frequency was used together with Relative Importance Index (RII) to analyse the data that was collected. Findings show that respondents have practical knowledge of constructability concepts and are capable of implementing them on construction sites. Effective planning of access to site ranked 1st with RII of 0.929 among the technical capabilities of the respondents; and also the capabilities of site engineers and resident builders to keep progress and quality management records ranked 1st among their constructability enhancement capabilities.
Keywords: Constructability, constructability concepts, constructability enhancement techniques.

1. Introduction

Constructability is the best use of construction knowledge and experience in the planning, design, procurement and site operations to achieve overall project objectives (Construction Industry Institute, 1987, 2012). It concerns balancing the various project and environmental constraints to achieve project goals and building performance at an optimal level (Construction Industry Institute Australia, 1992 cited in Akpan et al., 2014). Also, it measures the ease or expediency of construction (Highway Constructability Guide, 1990) and addresses lack of integration between design and construction processes (Rosli, 2004 cited in Zolfagharian et al., 2012). Bakti and Trigunarsyah (2003) observed that constructability requires the integration of the knowledge and experience of project team members in project delivery. Wong et al. (2006) opined that constructability was proposed to improve cost-effectiveness and quality of the Construction Industry and to ensure that design follow practicable construction methods.

As stated by Akpan et al. (2014), Construction Industry Institute, (2012), Highway Construction Guide (1990), Ruby et al. (2007) and Trigunarsyah et al. (2007), constructability reduces overall project costs 4.3% on average, reduces project schedule 7.5% on average, improves project security and safety, increases project quality, and improves project team relationships. The application of constructability principles is as important as the principles themselves, and the construction site is where the application can be carried out. Construction Industry Institute (1987) noted that constructability concept is more comprehensive than buildability concept as constructability covers the overall management systems in the building development, procurement and production process and site operations; while buildability deals only with the development of building designs and deliverables. Zolfagharian et al. (2012) argued that constructability principles should not only be limited to design stage; though construction follows the design but beside the implementation of constructability at the design stage, its benefits can be enhanced during the whole project lifecycle and especially during site operations. In line with this argument, Ruby et al. (2007) argued that constructability brings construction perspective into design stage and enables the development of creative solutions to design problems and enhancement of projects' value. Akpan et al. (2014) attributed failures of construction projects in Nigeria to lack of constructability practices on construction sites. The integrated efforts required to improve constructability on construction sites can be derived from project members' team work (Bakti and Trigunarsyah, 2003). Constructability is a team effort making it imperative to have the team collectively define constructability challenges, opportunities and solutions; owing to the need to share construction innovations within and across site team members. The site team innovations and contributions may be small in scope but are numerous in quantity and collectively have significant effect (University of Texas, 1997).

Tradesmen and professionals are technical experts in their respective field and must therefore be allowed to improve constructability through their suggestions, reviews and request for material and methods substitution. Achieving constructability objectives is the responsibility of all project participants and the

implementation of its principles cannot be successful without the possession of technical skills by the project team members and the establishment of strong communication routines among project parties (Othman, 2011). According to Highway Constructability Guide (1990), the nature of the construction operation and the higher performance expectations by the clients necessitated the pursuance and enhancement of constructability during the planning and execution of projects; and also, a proactive approach to constructability needs to be taken including greater participation of project parties. Chua (2003) noted that it is important that constructability principles become an integral part team members because constructability enhancement is multidisciplinary and multifaceted and means different things to the project team; and also because the efficiency and effectiveness of construction can only be improved on site through task sequencing, innovative use of resources and equipment.

Constructability input in project design includes knowledge of local factors and site conditions that can influence the choice of construction methods, design and feasible schedule; and only the selection of experienced team members with team working skills and openness to new ideas gives chance for implementation and enhancement of constructability (Construction Industry Institute, 2012; Chua, 2003). A lot of works have been done on the implementation and enhancement of constructability during the design stage. However, few studies have been done related to constructability enhancement during the actual construction stage by the construction team members. Therefore, this study aims to study constructability concepts and enhancement capabilities of construction site team members. In order to achieve this aim, the following objectives would have to be accomplished: identification of applicable constructability concepts on construction sites by the site team members, examination of the technical capabilities of construction site team members, examination of the capabilities of construction site team members to enhance constructability, and assessment of ways of enhancing constructability on construction sites.

2. Constructability concepts

In a survey of constructability practice in the Nigerian Construction Industry, Akpan et al (2014) found that constructability concepts and techniques are not being applied appropriately in Nigeria as found in the developed countries. Also, Nima et al. (2001) found that constructability concepts are not being practised in the Malaysian Construction Industry. Towards the improvement of highway construction in Malaysia, Rosli and Siti (2006) carried out a survey of constructability concepts that are suitable to be implemented in highway construction projects in Malaysia. The study identified eighteen concepts that designers of highways need to consider during the design process. Akpan et al. (2014) further identified twenty principles of constructability, these includes; site investigation, project plan development, selection of construction methods, involvement of construction personnel, understanding clients corporate and project objectives, construction driven schedule, simplification of erection process, standardization, modularization, virtual construction, practical sequence of work, storage consideration, safe construction systems, design for available skills, use of suitable materials, plant maximization, provision of clear and detail information, allowance for sensible tolerances, avoidance of return visits by trades and consideration of adverse effects of weather in the selection of construction materials. Chua (2003) identified the constructability process as follows; organization of the design team, collection of data, constraints identification, program development, evaluation of construction methods option, development of preliminary design, options checking, final design, bid package development, bidding procedure, fabrication procedure, and installation process. Similarly, Highway Constructability Guide (1990) and Center for Transportation Research (1989) identified the considerable factors during the development of a project for constructability; the factors are environmental factors such as available technology, accessibility, topographical, economical, sociological and regulations; project scope, information and communication, resources, construction methods, control, and innovation. The principles of constructability, according to Construction Industry Research Information Association (1983) includes the integration of constructability as an integral part of the project plan; incorporation of construction expertise in project planning; appropriation of experience and skills in the composition of the project team; an understanding of the clients' corporate and project objectives; matching of technology with the available skills and resources; setting realistic objectives; consideration of construction methods; consideration of accessibility and efficiency in the specification of development; and undertaking post construction analysis of the project. The general principle of constructability is to provide design configurations that will reduce site operations and increase standardization and task repeatability (Chua, 2003). According to the American Society of Civil Engineers cited in Griffith and Sidewell (1995), constructability should include evaluating the various design options, assessing project systems and their interface requirement with other project components, understanding trade skills and practices and plant and equipment, appreciation of local climatic conditions, determining availability of space and access routes on site, and evaluating site conditions in relation to their effects on construction.

2.1 Constructability enhancement techniques

Constructability enhancement requires efforts in carrying out through site and ground investigation prior to

design; coordinating design documents, components and working sequences; and designing for standardization, repetition, safety and ease of construction (Lam et al., 2005). Nima et al. (1999) opined that the designers should take project site layout into consideration; prepare designs that promote accessibility of manpower, material and equipment; and prepare designs that facilitate construction under adverse weather conditions; and surveyors should establish clear benchmarks to achieve efficient construction and collaboration with the designers to establish a master project schedule; the quantity surveyors should configure the designs within the limits allowed by the budget; while the site engineer or builder should do current issues on constructability concepts used throughout the project. In so doing, it was argued that constructability would be enhanced by the project team. A study by Trigunarsyah et al. (2007) indicated that the involvement of those who have construction knowledge in constructability implementation could provide information on site layout and selection of construction method, thereby enhancing constructability. Nima (2001) in his study of constructability factors in the Malaysian Construction Industry, found that factors such as organization type, level of education, design experience, construction experience and engineers' attitude significantly affect constructability implementation. The study recommend that these factors can be utilized to enhance constructability in the Malaysian Construction Industry. Another constructability enhancement techniques on construction sites as suggested by the University of Texas (1997) are crane usage, preassembly and labour-saving technique which can result from modified tools, equipment and methods. As proposed by the Highway Constructability Guide (1990), constructability can be enhanced through planning and design guidelines, specification improvements, effective communication, management of materials, innovation, optimal utilization of plant and equipment and responsibility allocation. Similarly, the Centre for Transportation Research (1989) recommended improvements of specification and sensitivity of project parties to the effectiveness of their communication skills and their information as ways of enhancing constructability. Zolfagharian et al. (2012) illustrated the application of constructability concepts during design stage of a 3-story residential building and suggested that precast system and dry walls should be employed for the building to improve its constructability rather than using cast-in-situ reinforced concrete and brick wall. O'Connor and Davis (1988) identified the use of innovative construction methods as a way of enhancing constructability on construction sites. Boyce (1991) introduced the Ten Commandments of KISS Design as a way of enhancing constructability; the commandments entail keeping design, standards and specification straight and simple. Construction Industry Institute (1987) pointed out that identifying the project team from the on-set, the use of IT and sequencing of design and construction can enhance constructability. In Singapore, Zolfagharian et al. (2012) reported the use of standardization, simplicity and single integrated element as appraisal system development to enhance constructability.

3. Methods

Questionnaire survey was used in this study. The questionnaire was divided into five sections, the first section addresses general information on respondents; while the second section covers ways of enhancing constructability. The third, fourth and fifth sections collect information on applicable constructability concepts on construction sites, technical capabilities of construction site team members and their capabilities to enhance constructability. From preliminary survey, eighteen active construction sites were identified in Ile-Ife with ninety site team members in all. The target population were site agents, resident builders, site engineers, plant engineers, general foremen, resident quantity surveyors, crew leaders and supervisors. The percentage selection of respondents through random sampling is 67% of the 90 site team members in the identified construction sites. A total of 60 questionnaires were administered to the site team members, out of which 42 were completed and returned, this gives 70% rate of response. Percentage frequency was used in conjunction with Relative Importance Index (RII) to analyse the collected data and rank the constructability enhancement capabilities of respondents. Out of the respondents, 40.5% are site engineers, 21.4% are resident quantity surveyors, 11.9% are resident builders, 2.4% are site agents, 2.4% are general foremen, and 21.4% did not indicate their designation in the site teams. The respondents are also well experienced as 23.8% had between 5 and 10 years of experience, 11.9% between 11 and 15 years, 9.1% between 16 and 20 years, 7.1% had 21 years and above experience, 47.6% had less than 5 years of experience; while 2.4% did not indicate their years of experience.

3.1 Findings and discussions

Table 1 shows that inclusion of construction plan in the overall project execution plan with RII of 0.952 can enhance constructability as 32 respondents out of 60 strongly agreed that construction plan included in overall project execution plan is a way of enhancing constructability. 30 respondents strongly agreed that the inclusion of contractor and contractor's personnel in the design team is also a way of enhancing constructability; 11 respondents agreed with this method, while one respondent disagreed with this method as a way of enhancing constructability. Based on RII, adequate consideration of construction methods during the project design stage with RII of 0.848 ranked 4th having 18 respondents that strongly agreed with it and 20 respondents that agreed with it. Fixing of completion date with adequate consideration of the construction stage ranked 3rd with RII of

0.910; inclusion of construction plan in the overall project execution plan ranked 1st with RII of 0.952, and inclusion of contractor and contractor's personnel in the design team with RII of 0.938 ranked 2nd.

Table 1: Ways of enhancing constructability

Ways of enhancing constructability	Strongly agreed 5	Agreed 4	Disagreed 3	Strongly disagreed 2	Undecided 1	Total	RII	Rank
Inclusion of construction plan in the overall project execution plan	32	10	0	0	0	42	0.952	1
Inclusion of contractor and contractor's personnel in the design team	30	11	1	0	0	42	0.938	2
Fixing of completion date with adequate consideration of the construction stage	18	20	2	0	2	42	0.848	4
Adequate consideration of construction methods during the project design stage	24	17	1	0	0	42	0.910	3

Table 2: Applicable constructability concepts

Applicable constructability concepts	Strongly agreed 5	Agreed 4	Disagreed 3	Strongly disagreed 2	Undecided 1	Total	RII	Rank
Formulation of a representative project team	27	14	0	0	1	42	0.914	1
Planning of project with current construction knowledge	26	14	1	0	1	42	0.905	2
Selection of project procurement method based on the selected construction methods	21	18	2	0	1	42	0.876	5
Design of project according to construction sequence and schedule	19	21	2	0	0	42	0.881	4
Standardization and modularization of project elements	22	17	2	0	1	42	0.881	4
Application of IT	17	21	3	0	1	42	0.852	6
Award of contract based on project delivery capabilities of contractors and not lowest bid criteria	26	11	3	1	1	42	0.886	3
Use of innovative construction materials and methods	16	20	5	0	1	42	0.838	7
Use of temporary facilities for construction	9	17	11	4	1	42	0.738	8

Table 2 shows that respondents agreed that constructability concepts are applicable on construction sites. Among the identified constructability concepts, formulation of representative project team ranked 1st with RII of 0.914. This indicates that the respondents considered this concept as the most applicable constructability concept. Closely next to this concept, is the planning of project with current construction knowledge it ranked 2nd with RII of 0.905. Other constructability concepts considered applicable by the respondents include; selection of project procurement method based on the selected construction method ranked 5th with RII of 0.876, design of project according to construction sequence and schedule, and standardization and modularization of project elements both ranked 4th with RII of 0.881, application of IT ranked 6th with RII of 0.852, while award of contract based on project delivery capabilities of contractors and not on lowest bid criteria, use of innovative construction materials and methods, and use of temporary facilities for construction ranked 3rd, 7th and 8th with RII of 0.886, 0.838 and 0.738 respectively.

Table 3: Technical capabilities of construction site team members

Technical capabilities of construction site team members	Strongly agreed 5	Agreed 4	Disagreed 3	Strongly disagreed 2	Undecided 1	Total	RII	Rank
Effective planning of access to site	28	13	1	0	0	42	0.929	1
Manpower planning for availability of required size and skills	24	17	1	0	0	42	0.910	2
Management of construction project	25	14	3	0	0	42	0.905	3
Material management	20	21	1	0	0	42	0.890	4
Good site layout	23	14	5	0	0	42	0.886	5
Quality management	20	19	3	0	0	42	0.881	6
Site security and safety for workers	21	16	5	0	0	42	0.876	7
Procurement of equipment and materials	20	17	5	0	0	42	0.871	8
Organizational planning	19	19	3	1	0	42	0.867	9
Effective maintenance of plants and equipment	18	19	5	0	0	42	0.862	10
Contracting strategy	15	24	3	0	0	42	0.857	11
Construction programme and sequencing of operations	15	21	6	0	0	42	0.843	12
Risk management of construction operations	16	18	7	1	0	42	0.833	13
prefabrication	12	18	12	0	0	42	0.800	14

Table 3 shows that respondents have practical knowledge of constructability concepts and are capable of implementing them on construction sites. As indicated by the respondents, effective planning of access to site ranked 1st with RII of 0.929 among the technical capabilities of the respondents. This is closely followed by manpower planning for availability for required number and skills which ranked 2nd with RII of 0.910; next to this is management of construction project which ranked 3rd with RII of 0.905. others include; management of construction materials which ranked 4th with RII of 0.890, good site layout which ranked 5th with RII of 0.886, quality management which ranked 6th with RII of 0.881, site security and safety for workers which ranked 7th with RII of 0.876, procurement of equipment and materials which ranked 8th with RII of 0.871, organizational planning which ranked 9th with RII of 0.867, effective maintenance of plants and equipment, contracting strategy, construction programming and sequencing of operations, risk management of construction operations, and prefabrication which ranked 10th, 11th, 12th, 13th and 14th with RII of 0.862, 0.857, 0.843, 0.833 and 0.800 respectively.

Table 4: Capabilities of construction site team members to enhance constructability

Capabilities of construction site team members	Very High 5	High 4	Average 3	Low 2	Very low 1	Total	RII	Rank
Site agent								
Development of project execution plan and monitoring of work progress	22	12	6	2	0	42	0.857	1
Recommendation of the programme of studies and analysis of the operations	11	23	5	3	0	42	0.800	2
Site engineer/ resident builder								
Keeping of progress and quality management records	19	13	10	0	0	42	0.843	1
Introduction of innovative construction methods	10	25	6	1	0	42	0.810	2
Resident quantity surveyor								
Cost control strategies	16	17	7	2	0	42	0.824	1
Work and method breakdown and planning	14	19	8	0	1	42	0.814	2
Plant operators								
Maintenance and regular servicing of plants and equipment and to make them available as required by the construction programme	20	18	4	0	0	42	0.876	1
General foremen								
Ability to read and interpret construction drawings	18	15	5	2	2	42	0.814	1
Crew leaders								
Improvising technical means of manipulating the available plant and labour to safely and economically perform functions they are not originally designed and trained for	11	18	12	1	0	42	0.786	1
Trade supervisors								
Personal innovation of temporary construction facilities and systems that will aid fast and easy operation and erection.	13	26	2	1	0	42	0.843	1

Table 4 shows the capabilities of construction site team members to enhance constructability as indicated and ranked by the respondents. Site agents indicated ranked 1st and their capabilities to develop project execution plan and monitor the progress of work, and capabilities to recommend the programme of studies and analysis of the operations. Site engineers and resident builders indicated and ranked as 1st, their capabilities to keep progress and quality management records and capabilities to introduce innovative construction methods ranked as 2nd. Resident quantity surveyors indicated and ranked as 1st their capabilities to control cost and capabilities to breakdown works and methods ranked 2nd. 20 plant operators and 18 general foremen indicated as very high their capabilities to maintain and service plants and equipment and capabilities to interpret construction drawings. Also, 18 crew leaders and 26 trade supervisors indicated as high their capabilities to improvise technical means of manipulating the available plant and labour to safety and economically perform functions for which they are not originally designed and trained and capabilities to personally innovate a temporary construction facilities and systems that will aid fast and easy operation and erection.

4. Conclusion

Even though the developed countries are deriving increasing benefits from the application of constructability concepts to construction projects, the concepts are still not deeply entrenched in the Nigerian Construction Industry. Although, the respondents are well informed about constructability concepts and enhancement factors and constructability concepts such as formulation of a representative project team, planning of project with current construction knowledge, selection of project procurement method based on the selected construction methods, design of project according to construction sequence and schedule, standardization and modularization of project elements, and application of IT are considered applicable on the Nigerian construction sites; yet the capabilities of project team and site team members that will aid fast and easy operations on construction sites are not being allowed to play adequately and to enhance constructability. This is due to the fact that the principles of

constructability are not being applied to project development in the Nigeria Construction Industry.
Construction site team members can enhance constructability with their construction experience and knowledge; their inclusion at the project inception will benefit the project execution plan with their knowledge, leading to the adoption of appropriate construction methods and schedule and therefore should be given the opportunity to contribute to project constructability.

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