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INFLUENCE OF CONSTRUCTABILITY AND QUALITY OF MANAGEMENT DURING DESIGN FACTORS ON PROJECT DELIVERY

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Abstract
Constructability, the integration of construction techniques at the stage in the development of designs has impact on the rate of construction. When this is absent it normally results in a negative impact. The aim of the study is to identify influencing factors of constructability and quality of management during design have on project delivery time with a view to alleviating their impact. A questionnaire survey was conducted among professionals in the Building Construction Industry to access influencing factors of constructability and quality of management during design. A total of eighty-eight questionnaires were analysed before reaching conclusion relative to the study. Inferential statistics was employed in the analysis of data. Finding relative to constructability factors include that participation in site inspection and control, knowledge of performance of materials and components, and appropriateness of working space and for quality of management during design, conflicting design information, missing information and timeliness of revised drawings are the factors that most influences project delivery time The recognizing of influencing factors of constructability and quality of management during design, could result in according more priority to them with a view to developing measures to mitigate their effects on project delivery. Based on the finding of the study, ways to mitigate poor constructability reviews and quality of management during design were highlighted.

Keywords: Construction, Constructability, Delivery time, Design, Management quality

1 Introduction

Clients expects the briefings of their intended facility to the designer to be accurately reflected in design and so built by the constructor. Client's desire is to procure a facility that is performing optimally. Contrary to these, dissatisfaction results, which may lead to litigation, extension of time, no returns on investment as planned by the client, and so on.

The ease of construction of a design is referred to as constructability. Constructability indicates the following: corresponding dimensions of design, adequate and accurate design information, and design void of omissions, which ultimately leads to delivery of facility as schedule, facility performing optimally to the satisfaction of the client.

The contrast is the case, relative to poor design and non-constructible design necessitating late delivery of projects, with a lot of problems associated to it. This study aims to identify and

assess factors of constructability issues and quality of management during design that could adversely influence project delivery time, with a view to suggesting mitigating factors.

2 Literature review

2.1 Importance of the study

The non-delivery of a project as at when specified causes unhealthiness in a contract and may lead to abandonment, disputes and litigation, increased project duration and cost resulting from inflation, bad image of contractor, client and consultants, and so on. Delay is associated with diverse issues, which are traceable to the contribution of the client, contractor, and consultant – designer, with respect to this study (Niazai and Gidado, 2012). Contribution from the designer could relate to issues of constructability of the design and quality of management during design. Some authors have identify factors relating to design that causes project delay. They are: design complexity (Sullivan and Hans, 1986); changes in scope of work (Assaf et al., 1995); waiting for information (Chan and Kumaraswamy, 1997) and design delay (Ogunlana et al., 1996); design changes (Kaming et al., 1997); Trigunarsyah (2004) identifies four stages of constructability implementation on a project. The stages are: during conceptual planning, during design, during procurement and during the construction stage, and each having sub-factors for consideration; late preparation and approval of drawings (Faridi and El-Sayegh, 2006); design (Long et al., 2008); late approval of shop drawings (Assaf and Al-Hejji, 2008), and ambiguities, mistakes, and inconsistencies in specification and drawings (Shehu; Endut, and Akintoye (2014). Based on these gaps, this study was initiated in South Africa, in addition that building construction processes are the same worldwide, to assess the factors that most influence delivery time of project based on issues of constructability of design.

2.2 Constructability of design

Mbamali et al. (2005) define the extent to which a building design facilitates the ease of construction as buildability: a British term or constructability: an American term which is defined as the grouping of similar work components and the use of modular dimensions in design to reduce construction cost. The constructability requirement is, however, one of the major factors necessitating the integration of construction experience into building designs. Oyedele and Tham (2005) provide a list of factors that could be used to assess constructability inter alia: flexibility of design to changes; dimensional coordination of elements; knowledge of performance of materials and components; effective constructability review of design, and effective participation in site inspection and control. The following factors are employed in the assessment of design constructability: the scope of off-site fabrication; complexity of offsite fabrication components; appropriateness of design tolerances; appropriateness of working space; implication upon trade coordination; impact of materials storage and movement, and impact on smooth activity workflow and activity sequencing.

2.2.1 Extent of grouping simultaneously

The extent to which similar kinds of work can be grouped together is an indication of how fast a design can be constructed. Works such as fixing of electrical wires into pipes for switches and sockets allow projects to gain time, because the wires to many switches and socket outlets can be contained in one pipe, with minimum cost. The extent to which a design can easily be changed also reflects how easily it can be constructed. Designs that are not subject to changes could have an adverse effect when errors are committed during construction. These errors could be design or construction related errors.

2.2.2 Extent of modular dimension in design

The utilisation of modularity in design facilitates easy and fast construction. The use of standard modules promotes standard sized materials and mitigates cutting. When standard items are customised in this way, projects may be completed more speedily. Additionally, the incorporation of these standard units in design can eliminate the delays relative to cast in-situ operations.

2.2.3 Knowledge of performance of materials and components

The knowledge of performance of materials and components provides opportunities for alternatives. Trigunarsyah (2007) suggests that the concept of constructability revolves around optimising the use of construction knowledge and experience provided by knowledgeable and experienced construction personnel who are part of the project team. The project managers, engineers, architects, and contractors should be knowledgeable about the characteristics and performance of materials and components integrated in the construction. This eliminates possible situations of delay which would have been caused by the non-availability of materials and also remedies the situation through informed substitution of materials and components.

2.2.4 Effective constructability review of design

Yates and Battersby (2003) suggest that designers must receive construction training prior to starting their design careers. This will aid the integration of construction experience into their designs for buildable designs. Designs should be reviewed to check for conformance with constructability. This process should be carried out at the design stage, so that the constructability count / rate of design is known before the contract is awarded. The process eliminates delay in project delivery.

2.2.5 Participation in site inspection and control

Effective participation in site inspection by parties involved in the project relative to their discipline is important. This process helps to discover the conformity of the construction to specifications and identify deviations. In this way errors are discovered early and are dealt with promptly.

2.2.6 Scope of site fabrication

The scope of off-site fabrication is an indication of the extent to which design could be easily constructed. A large scope of off-site fabrication is a likely indication of delays to the delivery of the project. Attributes such as fixing problems and delivery of prefabricated components to the site may constitute delay.

2.2.7 Complexity of off-site fabrication components

Arditi et al. (2002) declare that the probability of a problem occurring on a less complex project is low compared to a complex project. Complexity refers to the intricacy of construction and associated problems. Probable problems include design mistakes, poor quality and inaccuracy of dimensions. These associated problems may lead to delays in the delivery of the project. Trigunarsyah (2007) is of the opinion that constructability is enhanced when designs are simplified to enable efficient construction. This allows good planning of work and site layout.

2.2.8 Appropriateness of working space, its impact on smooth activity workflow and sequencing

Overcrowded work sites may cause conflicts in the work process, which may result in the decline of the effectiveness of operators. The lack of appropriate working space and congestion on the site can contribute to the slow progress of work.

2.2.9 Implications upon trade coordination

Congestion on site may lead to difficulty in the coordination of trades. During the process of planning work activities, mistakes might be made in the form of two different trade activities occurring simultaneously in the same work area with no space to work. This may lead to a delay in the project.

2.2.10 Appropriateness of design tolerances

Trigunarsyah (2007) posits that constructability will be enhanced when owner, designer, and constructor personnel review the construction specification in detail. The major factor to note during off-site fabrication is the provision of allowances for on-site fixing. In situations where the tolerance provided is not appropriate, two steps might be taken: re-fabrication or forging to allow for appropriateness. These two activities require time which is additional to the initial estimated period and may constitute delays when there is a large volume of such work. Arditi et al. (2002) suggest that faulty working drawings and incomplete specifications are the major constraints relative to constructability of designs.

2.2.11 Impact of materials storage and movement

Materials should be available when required in order to enhance production or maintain a constant production level. Storage for materials should be away from production points, but not too far. Interruptions of the smooth activity workflow and activity sequencing may negatively affect production levels when storage places are close to the production area. Activity sequencing is the particular arrangement of activities in such a way that the activities are executed chronologically without delay and the construction team can meet the completion deadline. When activities on a critical path of a project are disrupted, the project is bound to take longer than estimated to complete. Congestion on site is one factor that constrains adherence to activity sequencing. Sites should be well laid relative to movement of materials.

2.3 Quality of management during design

Project success is dependent on inter alia, the performance of the design team. Defective designs adversely impact on project performance and the participants and are responsible for many construction failures (Andi and Minato, 2003). Failure at the conceptual planning and design stages may lead to significant problems in successive stages of the project. Design inefficiencies could lead to redesign and rework or poor quality of products. Oyedele and Tham (2006) provide a listing of clients' ranking of designers' performance criteria among which were those that relate to quality of design coordination, smooth flow of work, vis-à-vis conflicting design information, timeliness of issuing of revised drawings, missing information, dimensional inaccuracies as well as delay of release of shop drawings.

2.3.1 Conflicting design information

Acharya et al. (2006) declare that ambiguous specifications are one of the six critical construction conflicting factors in the Korean context that affect project delivery time negatively. This refers to an item having double representation either in numerical value or in statement. For clarity and smooth flow of work, designs should be checked more than once before they reach the contractor. It is also advised that designs should be checked by the contractor for clarity and to avoid ambiguity upon receiving the award. If these exercises are not conducted, it may lead to delays.

2.3.2 Timeliness of issuing of revised drawings

According to Yakubu and Sun (2009), design change(s) is the most influential factor inhibiting the delivery of projects on time in the United Kingdom construction industry from the perspective of the contractor and the consultants. Walker and Shen (2002) declare that a delay

in design documentation was ranked the second most influencing factor that negatively affects project delivery. Time should not be wasted in the process of issuing revised drawings. The joint contract tribunal (JCT, 2005) specifies that revision of drawings should not take more than three days after which the contractor can claim for extension of time.

2.3.3 Missing information

Andi and Minato (2003) say that poor design and documentation quality negatively affect the construction process. Alaghbari et al. (2007) identify incomplete documents as one of the top ten factors causing delay in the delivery of projects in the Malaysian construction industry. Missing information interrupts the smooth flow of work. Contractors are employed to build in such a way that they adhere to design and specification. Assumptions should not be made while constructing, therefore missing information should be brought to the notice of the designer and a quick response should be given to address this.

2.3.4 Dimensional inaccuracies

Walker and Shen (2002) say that mistakes in design form part of the contractor-related factors which were ranked second in contributing to delays in the delivery of projects. Acharya et al. (2006) determined that design errors are one of the six critical construction conflicting factors in the Korean context. Dimensional inaccuracies are to be brought to the notice of designers and these should be resolved promptly, to avoid delays in the delivery of project. Joint Building Contract Committee (JBCC, 2000) clause 17.1.2 bestows the responsibility on the principal agent to issue the contractor instructions with regards to the rectification of discrepancies, errors in description or omission in contract documents other than this document.

2.3.5 Expediting shop drawings

Out of forty-four causes of delays identified by Faridi and El-sayegh (2006) in the United Arab Emirates, preparation and approval of drawings is the most influential. Delay in the release of shop drawings could affect speedy completion of work sections. Shop drawings should be delivered to the contractor whenever the need arises with no delays. Clause 32.5.1 of the JBCC states that the failure to issue or the late issue of a contract instruction following a request from the contractor entitles the contractor to claim for the expense in loss incurred, having notified the principal agent within forty working days from becoming aware or from when he / she ought reasonably to have become aware of such expense and loss.

3 Research Methodology

This section describes the procedure for data collection and the survey techniques used in the study. The study is titled influence of constructability and quality of management during design was undertaken to identify and assess factors influencing project delivery time. The study was conducted in Port Elizabeth in South Africa. The sample frame for the practitioners are: architects 1149 (SAIA); master builders 320 (MBA); clients 161 SAPOA); structural engineers 43 (CESA - East Cape), and quantity surveyors 473 (ASAQS). The sample consisted of industry practitioners who are: architects (9), master builders (18), quantity surveyors (23), and structural engineers (23), clients (12) and others (3).

Probability sampling technique was employed for sample selection, having calculated sample size based on the sample frame. Random sampling technique was employed for all professionals except the quantity surveyors and structural engineers. Systematic sampling techniques was used for the quantity surveyors, and for the structural engineers the entire sample, because they are few, based on the recommendation of Leedy and Omrod (2005). The study research instrument was a questionnaire survey, which was administered to respondents through post (Architects, MB, Structural engineers, and others) and e-mail (Quantity

Surveyors). These were received through the same means. Cronbach's coefficient test and validity test were performed and were found satisfactory. Cronbach's alpha of ≥ .97 and factor loading of >.60 for samples sizes 85-89 were obtained.

A total of eighty-eight (88) questionnaires representing 6.1% response rate achievement recorded on questionnaire administration. Simple statistical tools such as mean score, percentages and so on were used for data analysis.

A five-point Likert scale adjoined with 'Unsure' and 'Does not' options was employed to analysis summated scores of the respondent's responses. Given that there are five points on the scale, and that 5 – 1 = 4, the ranges were determined by dividing 4 by 5 which equates to 0.8. Consequently the ranges and their definitions are as follows:

- > 4.20 ≤ 5.00 between a near major to major / major influence;
- > 3.40 ≤ 4.20 between moderate influence to a near major / near major influence;
- > 2.60 ≤ 3.40 between a near minor to moderate influence / moderate influence;
- > 1.80 ≤ 2.60 between a minor to near minor influence / near minor influence, and
- > 1.00 ≤ 1.08 between a minor to near minor influence.

Most of the respondents belong to the private sector (74%), their average working years is 17, and over the age of thirty (300. Respondents with Bachelor's degree 25% predominate, and respondents have handled not less than six (6) types of projects. Based on these, data can be deemed reliable.

4 Findings and Discussion

4.1 Constructability of design

Table 1. The influence of constructability factors on project delivery time

Factor	Response (%)								
	Unsure	DN	Minor.....Major					Mean score	Rank
			1	2	3	4	5		
Participation in site inspection and control	3.8	2.5	1.3	7.5	18.8	27.5	38.8	3.86	1
Knowledge of performance of materials and components	4.7	1.2	3.5	10.5	18.6	38.4	23.3	3.62	2
Appropriateness of working space. Its impact on smooth activity workflow and sequencing	2.4	2.4	2.4	11.8	27.1	27.1	27.1	3.56	3
Effective constructability review of design	7.1	2.4	3.6	10.7	25.0	29.8	21.4	3.44	4
Impact of materials storage and movement	3.5	0.0	7.1	7.1	32.9	34.1	15.3	3.42	5
Implication upon trade co-ordinations	8.4	3.6	1.2	8.4	28.9	32.5	16.9	3.40	6
Appropriateness of design tolerances	7.1	1.2	6.0	15.5	21.4	34.5	14.3	3.29	7
Extent of modular dimensions in design	11.6	3.5	4.7	14.0	23.3	29.1	14.0	3.17	8
Complexity of off-site fabricated components	14.1	4.7	4.7	14.1	15.3	32.9	14.1	3.16	9
Scope of site fabrication	21.2	2.4	4.7	11.8	22.4	27.1	10.6	3.09	10
Extent of grouping simultaneous	12.9	3.5	4.7	11.8	32.9	24.7	9.4	3.05	11

Table 1 presents respondents' rating of the influence constructability of design factors have on project delivery time. It is observed that all factors in the category have MSs > 2.60 ≤ 3.40, which indicates that these factors have between a near minor to moderate / moderate influence on project delivery time.

The most significant of these factors is the scope of site fabrication. One of the quickest ways of identification and correction of problems on site is the participation of the project team during site inspections. Owing to the large pool of knowledge available when the project team is involved in inspections, their wealth of experiences and knowledge provide a platform for immediate solutions to identified problems on site, and therefore engender processes that minimises or eliminate project delays.

The next factor is knowledge relative to the performance of materials and components. In the instance that a project manager or a contractor lacks adequate knowledge of material and component performance, it implies that when a material is not available for construction purposes the project will have to stop until such time that it would be available because alternatives cannot be suggested as a result of lack of knowledge of material performance.

The third most significant factor is the appropriateness of working space. When the space available on site to carry out construction tasks is limited, it adversely impacts the smooth flow of activities and reduces the number of activities that can be done at any time. Where the working space is adequate numerous activities can be carried out simultaneously, thereby increasing the rate of building. All of these factors agrees with Trigunarsyah (2004) stated factors for consideration during design and construction of a project relative to constructability issues.

The least significant factor in this category is the extent of grouping simultaneously. This factor is most effective relative to electrical installations. When comparing other sections of work with the impact this factor could have in speeding up work, it is negligible. Therefore, on the average, it could be deemed that it has a negligible effect on project delivery time.

4.2 Quality of management during design

Table 2. The influence of quality of management during design factors of project delivery time

Factor	Response (%)							Mean score	Rank
	Unsure	DN	Minor.....Major						
			1	2	3	4	5		
Conflicting design information	2.3	1.2	13.8	9.2	23.	24.	26.4	3.36	1
Missing information	1.2	2.3	11.6	15.1	25.6	20.9	23.3	3.22	2
Timeliness of revised drawings	8.1	1.2	14.0	12.8	23.3	21.0	19.8	3.17	3
Expediting shop drawings	5.8	4.7	14.0	18.6	18.6	29.1	9.3	2.84	4
Dimensional inaccuracies	2.3	3.5	20.9	12.8	32.6	11.3	16.3	2.78	5

Table 2 presents the respondents rating regarding the influence of quality of management during design, on project delivery time. All factors in this category have MSs > 2.60 ≤ 3.40, which indicates that these factors have between a near minor to moderate / moderate influence on the project delivery time.

The factor that has the most significant influence in the category of quality of management during design is conflicting design information, this corroborates with Shehu and Endut, (2013) finding. The probable reason for this is the process it will take to correct a mistake. It may require checking the design from the beginning, which may take longer than expected. The second most significant factor is missing information. This factor also agrees with Chan and Kumaraswamy (1998) finding of waiting for information. This factor may lead to delays as a

result of carelessness or incompetence in design. Missing design information will inhibit the smooth flow of operations on site, therefore introducing delay to the scheduled project completion date.

The least significant factor in this category is dimensional inaccuracies. Although this factor is the least influential in this category, it does not imply that its effect is negligible because of the time it takes to clarify inaccuracies may result in delay in the delivery of the project.

5 Conclusion and Further Research

Conclusion to this study is in two parts, relative to influencing factors of constructability and quality of management during design on project delivery. With respect to influencing factors of constructability: that appropriateness of working space may negatively impact on the smooth activity workflow and sequencing, non-effective constructability review of design leads to revisions and time wastage, which negatively affects project delivery time, and materials shortage adversely affects project delivery.

Relative to influencing factors of quality of management during design, conflicting and missing information adversely affect project delivery time.

Based on the conclusion reached in this study, it is evident that the non-effective conduction of constructability reviews of design may lead to conflicting and missing of information, and inaccurate dimensional coordination of designs information, that could engender delay in the delivery of project. Therefore, it is suggested that the construction industry should provide quality management guidelines and should be enforced by consultant on projects. Stakeholders relative to design should be committed to quality management during designer. Designers' quality management should focus on the following:

- Committed to providing a quality service;
- Production of correct and complete drawings and specifications;
- Coordinating and checking of design documentation;
- Conducting design verification through design analysis reviews, and
- Conducting constructability reviews.

It is hereby recommended that further study be conducted on the extent of constructability reviews on design and quality of management during design

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