THE BENEFITS OF USING CONSTRUCTABLITY DURING THE DESIGN PROCESS.

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ABSTRACT

Purpose of this paper-The construction industry is known for its lack of integration of design and construction which hinders constructability and the delivery of projects in the most cost effective manner. It is against this background that this study examined the integration of design and construction in the construction industry in KwaZulu-Natal to evaluate designers' perception and implementation of constructability in their designs.

Methodology/Scope-A questionnaire survey of 100 designers was conducted to investigate their perception of constructability and the extent of its implementation in their designs. Data were analysed using percentile and mean score methods.

Findings-The results showed that most designers require contractors' experience (76%) and consider constructability (84%) in their designs. However, only 48% of them indicated that contractors often contribute to their designs. Designers' lack of construction knowledge was found to be the most critical obstacle to the implementation of constructability in design.

Research limitations-This study covered KwaZulu-Natal only and the results may not be generalized beyond the province.

Practical implications-Although most designers indicated that they required contractors' experience in their designs only 48% were often involved with contractors in the design process. To optimize the constructability of their designs, designers need more feedback from the site which only contractors can provide. This calls for a total dismantling of the traditional compartmentalization of design and construction by more widespread use of non-conventional procurement methods which give contractors a greater role in design.

Value-The results should guide the efforts of construction stakeholders to optimize cost through the implementation of constructability during designs.

Keywords: constructability, designers, contractors, project costs, construction knowledge and experience.

1. INTRODUCTION

Reducing building cost is a primary concern for clients, designers, contractors and other stakeholders in the construction industry. According to McCullouch (1996), the input of construction knowledge during the design phase is especially necessary to achieve this goal. The Construction Industry Institute (CII) (1987) defines constructability as the optimum use of construction knowledge and contractor experience in the conceptual planning, design, procurement and field operation of a project to achieve overall project objectives in the best possible time and

accuracy at the most cost effective levels (Construction Industry Institute, 1986). Constructability therefore is a tool for enhancing project performance (McCullouch, 1996).

The traditional procurement approach commonly used in the construction industry tends to create a division between contractors and designers, separating design from construction. This division prevents contractors from delivering their comments and feedback to designers and hinders the application of the concept of constructability which involves the integration of construction knowledge and contractors experience into the design process. This ultimately prevents the delivery of projects in the most cost effective manner. It is against this background that this paper investigated the level implementation of the concept of constructability and designers' perception of its usefulness in the design process..

2. THE LINK BETWEEN CONSTRUCTABILITY AND BUILDING COST-A REVIEW OF THE LITERATURE.

Constructability also known as buildability has been defined by Nima *et a*l. (1999) as the optimum use of construction knowledge and experience by the owner, engineer, contractor and construction manager in the conceptual planning, detailed engineering, procurement and field operations phases to achieve overall project objectives. The concept denotes the ease with which the raw materials of the construction process (labour, production equipment and tools, and materials and installed equipment) can be brought together by a builder to complete a project in a timely and economic manner (Glavinich, 1995). According to Low (2001), the concept first emerged in the United Kingdom and United State of America in the late 1970's following studies into how efficiency, productivity, cost effectiveness and quality could be achieved in the construction industry. The studies showed that the lack of integration of construction knowledge into the design process hindered the ability to construct and this was cited as one reason for projects exceeding budgets and schedule deadlines (Trigunarsyah, 2004).

Constructability links the construction and the design phases and has an important role to play in the success of a project. Many of the decisions made early in the design process affect the construction of the project and so construction expertise need to be incorporated in the process to improve the design. Thus, according to the Construction Industry Institute (1993) and as shown in Figure 1, maximum benefits occur when individuals with construction knowledge and experience become involved in the early stages of a project life cycle. Constructability should be applied at the early stage and considered as an important objective in all the stages of the construction process. This is because of its ability to influence project cost and add better value for money.

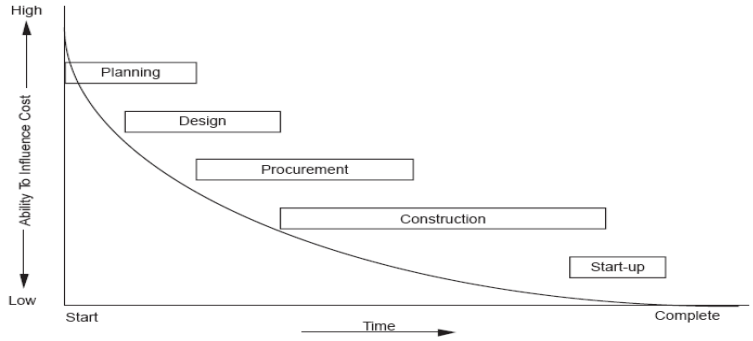

Figure.1: Ability to influence final cost over project life
(Source: Construction Industry Institute, 1993)

Based on their construction knowledge and experience, contractors can play a major role in enhancing constructability (Nima *et al*, 2001). Constructability is most effective if it is included as

an integral part of the project execution plan and project procedures (Construction Industry Institute, 1993). Griffith and Sidwell (1995) state that in any building or engineering project, improvement could be achieved through careful consideration of procurement, design, construction techniques and management approach. The separation of design and construction within the construction process is responsible for the lack of consideration given to the necessary coordination and integration between project phases.

According to Griffith and Sidwell (1995), many of the problems of inadequate design and production methods within both traditional and non-traditional construction contracts were caused by unclear or missing project information, inadequacies in the quality of information provided or lack of complete information, and general lack of co-ordination of design with construction Effective utilisation of the concept of constructability to overcome these problems depends on the availability of the right information at the appropriate level of detail (Pulaski & Horman, 2005). This requires that designers and contractors improve the quality of information passed between stages, using the right people and doing so at the right time.

2.1 **Constructability Concepts**

Nima *et al.* (2001) have formulated 23 constructability concepts applied to the conceptual planning, design and procurement, and field operation phases of the project cycle. The conceptual planning phase has 7 concepts, the design and procurement phase 8 concepts and the field operations phase 8 concepts. These concepts are construction principles that should be applied during the project delivery process to stimulate thinking about constructability and how to make it work (Trigunarsyah, 2004). To assist in applying the constructability concepts, the Constructability Implementation Task Force of the Construction Industry Institute developed application matrices. The matrices are useful tools that link constructability concepts to specific activities within each phase when developing a project execution plan (Construction Industry Institute, 1993). A road map was used to incorporate the matrices as follows as shown in Figure 2.

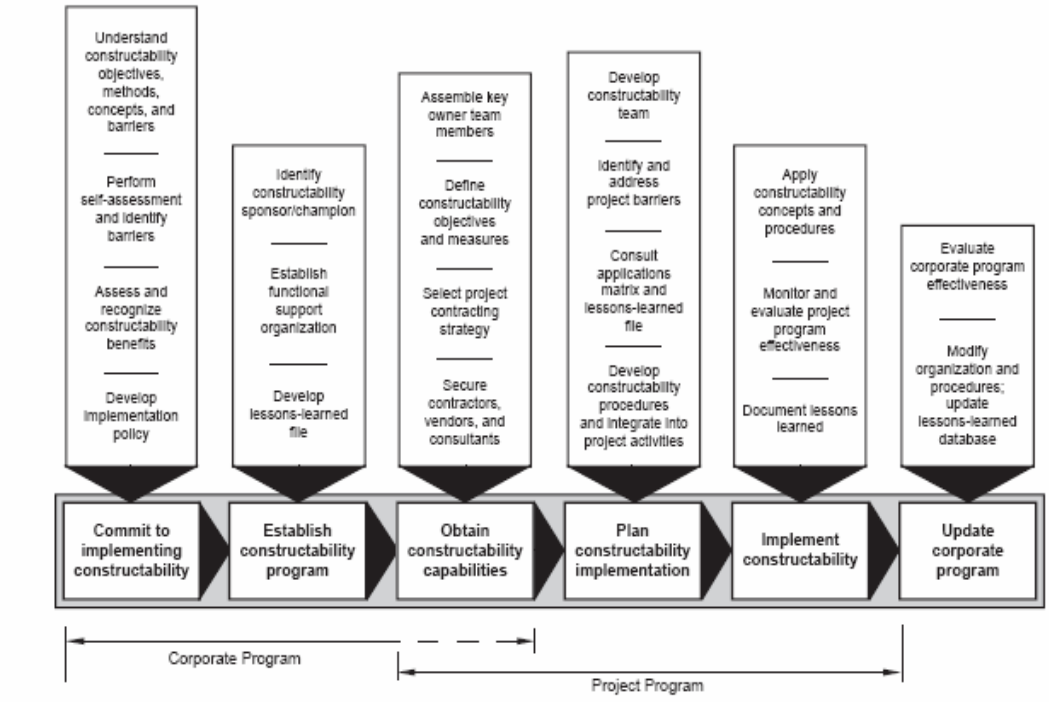

Figure 2: Constructability Implementation Roadmap
(Source: Construction Industry Institute, 1993)

2.2 .**Factors that enhance constructability**

According to Griffith and Sidwell (1995), many of the factors that influence the implementation of constructability are related to the type of project. This is confirmed by Arditi *et al* (2002) in their study of design firms. They found out that project complexity, design practices and philosophy, and project delivery (procurement) systems were the most significant factors that enhanced constructability while project location and design standards were the least significant.

2.3 **Factors that impede constructability**

O'Connor and Miller (1994) identified barriers to constructability as significant inhibitors that prevent effective implementation of a constructability programme. According to O'Connor & Miller (1994), barriers to implementing constructability still exist and must be identified during the project. The Construction Industry Institute (1993) has classified the barriers into general, owner, designer and contractor barriers detailed as follows:

2.3.1 General barriers

- Complacency with status quo
- "This is just another programme"
- "Right people" are not available
- Discontinuity of key project team personnel
- No documentation of lessons learned
- Failure to search out problems and opportunities

2.3.2 Owner barriers

- Lack of awareness of benefits, concepts, etc
- Perception that constructability delays project schedule
- Reluctance to invest additional money and/or effort in early project stages
- Lack of genuine commitment
- Distinctly separate design management and construction management operations
- Lack of construction experience
- Lack of team-building or partnering
- Disregard of constructability in selecting contractors and consultants
- Contracting difficulties in defining constructability scope
- Misdirected design objectives and performance measures
- Lack of financial incentive for designer
- Gold-plated standard specifications
- Limitations of lump-sum competitive contracting
- Unreceptive to contractor innovation

2.3.3 Designer barriers

- Perception that they have considered it
- Lack of awareness of benefits, concepts, etc.
- Lack of construction experience/qualified personnel
- Setting company goals over project goals
- Lack of awareness of construction technologies
- Lack of mutual respect between designers and constructors
- Perception of increased designer liability
- Construction input is requested too late to be of value

2.3.4 Contractor barriers

- Reluctance of field personnel to offer preconstruction advice
- Poor timeliness of input
- Poor communication skills
- Lack of involvement in tool and equipment development

In their study of design firms, Arditi *et al*. (2002) reported that faulty, ambiguous, or defective working drawings, incomplete specifications, and adversarial relationships were found to be the three major factors that impede constructability. Budgetary limitations, resistance of the owner to formal constructability programmes, and non-standardisation of design were found to be the least influential constraints that hinder constructability. This finding challenges the common misconception that clients are a barrier to formal constructability programmes because constructability programmes constitute extra project cost. According to Arditi *et al* (2002), this suggests that there is no tendency on the part of project owners to prevent constructability programmes, probably because of their proven cost savings.

2.4 **Benefits of implementing constructability**

Although, according to Arditi *et al*. (2002), a constructability programme introduces a cost that is usually added to the design fee and might harm the competitiveness of the firm, there are some benefits to the design firms in return for their investment in more buildable designs. Thus constructability leads to important direct and indirect benefit, which according to Griffith and Sidwell (1995), are measurable not only in cost and time but also in terms of the physiological and psychological gains for the people involved in the construction process. Construction clients demand a high quality of service and value for money by expecting their projects to be completed on time, within the anticipated budget and as specified, trouble-free and relatively inexpensive to use and maintain. The clients' requirement can be achieved through the implementation of constructability. Constructability also enhances the reputation of the designer and contractor, minimises the waste of resources and produces a finished product with better quality and less defects (Griffith and Sidwell, 1995). The implementation of constructability programmess helps to develop better relationships with clients and contractors, being involved in fewer lawsuits, and building a good reputation that can reduce antagonism and disputes between designer and contractor (Gambatese and McManus, 1999, Arditi *et a*l., 2002).

3 **RESEARCH METHODOLOGY**

A questionnaire survey of designers was conducted to investigate their perception of constructability and the extent of its implementation in their designs. Out of the 100 copies of the questionnaire distributed 40 were returned by the respondents. The first part of the questionnaire sought general information on the respondent firms and their practices while the second part asked the respondents to rank the impact of relevant factors on a 5-point Likert scale ranging from 1=Very unimportant/insignificant to 5=Very important/significant. The data were analysed using the percentile method and mean score analysis. The mean score is determined as follows (Akintoye, 2000; Odeyinka, 2003):

$$\text{Mean Score} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{(n_1 + n_2 + n_3 + n_4 + n_5)} \quad (1)$$

where n_1 = number of respondents who answered "very unimportant/insignificant"
n_2 = number of respondents who answered "unimportant/insignificant"
n_3 = number of respondents who answered "average"
n_4 = number of respondents who answered "important/significant"
n_5 = number of respondents who answered "very important/significant"

4. DATA ANALYSIS AND RESULTS

Of the 40 questionnaires returned only 38 were found to be properly answered and suitable for analysis. This represents a response rate of 38% which, according Elhag & Boussabaine (1999) and Idrus & Newman (2002), is good enough for construction research.

4.1 Level of awareness and use of constructability concept by design firms

As shown in Figure 3, most of the firms were aware of the concept of constructability, with 84% indicating that they had used it before in the design process.

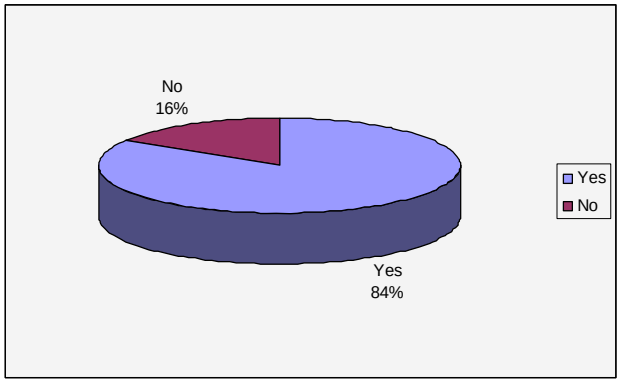

Figure 3: The awareness and use of constructability concept by design firms

Also, 76% of the respondents indicated that they required contractors' experience in their designs (Figure 4). The reasons given for this included "the contractor would know better about availability of materials and time delays associated with obtaining them" and "help in the use of appropriate technology which affects design and cost". The reasons why some firms did not require contractors' experience included "if there are any changes to be made in the design, a variation will be issued to the contractor, therefore there is no need for the contractor to be part of the design team" and "they have the experience necessary for the type of work they do".

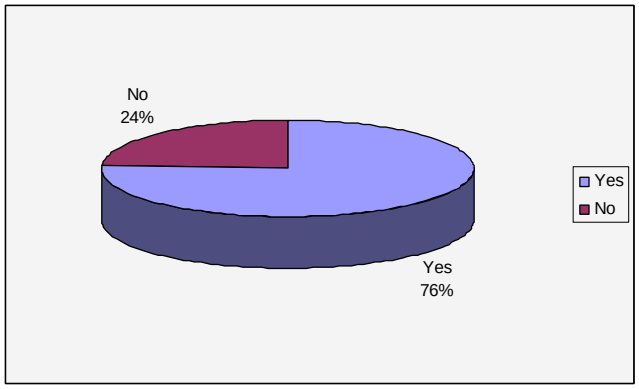

Figure 4: The use of contractors' experience during design

Table 1 shows that most of the firms (58%) who claimed to be using the concept of constructability indicated that they implemented the concept at the outline proposal stage while only a few (13.2%) implemented it at the tender stage

Table 1: Stage at which constructability is implemented

Stage of implementation	No. of respondent	% response
Strategic briefing	13	34.2
Outline proposal	22	58.0
Detailed proposal	19	50.0
Final proposal	13	34.2
Production information	13	34.2
Tender documentation	12	31.6
Tender action	5	13.2

4.2 The procurement systems commonly used and the professionals involved in the design process

The design firms were asked to indicate the professionals they usually involve in their design processes. Their responses in Table 2 indicate that structural engineers (100%) were most commonly involved while specialist subcontractors (17%) were least commonly involved. Table 3 shows that the conventional (traditional) procurement method which is generally considered a barrier to constructability is used by a majority of the respondents (94.7%) while only a few use the non-conventional methods of design and build (2.6%), turnkey (5.3%) and develop and construct (7.9%) which enhance constructability.

Table 2: Professionals commonly involved in the design process

Professionals	No. of respondent	% Response
Quantity surveyors	36	94.7
Main Contractors	18	47.4
Subcontractors	18	47.4
Specialist subcontractors	17	44.7
Structural engineers	38	100
Electrical engineers	33	86.8
Mechanical Engineers	33	86.8
Land surveyors	28	73.7

Table 3: Procurement methods the designers are commonly involved in

Procurement methods	No. of respondent	% response
Traditional method	32	84.2
Design and build	1	2.6
Construction management	7	18.4
Turnkey	2	5.3
Develop and construct	3	7.9
Design and manage	14	36.8
Management contracting	1	2.6

4.3 Factors considered in implementing constructability during design

The firms that had used the concept before were asked to rank in importance (ranging from 1 = very unimportant to 5 = very important) the factors they considered in pursuing constructability in their designs. Using the mean score formula in Equation 1, the factors are ranked in Table 4, which shows that client satisfaction is the most important and ease of construction the least. This tends to suggest that designers do not consider ease of construction as high priority in their designs.

Table 4: Factors considered in implementing constructability

	Ranking/no. of responses						
Factor	**1**	**2**	**3**	**4**	**5**	**Mean score**	**Rank**
Client's brief	0	0	0	2	29	4.94	2
Reducing costs	0	2	8	11	9	3.90	6
Functionality	0	0	0	8	23	4.74	4
Aesthetics	0	0	1	6	24	4.74	3
Ease of construction	0	1	14	9	5	3.62	8
Environmental impact	0	4	8	9	10	3.81	7
Adding value for money	0	0	8	8	15	4.23	5
Client satisfaction	0	0	0	0	30	5.00	1

4.4 **Benefits of constructability**

The respondents' perceptions of some of the benefits of implementing constructability in design are shown in Table 5. It is not surprising that the fact that constructability gives "better design" is ranked 1 as a better design no doubt produces all the other benefits.

Table 5: Benefits of implementing constructability

	Ranking/ No. of responses						
Benefits of constructability	**1**	**2**	**3**	**4**	**5**	**Mean score**	**Rank**
Enhances project quality	2	3	2	8	16	4.06	4
Reduces project duration	0	6	7	8	10	3.71	10
Reduces project cost	0	2	9	10	10	3.90	8
Enhances partnering and trust among project team	3	1	11	8	8	3.55	14
Increases owner satisfaction	2	2	12	3	12	3.67	12
Minimizes contract variation orders and disputes	0	3	6	14	9	3.91	7
Better design	1	0	4	6	20	4.42	1
More effective construction planning	2	1	4	9	14	4.07	3
Increased project performance	2	1	5	9	11	3.93	6
Fewer delays and disruptions	0	4	7	6	13	3.93	6
Better communication	2	1	8	8	10	3.79	9
Improved site management	0	2	13	11	8	4.12	2
Efficient management of problems	0	2	7	11	11	4.00	5
Earlier client occupation	2	1	10	15	5	3.61	13
Provision of feedback for future projects	1	2	6	13	5	3.70	11
Increased job satisfaction	1	2	7	5	12	3.93	6

4.5 **Barriers to the implementation of constructability**

While constructability, no doubt, improves project delivery, there are barriers preventing its wholesale adoption and use by design firms. In Table 6 the respondents indicated that "design teams' lack of adequate construction experience" is the most significant barrier and the perceived "high cost of the system" the least.

Table 6: Barriers to the implementation of constructability in design

	Ranking/ No. of responses						
Barriers to constructability	**1**	**2**	**3**	**4**	**5**	**Mean score**	**Rank**
Traditional project delivery methods	7	2	7	12	7	3.29	7
Contract type	10	2	7	9	9	3.14	10
Not enough resources	4	0	8	11	15	3.87	2
Design teams' lack of adequate construction experience	1	1	9	11	15	4.03	1
Reluctance to adopt a new system	4	3	10	8	10	3.49	5
High cost of system	6	4	15	3	8	3.08	12
Prolongation of the project period	4	4	18	6	5	3.12	11
Inconsistent terminologies	6	6	9	9	8	3.18	9
Lack of open communication between designers and contractors	4	10	4	5	12	3.31	6
Difficulty in coordinating different disciplines	4	2	8	10	12	3.67	3
Lack of awareness of benefits	7	2	9	12	7	3.27	8
Poor timeliness of contractor input	5	0	9	10	11	3.63	4

5. CONCLUSION

The study has shown that there is a high level of awareness of the concept of constructability among design firms, which believe that it improves designs and leads to other benefits. However, the widespread use of the concept is hindered by many factors, the most significant of which is designers' lack of construction knowledge. It is concluded that although most designers indicated that they required contractors' experience in their designs, only 48% were often involved with contractors in the design process. To gain more construction knowledge to improve the constructability of their designs, designers need more feedback from the site which only contractors can provide. This calls for a total dismantling of the traditional compartmentalization of design and construction by more widespread use of non-conventional procurement methods which give contractors a greater role in design.

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