CONSTRUCTABILITY REVIEWS: A STRATEGIC PROCESS IN DESIGN DEVELOPMENT

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Abstract

Construction designs are often produced with insufficient considerations on the constructability aspects. Poor constructability has resulted in delay, cost increase, disputes, safety hazards and inconvenience to the public. Increasingly, there has been a call for more systematic input of construction knowledge in the planning and design processes of modern day's infrastructure development. In some countries, notably the US, the practice of constructability reviews is on the rise, with concomitant benefits. It is advocated that construction plans and designs be subject to constructability reviews as early as possible. It should be made part of the project management strategy driven by the client. This paper outlines the constructability review process and benefits, whilst drawing lessons from a number of case studies.

Keywords: Constructability Reviews, Design Development, Strategy, Case Studies

1. Introduction

Construction designs often pose problems when they are executed on site. Mendelsohn (1997) speculated that 75 per cent of the problems encountered in the field are generated in the design phase. Whilst contractors concede that they do create their own problems, these are sometimes compounded by inherent design flaws. Clients and consultants may regard this as exaggeration, but many studies in different countries have pointed to the benefits of constructable designs (e.g., CII-Australia, 1996; Uhlik, *et al*, 1998; Jergeas, *et al*, 2001 and Pocock, *et al*, 2006).

The main barriers to improved constructability have been revealed as "lack of open communication between designers and constructors" and "inadequate construction experience of designers" (Pocock, *et al*, 2006). Whilst it is understandable that design teams need to concentrate in producing designs to meet their clients' aesthetic and functional requirements under tight timeframe, they should not be apathetic to

constructional problems, since otherwise the time, cost and quality performance of their projects would be adversely affected. Hence, it is of strategic importance that their designs be reviewed for constructability before works start on site. Constructability has been defined in numerous ways, but in essence it means "the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives" (CII, 1986).

2. Objectives Of Constructability Reviews

Whether Constructability Reviews are carried out by the design team or independently by construction experts, the aim would be to enhance the constructability of designs for the eventual benefits of the client, although the intermediate beneficiary could be the constructor. More specifically, the objectives of Constructability Reviews are to:-

(i) Reduce costs caused by incompatibility, reworks and material waste;
(ii) Reduce change or variation orders;
(iii) Enhance quality through do-it-right first time;
(iv) Ensure or shorten project duration;
(v) Improve public and construction crew safety;
(vi) Reduce environmental license violation or non-compliance;
(vii) Minimize user/public inconvenience and intrusion; and
(viii) Increase compatibility between client's requirements and construction practices

In the US, Constructability Reviews (CR) are often carried out in conjunction with or independent of Value Analysis. Whilst there are some overlaps in terms of both trying to achieving essential functions at the lowest total cost, the two activities differ by their focal points. Value Analysis focuses on function analysis and life-cycle cost, whereas CR focuses on compatibility of design information with realities of site constraints and practices. More often than not, they are conducted as separate activities, although co-ordination is required to avoid wasteful overlaps. For example, the Oregon Department of Transportation (ODOT) guidelines specifically state that CR would not replace the Department's Value Engineering Program.

3. Forms and Timing of Constructability Reviews

Constructability Reviews can be carried out in-house by the design team as part of the design process at designated milestones such as the commencement of concept design, schematic design or detail design stages. It is a systematic reflection by the same design team members of design decisions made in the preceding stage with a view of the up-to-date site conditions and prevailing market situations. Advantages include

confidentiality and minimal additional costs, since the design team members meet regularly anyway. Disadvantages lie in the lack of objectivity and a fresh mindset, not to mention the apparent maintenance of status quo in terms of construction expertise within the design team.

A more objective and meaningful review is carried out by an independent party or panel comprising of construction experts from different disciplines, such as builder's work and E & M installations. The lead-expert can be a Construction Manager, if the Construction Management project delivery mode is envisaged. If a Design & Build contract is going to be awarded, the independent party can be chosen from the Design & Build contractors contending for the works. Each contender, however, would have to be met separately to prevent divulge of designs. For the traditional project delivery method, or Design-Bid-Build, a reputable contractor with vast construction experience can be invited with or without being given the opportunity to tender for the same works. In the latter case, a fee should be paid for the service provided. The review process can be informal or fully documented to generate "Lessons Learnt" and capture savings made, as necessary.

As an example, the ODOT (2006) has established the following criteria for using external reviewer in its CRs (where "S" stands for "Should" and "C" stands for "Consider"):-

S Alternative contracting is being considered
S The project team calls for a formal CR
S All modernization projects
S Projects with complex staging and traffic control
S Bridge replacement (reconstruction and rehabilitation)
S Extraordinary environmental circumstances
S Consultant designs
C Multi-year projects
C Projects with innovative materials and techniques
C Project requiring shoring
C Sensitive neighborhoods

Constructability Reviews should be started as early as possible, preferably at the project planning stage to gain the maximum benefit. Other possible times have been suggested at the 30 per cent, 60 per cent, 90 per cent design completion stage (Mendelsohn, 1997). Constructability efforts can result in higher payoffs during the earlier stages, as the ability to influence final cost will decline with design progression (CII-Australia, 1996). A recent survey (Pocock *et al*, 2006) of about 100 construction practitioners (including clients, consultants and contractors) in the US indicates that 18 per cent of the respondents experienced CR at pre-project planning stage; 41 per cent at conceptual design stage and 24 per cent at detailed design stage, while only 9 per cent was at contract award or construction stage. This study indicates a trend towards earlier CR as compared with earlier studies (Uhlik *et al*, 1998 and Jergeas *et al*, 2001).

4. Conducting Constructability Reviews

Many formal CR meetings in the US are conducted with checklists and some agencies have developed guidance manuals to facilitate the process. Some agencies (such as those in Washington State) have arranged 40-hour workshops whereas others use one day as the time frame for each review.

Drawings and specifications available to-date are invariably provided during the CR for the reviewers to work through, identifying any discrepancies, errors and factors incompatible with site conditions. Over-specification (e.g., tight tolerances) and wrong specifications have been common findings amongst all irregularities.

A CR champion or leader acts as facilitator, and he/she invites representatives of each technical area to give a brief overview of their project aspects to stimulate discussion. Construction problems and potential risks are the focal points of discussion, assisted by 3-D animation where available. Site visits can be conducted to get a real feel of the conditions. Maintainability issues are also addressed where appropriate. Sometimes, CRs are carried out during construction and also after construction to secure the maximum benefits of "lesson learnt". Especially for post-construction CR, explicit advice should be given to "check egos at the door", avoiding situations where designers and contractors become defensive over errors committed (ODOT, 2006). In case the contractor requests for a post-construction CR, he/she becomes the owner of that process but the overall ownership of the entire CR process belongs to the client. As such, the necessary balance is instilled for an objective review for drawing useful experience for future projects.

5. Cost/Benefits of Constructability Reviews

Positive impacts on project outcomes have been recorded for CRs completed in the US and Canada. In the former (Russell *et al*, 1994), cost savings between 1.1 to 10.7 per cent have been tracked for case studies on manufacturing and petrochemical projects. Time savings for these projects ranged from 5 to 10 per cent. Safety incident rates were down by 32 to 87 per cent compared with industrial standards (OSHA). Safety was enhanced through rigging and erection studies, whilst pre-assembly, prefabrication and modularization techniques reduced work performed on scaffolding.

In Canada, it was reported that a compressor station project completed in 1995 had achieved a saving of 40 per cent compared with historical cost of similar facilities as a result of applying constructability (Jergeas *et al*, 2001).

Taking into account the cost of implementing CRs, the cost/benefit ratios (cost being measured either in hours or monetary value) usually exceed 10:1 (Russell *et al*, 1994).

6. Case Studies

In the following sections, 4 case studies are depicted on the use and suspected non-use of CR in the design development stage. These case studies illustrate the strategic importance of CR in the execution of major construction projects, many of which affect the public interest. The lack of CR could have significant impact on project performance.

6.1 Use of Constructability Reviews

Case 1: Lions Gate Bridge in Vancouver, Canada

Reconstruction of this 45-year old 1,518-meter long suspension bridge was the result of an extensive constructability study of 9 different transport options (the "long list" of choices), some of which would involve digging new tunnels under the scenic Stanley Park (Lea, 1995). The least disturbing option was chosen to carry out seismic retrofit and deck replacement for the existing bridge. Works could only take place during 10-hour night closures under stipulated wind conditions while daytime traffic was maintained. Under a combined Design-Bid-Build and Design-Build arrangement, the contractor had custom-designed and fabricated equipment and construction method for the deck replacement task, which was a substantial engineering challenge. Works were completed with an extra of CAD$5 million and a delay of 6 months in 2001, but the extra only amounted to 16 per cent compared to an expected contingency of 15 to 25 per cent (Cho, 2002).

Case 2: Central Library at Seattle, Washington, USA

The new Central Library has 362,987 sq. ft and an underground carpark for 143 vehicles, costing US$107 million to build. It was named by Time Magazine as "Building of the Year" and won numerous awards due to its unique architecture. It resembles an uneven stack of books, with 5 platforms being aligned directly on top of one another but off centered to provide wide views and airy space. This 11-storey glass curtain walled building has cantilevered floors encased by a steel latticework.

Contract was based on General Contractor/Construction Manager with special clause on constructability and pre-construction services, which are extracted below (MRSC, 2002):

> *3.1.10 Provide constructability review and related suggestions to improve the constructability of the Project to the Owner and Architect for consideration.*
>
> *3.1.11 Work with the Owner and Architect to prepare a constructability plan for the project to reduce cost, save time, improve quality, reduce risk and improve the*

overall process of Project delivery. Key objectives of the constructability program will be to create a well-planned, safe, effective, cooperative and mutually beneficial wok environment for all participants.

3.1.12 Review the Schematic Design Documents, the Design Development Documents, the Construction Documents and other Contract Documents and prepare appropriate reports to the Owner noting any inconsistencies, incomplete information or other deficiencies that need to be resolved for the successful completion of the Work. Design review activities are to be a cooperative effort with the Architect and its Consultants.

Constructability review and constructability program formed part of the evaluation criteria for the Qualification Proposals and accounted for 15 points out of the maximum obtainable 100.

The Central Library was opened in 2004, with an extra cost of US$4.33 million for the enhanced glass and metal exterior approved by the stakeholders.

6.2 Suspected Non-use of Constructability Review

Case 3: Central Artery/Third Harbor Tunnel Project, Boston, Massachusetts, USA

Being dubbed the "Big Dig", this is a massive civil engineering project replacing the surface transport system in Boston with 8-10 lane underground highway system linking up Interstate systems. The project was divided into many contract packages, which took over 10 years to complete.

One of the packages (C07C1: East Boston Toll Facility) was criticized by the Office of the Inspector General as lacking CR for its contract (OCC, 1999). Against an initial estimate of US$5 million in 1993, the 1998 revised cost estimate became US$10 million. Question was also raised on the extra US$2 million spent on the design. There was a distinct design for the canopy that is not ordinarily seen for a toll facility. It was also alleged that the lack of a thorough and complete review of wind load calculation posed a potential public safety hazard. Eventually, the project team initiated design changes that would save the project an estimated US$1.1 million.

Case 4: Tuen Mun Highway, Hong Kong SAR, China

A 8.5km stretch of the Tuen Mun Highway between Kowloon and the New Territories underwent upgrading works, costing US$68 million. The works entailed cutting back some steep rock slopes along the Tuen Mun Highway with difficult and complex geometry.

The joint venture contractor stopped work when a rock slide caused a fatal accident. Dispute broke out between the Highways Department and the Contractor, who claimed that the works were impossible to build under the fixed price Design & Build contract. The contractor's contention was that it would be unsafe to carry out works without closing some lanes, a section of which was not approved by the Highways Department. The contract required 3 full width lanes in both carriageways be kept open at all times under general circumstances.

In 1996, the Contractor instituted mediation proceedings against the Government to resolve the dispute over the impossibility claim. The Mediator found in favour of the Contractor and held that it was impossible for the Contractor to complete the works in strict accordance with the Contract, especially in relation to lane closures and safety of operation. The Contractor was relieved from his contractual obligation to complete. The Government did not proceed with arbitration in the public interest, as otherwise further delay would be caused (PoT, 1996).

Although no information on CR is available for this project, currently the Highways Department calls for consultancy studies on the engineering feasibility of its projects.

7. Conclusion

Constructability is often down-played by the Design Team, which tends to pass the onus of difficult construction to the constructor. There are several reasons for this. Firstly, they believe that constructors are paid to sort out construction problems and bear the risks. Secondly, they consider that the detrimental effects, if any, are transient compared with the long-term design functions which they set out to achieve. Thirdly, they may not be aware of the construction difficulties. Through the case studies illustrated above, the consequences of poor constructability have bearings on project performance and sometimes these affect safety of the construction team and the public. Hence, it is of strategic importance that constructability is reviewed before actual works are carried out on site. A system of Constructability Review has been developed, notably in the US and Canada, which serves as good pointers for all to follow. Studies have shown that these Constructability Reviews are good value for money and efforts. A comprehensive Constructability Review program should complement our ongoing efforts to produce designs which are cost and time effective.

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