



# Constructability

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## Introduction

As projects get more and more complex the issue of constructability becomes important. Constructability infiltrates all parts of a project, especially those related to the engineering and architectural professions. With projects becoming more and more complex and time frames shorter and shorter, implied warranty and severe professional liability issues may arise.

Design professionals need to be aware of the potential issues and claims implied by a design's constructability or buildability profile. When a project has inherent constructability issues, resulting litigation can involve delay claims, change order issues and disputes, and owner's dissatisfaction with delivery. In extreme situations, direct claims may be made against the design principal for poor plans, specifications or estimates, or schedules that have made the project difficult to build, or more costly or time consuming than anticipated.

The issue is well recognised in the construction industry, but what is not so well recognised is when to do constructability reviews, who should do them and how they should be done. This *Practice Note* provides suggestions and a methodology for conducting constructability reviews of projects of all types and sizes. Constructability issues not only involve issues of buildability, but also the sequence of construction and integration of systems in a logical sequence using standard substructures.

## The Meaning of Constructability

Constructability is a project management technique for reviewing construction processes from start to finish during the pre-construction phase. It will identify obstacles before a project is actually built to reduce or prevent error, delays and cost overruns.

The term "constructability" is referred to as:

- the extent to which the design of the building facilitates ease of construction, subject to the overall requirements for the completed building
- a system for achieving optimum integration of construction knowledge and experience in planning, engineering, procurement and field operations in the building process, and balancing the various project and environmental constraints to achieve overall objectives
- a system for achieving optimum integration of construction knowledge in the building process and balancing the various project and environmental constraints to maximise achievement of project goals and building performance

## Barriers to Improving Constructability

Resistance to performing constructability reviews results from a number of well-known factors, including:

- complacency with the status quo
- reluctance to invest additional money and effort in the early stages of a project
- limitations of lump-sum and design-build contracts
- lack of construction experience in the design firm

- the designers' perception that they already perform an analysis
- lack of mutual respect between constructors and designers
- construction input that is requested too late to be of value

Overcoming this resistance involves "changes in procedures, company culture, and awareness of potential constructability issues both at the corporate and project level" (O'Connor and Miller, 1995).

Litigation usually involves the "claim starters" listed below, which clearly include issues relating to constructability. The list provides an "insight as to why constructability claims arise because almost all of these factors relate to inadequate communication, lack of coordination, and inexperienced project teams that do not obtain guidance from those who have previously handled similar projects" (Folk, 2005).

- Site responsibilities are not clear and co-ordinated.
- Client differences are not resolved immediately.
- The construction schedule and budget are not tied to scope.
- The client's project representative is inexperienced.
- The firm accepts the project with uncompensated risks.
- There are infrequent site observations.
- The client has difficulty making decisions.
- Key issues are resolved after the agreement is signed.
- The firm has a high professional staff turnover rate.
- The consultant's project staff are inexperienced.
- The firm's project manager is inexperienced.
- Construction contract administration services are not in the contract.
- Project agreements are not well co-ordinated.
- The project is fast tracked.
- The construction budget is inflexible.
- There is a high volume of change orders.
- The construction schedule is inflexible.
- Client decisions are not systematically documented.
- The consultant's project manager is inexperienced.
- The client is a committee.
- The client has a high public profile which generates public attention, putting pressure on design decision-making processes.

## When Should the Constructability Review be Performed?

Many constructability issues occur as a result of a lack of communication between the project owner, architect or designer and the construction company before construction commences. This is especially so with so-called design-bid-build projects. Architects, engineers and designers by their nature are not experts in construction methodologies. For these reasons, and for "liability reasons, most plans and specifications tend to be performance oriented, specifying the end result and materials to be used" (Galvinich, 1995). The lack of communication between designers and construction companies is often covered or hidden by the use of performance specifications. While the use of performance specifications is justified it cannot be overused in the name of risk management.

By incorporating constructability reviews into the design process at an early stage, project delivery is more assured and results in fewer post-construction disputes. However, in New Zealand many projects are design-bid-build and therefore there is little opportunity for the construction company to get involved in the design phase as it is unlikely to be contracted at that time.

The “normal” alternative to performing constructability reviews during the design process phase is to hire a peer reviewer consultant. The peer reviewer consultant needs to be a construction expert with considerable experience in construction methods and the capacity to run alongside the architects and engineers during intense design process phases. This is no easy task and such consultants are rare.

Another approach is to identify the likely tendering construction companies (perhaps four to six candidates) and ask them to each provide an experienced construction engineer or construction manager to form a team to help the designers develop a buildable solution from the outset. This team could serve again and again, and lessons learned on one project could be leveraged into new projects as time goes by. Obviously this requires some expense from the construction companies, but the client may well see benefit in providing a consulting fee for this process, treating it as an investment that returns no construction surprises or time delays, and fewer litigation issues. For the professional, this approach may eliminate the issue of liability for poor plans, drawings and specifications.

A third alternative is for the design company (or the client) to post relatively complete designs (say 80 per cent and beyond) on the Internet and request feedback on the design.

Constructability reviews should be conducted for all construction projects irrespective of their size – what changes is the scope and intensity of the study. For projects circa \$2 million or less, a simple constructability study is performed at initiation, then at the 90 per cent design stage. For others, say in the \$25 million or less range, constructability reviews are done at initiation, and at the 30, 60 and 90 per cent design stages. For projects over \$25 million the constructability review process should be more or less continuous during the entire design phase.

### **Who Should Perform the Constructability Review?**

Constructability reviews are easily managed for projects where the contractor is determined beforehand. The preferred contractor is engaged at the first client briefing stage and is involved all the way through the design phases. The contractor is an integral part of all design meetings and reviews all documents, plans, drawings, specifications, tender documents and procurement schedules.

Construction companies involved in the tendering phase of a design-bid-build project must conduct a constructability analysis before pricing the bid documents. This is usually very difficult as there has been no prior communication about the design. Constructability reviewers working for the construction company have to be very experienced and fast on their feet in order to advise the bidding company on the constructability issues that are likely to affect costs and schedules. Severe

constructability issues on design-bid-build projects can bankrupt a construction company. There is a greater chance of bankruptcy if these issues are not identified up front, or if uncompensated constructability risks are not properly analysed.

A constructability analysis must be a principal component of a construction company’s integrated approach to risk management. Construction companies that do not undertake a constructability analysis and review increase their risk profile, as the idea is to identify, categorise, quantify and then reduce or eliminate the risk. Design risk is, by its very nature, an expression of constructability.

For build-own-operate-transfer (BOOT) projects (where the construction company is entirely responsible for all project design and construction), in the absence of an internal constructability review function the company must bring in external constructability expertise to establish a rigorous design review that is fully buildable, without excessive costs or time delays. This requires designers to provide their designs for external review at all levels, something that some architects are unwilling to do.

A constructability review is easy to implement for projects employing the principles of “alliancing”, especially those related to large public works which by their nature employ a “just in time” design process. This is because the entire team, from designers and engineers to those involved in construction and commissioning (see *IPENZ Practice Note 09 “Commissioning Capital Plant”*), are all on the same side, sharing project “gain” and “pain”. In this kind of relationship communication pathways are very strong and co-operative, and all participants can contribute expertise to the constructability review. There are generally few litigation issues related to constructability, as any difficulties are worked out at an early stage and there are no constructability surprises.

Regardless of construction option, project timeframe or size, the constructability review should commence at the client brief stage and run right through the design process stages and into construction. The constructor must be involved in reviewing constructability at all design stages.

The project must have an integrated information source system to capture the lessons learned throughout all project phases. This includes what went wrong, what went right, change orders, variations and commissioning reports. The construction team needs to provide a continuous stream of information into the database so that when the next project is started the constructability review is up to date.

### **The Constructability Review and Analysis Process**

A constructability review and analysis comprises a review of documentation and its completeness and adequacy for the task at hand, and an analysis of buildability, logical sequencing, scheduling and complexity of project elements.

Complexity analysis determines whether or not elements can be simplified. This is especially important for infrastructure elements such as piping and cabling in, for example, a large

complex building with a complicated services function. Rising cable ways and similar systems are analysed to see if a simpler installation system could save cost, time and construction frustration. For example, a rising service duct may be sized by the designer so that the construction company cannot use a standard support stanchion and a special one must be fabricated. If several hundred rising ducts are required then a case could be made during the constructability analysis to simplify this element by redesigning the rising duct so that the standard bracket can be used.

The main objective of a constructability review should be to minimise or eliminate potential change orders and schedule delays during construction by ensuring that the construction documents are fully co-ordinated, complete and buildable. A constructability review should also seek to eliminate redundancy in quality control reviews performed by different entities involved in the project, such as architects, peer reviewers and permitting agencies.

The scope of the review cannot be limited to a review of contract documents provided by the architect. Traditionally, owners provide integral portions of the contract documents, such as survey, as-site existing, geotechnical, hazardous material, environmental and other pre-construction documentation. All elements that “make up the contract documents need to be concurrently reviewed – drawings, as-built conditions, specifications, geotechnical reports, environmental documents, site topographic and utility surveys, etc” (Pruett, 2004).

## Personnel

The right personnel and tools are necessary to effectively execute the review. A common approach is to:

- establish a multidisciplinary review team with construction-experienced personnel
- create comprehensive constructability management tools which are provided to the reviewers
- conduct constructability audits on projects either under construction or completed to ascertain and prevent recurring bid document errors
- conduct site visits to verify site topographic, utility, easement, surrounding public utility and other existing conditions

Individuals with direct construction field experience should be selected to perform constructability reviews. The most qualified “constructability reviewers are those individuals that have dealt with the by-product of bid document errors and omissions in the field. Supervisors, inspectors, or managers who have been involved in resolving unclear construction conditions or settling change orders and claims have an excellent background that can be applied in the up front constructability reviews” (Pruett, 2004). Their knowledge, combined with some form of a constructability checklist derived from audits of previous projects and changes, is necessary for a comprehensive and successful constructability review.

The initial programme, design and peer reviews are typically done by architects and engineers and are viewed from a designer’s perspective. In contrast, the constructability review team views the documents from a builder’s perspective. The review team needs to have management tools that act as a guide to finding missing or unco-ordinated contract document information, including a detailed constructability scope of work. The team must be able to continually build upon and access a “lessons learned” database of specific problem areas.

The detailed constructability scope of work defines areas to be reviewed in the documents and assigns multidisciplinary team members responsible for completing them. In practice, each reviewer is responsible for catching comments such as “see structural”, “provided by others” or “provide as required” and frequently repeated errors or omissions that have resulted in variations or change orders on previous projects (Pruett, 2004).

A professional journal is an important tool for an engineer engaged to perform a constructability review. The engineer can use his or her journal to log the lessons learned during construction and the output of the review process, so that this information can be fed into the next project.

Following a constructability review, the designer incorporates the constructability comments (this is called back-checking). Several meetings with the architect or engineer after the review may be necessary to resolve all of the identified issues. The project team should reach a consensus on whether or not to incorporate each constructability comment.

The constructability review will pay for itself if it is conducted properly and focused on the issues that affect buildability. It can be difficult to quantify the financial savings delivered by the review as the stage of construction in which an error is discovered has the biggest impact on its cost. However, only a few of the major and recurring issues need to be identified to realise its value.

It is essential that the review and analysis process is systemised so that it follows a set procedure. Either an expert computer-based system or a simple matrix (see Table 1 for an example) can be used. The required elements are arranged in a sequence allowing all components to be located and easily applied.

**Table 1: Matrix for Constructability Review and Analysis**

	<b>Part 1</b>	<b>Part 2</b>	<b>Part 3</b>	<b>Part 4</b>
<b>Section</b>	Constructability review (Form set A1000)	Constructability analysis tools (Form set B1000)	Quality assurance (Form set C1000)	Review reports (Form set D1000)
<b>Section 1 Client brief</b>	<ul style="list-style-type: none"> <li>• Building purpose</li> <li>• Fitness</li> <li>• Functionality</li> </ul>	Decision support system (DSS) tool to ascertain building is “on strategy”.	S1C1000 question set	S1D1000 report
<b>Section 2 Design</b>	<ul style="list-style-type: none"> <li>• Buildable</li> <li>• Difficult elements</li> <li>• Uncompensated risks</li> <li>• Design risk</li> <li>• Resource risk</li> <li>• Load lift risk</li> <li>• Construction risk</li> <li>• Erection risk</li> <li>• Commissioning risk</li> </ul>	DSS to determine veracity of buildability, construction of difficult elements, and completeness of design to permit construction. Value engineering for risk analysis during construction.	S2C1000 question set	S2D1000 report
<b>Section 3 Site inspection</b>	<ul style="list-style-type: none"> <li>• Easements</li> <li>• Utility access</li> <li>• Location</li> <li>• Storage</li> <li>• Activity</li> <li>• Lay down</li> <li>• Boneyard</li> <li>• Hard arrival receival</li> <li>• Telecoms and comms</li> <li>• Traffic</li> <li>• Public</li> </ul>	DSS to determine if all the activity can be performed on the site.	S3C1000 question set	S3D1000 report
<b>Section 4 Drawings and plans</b>	<ul style="list-style-type: none"> <li>• Accuracy</li> <li>• Completeness</li> <li>• Nomenclature</li> <li>• Schedules and tables</li> <li>• Vendor-supplied bid documents</li> <li>• Utility or agency bid documents</li> <li>• Environmental documentation</li> <li>• Resource consent documents</li> <li>• Consent conditions</li> <li>• Complete geotech surveys</li> </ul>	Schedule analysis to determine errors and omissions that lead to constructability and time delay issues.	S4C1000 question set	S4D1000 report
<b>Section 5 GA, layouts, scope</b>	<ul style="list-style-type: none"> <li>• Nomenclature</li> <li>• Orientation</li> <li>• Locations</li> <li>• Floor elevations</li> <li>• Tilts, slabs, beams, columns</li> <li>• Fitout</li> <li>• Glazing</li> <li>• Piping and cables</li> <li>• Cable racking</li> <li>• machine platforms</li> <li>• HVAC systems standardised</li> <li>• Sizes standardised</li> <li>• Brackets and support structures standardised</li> <li>• Types rationalised</li> <li>• Translatable to subcontractor level with minimum instruction</li> <li>• Oriented to operations and maintenance</li> <li>• Oriented to commissioning</li> </ul>	Standardisation analysis is used to determine if all physical systems use standard methods and systems, so that over-engineering is not used in the design process.	S5C1000 question set	S5D1000 report

	Part 1	Part 2	Part 3	Part 4
<b>Section 6 Schedules</b>	<ul style="list-style-type: none"> <li>Standardised for all elements and systems</li> <li>Correctly tied to nomenclature</li> <li>Oriented to commissioning</li> </ul>	Standardised analysis is used to ensure that all the tables and schedules are structured to follow the design and are simple to follow and oriented to commissioning.	S6C1000 question set	S6D1000 report
<b>Section 7 Performance specifications</b>	<ul style="list-style-type: none"> <li>Minimal reference to “as required”</li> <li>Translatable to subcontracts with minimum instruction</li> </ul>	Errors and omissions analysis are used to determine accuracy and veracity of performance specifications so that there are no uncompensated risks.	S7C1000 question set	S7D1000 report

## Key Points for the Constructability Reviewer

### Bid documents

The constructability review should never target only the bid documents provided by the designer. Although the bulk of the bid documents will be produced by the architect or engineer, the effect of owner-furnished, utility agency or environmental documentation needs to be concurrently reviewed.

### Back-checking

Following a constructability review, the designer incorporates the constructability comments. Several meetings with the architect or engineer after the review may be necessary to resolve all of the identified issues. The project team should reach a consensus on whether or not to incorporate each constructability comment.

### Constructability team members

The right personnel and tools are necessary to effectively execute the review.

### Two parts to constructability

A constructability review and analysis comprises a review of documentation and its completeness and adequacy for the task at hand, and an analysis of buildability, logical sequencing, scheduling and complexity of project elements.

### Constructability scope of work

The detailed constructability scope of work defines areas to be reviewed in the documents and assigns multidisciplinary team members responsible for their completion.

### Knowledge management

A database of lessons learned, critical decisions and design elements from previous projects, can, on a company-by-company basis, create a checklist for future design teams working on new projects. Knowledge management in this area within the construction industry becomes a critical link between risk management and constructability. Individual engineers' lessons learned could be extracted from their professional journals (perhaps with specific software) and deposited in a communal database, thereby becoming the feedstock of such a knowledge management process.

### The review

The main objective of a constructability review should be to minimise or eliminate potential change orders and schedule delays during construction by ensuring that the construction documents are fully co-ordinated, complete and buildable. A constructability review should also seek to eliminate redundancy in quality control reviews performed by different entities involved in the project, such as architects, peer reviewers and permitting agencies.

### Further Reading

Folk, P 2005, *Constructability: Does the Design Convey Enough Information?*, Victor O. Schinnerer & Company.

IPENZ 2007, *Practice Note 09* “Commissioning Capital Plant”, IPENZ.

Pruett, K 2004, *Case Study of Bid Documents Errors and Omissions*, Construction Management Association of America.

Wright, E 1994, *Constructability Guide*, Obrien-Kreitzberg Assoc Inc.

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