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FIGURES

1. INTRODUCTION

THE MEANING OF CONSTRUCTABILITY ANALYSIS

Constructability can be defined as “the optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives” - *Construction Industry Institute*.

[6] Defines constructability as: “The extent to which a design of a facility provides for ease of construction, yet meets the overall requirements of that facility”.

Perform constructability analysis refers to the design analysis performed to evaluate the constructability of a specific design by identification and subsequent elimination of barriers in constructability (e.g. correct sequencing of construction tasks).

Constructability Analysis 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 errors, delays and cost overruns.”

LIMITATIONS OF THIS CONSTRUCTABILITY ANALYSIS GUIDELINE

This guideline is intended to describe aspects to be considered during the design of a system and to facilitate and improve constructability. It makes extensive use of information provided by references [3] and [4].

This guideline is not intended to serve as a handbook or a source of constructability improvement methods and techniques; these aspects of constructability often differ for various construction projects. The references, however, provide some information referring to different projects.

2. SUPPORTING CLAUSES

2.1 SCOPE

2.1.1 Purpose

This Constructability Analysis Guideline describes the advantages of Constructability Analysis and is a guideline, or a roadmap, to implementing a Constructability Analysis. The principles, process and barriers to constructability are described; tools for the practise of Constructability Analysis are suggested.

This document is important for Eskom even though Eskom does not perform construction of plant, but contracts it out. In the Eskom environment, it is still advantageous if Eskom project managers monitor constructability; it will ensure that contractors utilise construction methods that are not conducive to waste, for example during the design one needs to consider the special limitations to ensure minimal demolishing of a section that blocked access to current installations (Arrangement Design should be consulted). Constructability analysis may also identify new and innovative construction methods that can save money.

2.1.2 Applicability

This guideline applies to all Eskom projects that include a construction phase.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] ISO 9001 Quality Management Systems

2.2.2 Informative

The following documents as listed, although not invoked in this specification, provide additional information or examples:

[2] Construction Industry Institute "Constructability: A Primer"

Publication 3-1 July 1986, reformatted May 2009

[3] Construction Industry Institute, "Constructability Implementation Guide", Special Publication 34-1, Second Edition, December 2006

[4] Constructability. The Institution of Professional Engineers New Zealand Incorporated

(IPENZ) Practice Note 13; ISSN 1176–0907.

[5] Constructability Guide, 1994, Prepared by Edward D. Wright, PE.

[6] Presentation on Constructability by Brehm.

http://ebookbrowse.com/brehm-constructability-20061102-ppt-d114492724

2.3 DEFINITIONS

A. Terms

Build-own-operate-transfer (BOOT) project: A contracting model or approach where the construction company takes all the responsibility and risk to ensure that an operating plant or facility is transferred to the final user in a state that fulfils all requirements, making the constructor a stakeholder which takes a larger risk than most other approaches.

Constructability: The optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives i.e. the "buildability" in the construction industry.

Constructability Analysis: The systematic review process of all available design data prior to construction to ensure the optimum design configuration, scheduling and procurement for the construction of plant and facilities at the relevant stages of a project.

Design-bid-build project: A contracting model or approach where the construction company needs to do a certain amount of design prior to being able to do the costing that will enable it to tender for a construction project.

Designed, owned, and operated maintained (BOOM): A contracting model or approach where the constructing company is liable for plant performance and delivery of desired outcome. The contract is put in place for a set period of time and the plant will be removed from site once the objective has been achieved. The project risk is transferred to the appointed contractor.

Immature technology: Technology that has come into use fairly recently, although, the full industrialisation may not have been proven. It usually implies that the technology has not been applied widely and it is often deployed to solve issues that could not have been solved without it, or to be ahead of competition in the market. The use there-off involves increased risk.

Spatial Interference: The result of a design that leads to placing more than one construction element in a position or too close together; this may be undesirable or impossible if the elements are to function as intended.

2.3.1 Disclosure Classification

Controlled Disclosure: Controlled Disclosure to external parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description
BOOT	Build-own-operate-transfer
CII	Construction Industry Institute. The University of Texas at Austin
DOOM	Design-own-operate-maintain
IPENZ	The Institution of Professional Engineers New Zealand Incorporated
TBD	To Be Defined

2.5 ROLES AND RESPONSIBILITIES

Not Applicable.

2.6 PROCESS FOR MONITORING

Not Applicable.

2.7 RELATED/SUPPORTING DOCUMENTS

Not Applicable.

3. CONSTRUCTABILITY ANALYSIS

Constructability Analysis is required to answer the question: whether a designed system or facility can be constructed, as intended. While constructability analysis should consider assumptions made during design and planning, the analysis should also provide an indication if the construction can be optimised.

Where Value Engineering places more emphasis on the earlier stages of the design activities, Constructability Analysis considers optimisation of the construction phase. However, Constructability Analysis should start as early as Value Engineering – the two practises augment each other and they are not in conflict.

A constructability analysis must be a principal component of a construction company's integrated approach to risk management. Design risk is, by its very nature, an expression of constructability.

3.1 PURPOSE AND OBJECTIVES OF CONSTRUCTABILITY ANALYSIS

The main purpose of Constructability Analysis is to ascertain whether it is technically feasible that a system, plant or facility can be constructed.

It also serves to verify that the construction plan, if executed as specified, will not lead to unexpected delays, installation problems and construction costs higher than anticipated.

The attention to the above two issues contribute greatly to successful projects that are completed on time, within budgeted cost, conforming to specifications and that leads to satisfied customers; in short, achieving the goals of project management.

Constructability issues not only involve issues of "buildability" but also the sequence of construction and integration of systems in a logical sequence using standard sub-structures.

3.2 CONSTRUCTABILITY PRINCIPLES

The Institution of Professional Engineers New Zealand Incorporated (IPENZ), Practice Note 13, defines twelve principles of constructability which are mapped on to the procurement process. They should be considered as aspects of a project that should be handled with due consideration of the impact on constructability:

1. Integration
2. Construction knowledge
3. Team skills
4. Corporate objectives
5. Available resources
6. External factors
7. Programme
8. Construction methodology
9. Accessibility
10. Specifications
11. Construction innovation
12. Feedback

3.3 THE CONSTRUCTABILITY ANALYSIS AND REVIEW PROCESS

A standardised review and analysis process should be used by an organisation and the same process can be followed for different projects. However, projects are unique and will include different stake-holders at different times, as a result, it will often be necessary to tailor processes for a specific project.

The important principle is that the constructability analysis process is addressed and documented at a very early stage in the project life-cycle.

The following tools and techniques, amongst others, can be used to facilitate the process:

- Feedback from previous similar projects, documented lessons learnt;
- 3-D CAD drawings and physical models; and
- 3-D models of consecutive stages of construction, introducing the time dimension from the schedule. This facilitates improved sequencing of construction activities.

These techniques should form part of reviews that are conducted periodically during the project.

A periodic review should be the most important instrument used to analyse constructability. This section, therefore, will address the review.

3.3.1 When and by whom should the Constructability be reviewed by?

Essentially, all parties involved in the design and construction phases should analyse and review constructability as an ongoing activity. Different project business models, however, influence the way that involved parties communicate, resulting in varying degrees of complexity of the review process.

Some examples of different approaches due to contracting models are:

- For design-bid-build projects, the constructing companies are forced to do the constructability analysis before finalising the pricing and bid documents. This approach requires very competent and experienced reviewers due to the inherent risk that the bidding construction company is exposed to. A constructability analysis must be a principal component of a construction company's integrated approach to risk management. Severe constructability problems that are identified too late can lead to bankruptcy should the contractor not be compensated;
- For a project where the contractor is determined before project start: The contractor is involved from the first client briefing meeting through the design phases and is part of all design meetings, reviews of documents, plans, specification preparations and procurement schedules. In this case, reviewing and managing constructability seldom present big challenges; and
- The build-own-operate-transfer (BOOT) projects transfer all project risks to the construction company. If the company does not have a strong constructability review function, external consultants should be appointed to lead and conduct rigorous reviews. This requires planners and designers to provide their designs for external review at all levels. Often team members are unwilling to do that.

  Mostly only the first contract model mentioned above is used by Eskom, the others are however listed as additional examples.

The referenced IPENZ Practice Note 13 states:

"Regardless of construction option, project timeframe or size, the constructability review should commence as early as 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."

3.3.2 Requirements for the Constructability Review Process

a) Preparation for the Constructability Review

- Notice of the event should be given within the required time according to company/project policy;
- The review team should include individuals with the relevant direct construction field experience;
- The review team should include, or have access to, a project and/or company official that is authorised to approve decisions by the team, up to the anticipated level of impact; and
- The required inputs to the review meeting or workshop should be available to members of the review team beforehand. It may not be practical to make reproductions or copies of all input material for all team members. Some items can be prepared in advance, such as:

  - Explanation of the format, or agenda;
  - Technical documentation, such as plans, design drawings, etc;
  - Reports of corrective action from previous reviews; and
  - Roles to be played by members, e.g. chairman, secretary.

b) Execution of the Constructability Review

- The review process should be conducted systematically, according to a well-defined process and accompanying procedures;
- A constructability review should minimise or eliminate potential change orders and schedule delays, during construction;
- The review should ascertain that construction documents are fully co-ordinated, complete and buildable;
- The review should endeavour to eliminate redundancy in quality control reviews, e.g. duplications at the different project participants, such as designers, constructors, licensing agencies and approval by local authorities; and
- The review procedure (and agenda) should allow sufficient flexibility to enable the team to handle identified problems with more serious impact than normally anticipated.

c) Documentation of the Constructability Review

- Important aspects of discussions must be documented for the duration of the review;
- All decisions and allocation of responsibilities for action must be documented;
- A Review Report should be prepared after the review to the desired/practical level of detail;

- Corrective actions should be listed and ranked in a separate document for prompt distribution to affected parties; and

- The review documentation should be placed under configuration control.

d) Corrective action after the Constructability Review

- Notice of corrective actions required and the nominated responsible individuals or parties should be given to all stake-holders and affected project team members;

- The execution of the corrective actions shall be included in all project management actions, plans, schedules, budgets and progress monitoring activities; and

- The results and progress shall be reported as input to follow up reviews

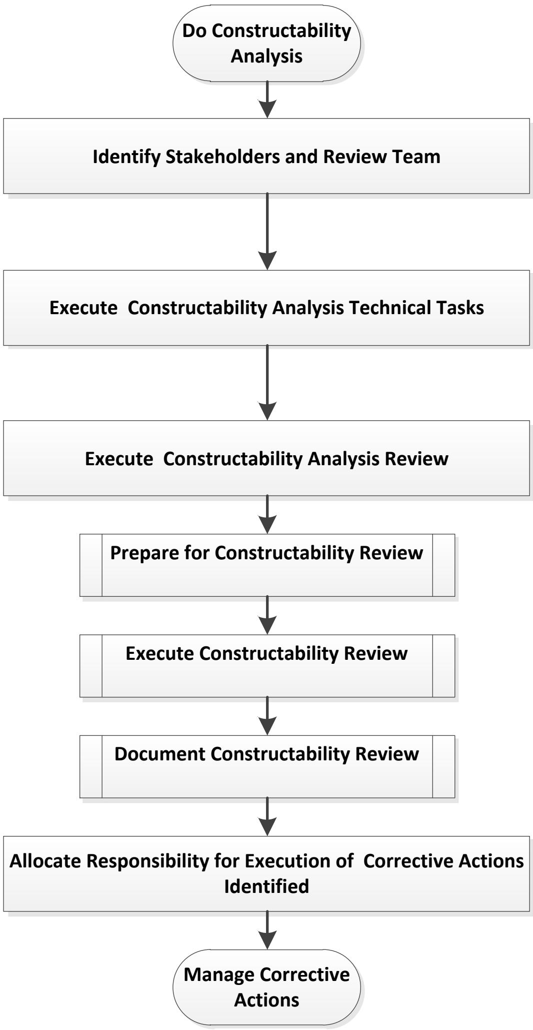

Figure 1: Constructability Analysis Process Flowchart

3.4 LIMITATIONS OF CONSTRUCTABILITY ANALYSIS

3.4.1 Limitations

- Not all constructability problems will be identified if the review team does not include experienced individuals with specific domain knowledge;
- Where a project makes use of new technology or immature technology, there is a greater probability that potential constructability problems will go undetected until they appear during the actual construction task; and
- Despite the fact that constructability problems are identified at reviews, the solution often cannot be identified until construction and integration. This can happen due to uncertainty about interface designs that are still incomplete and have been scheduled for completion at a later stage due to the schedule being too constrained. It should be minuted at the review that the possible problems should be addressed when it occurs.

3.4.2 Barriers to the implementation of constructability analysis

Research conducted by CII, involving 62 companies, has identified several barriers, which have been categorised and presented in the publication.

Some of these are:

- 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 performed an analysis; and
- Lack of mutual respect between constructors and designers.

3.5 GENERAL CONSTRUCTABILITY ISSUES

"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."

While the above statement about insufficient communication is very valid, there are also other common causes of constructability problems that often occur, despite the fact that they are elementary.

The real problem often lies in the degree of difficulty involved in detecting the problems. The following are examples of such issues:

- Spatial Interference, i.e. during construction, it is found that some components, structures and layouts are designed to occupy the same area on a site or space in a building. This mostly occurs due to communication problems between different design-groups but also frequently happens due to errors when two dimensional design drawings are interpreted. This is an example of a constructability problem that is increasingly mitigated by the use of three dimensional views, such as the ones produced by CAD systems and other computer resources like SmartPlant;

- Sequence of construction is an aspect that needs special attention because if the schedule calls for elements to be constructed early, due to manpower availability, those elements may prevent construction of elements scheduled for a later date. Completed structures may prevent access to space required for installation of other elements. Such sequencing problems, in the worst case, can lead to demolishing and rebuilding of elements;

- Where designers have utilised out-dated databases concerning interfaces with other elements, delays will occur and re-work may be required. The project must have an integrated information source system to capture the lessons learned throughout all project phases. This includes records of what went wrong, what went right, change orders, variations and commissioning reports. The construction team is required 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.

4. AUTHORISATION

This document has been seen and accepted by:

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5. REVISIONS

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6. DEVELOPMENT TEAM

The following people were involved in the development of this document:

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7. ACKNOWLEDGEMENTS

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APPENDIX A:

I. CONSTRUCTABILITY IMPLEMENTATION ROADMAP

The constructability implementation roadmap, as defined by CII, is used to guide the implementation and utilisation of a constructability program by means of six milestones. These milestones are:

- Commitment to implementing constructability;
- Establishment of a corporate constructability program;
- Obtain constructability capabilities;
- Plan constructability implementation;
- Implement Constructability; and
- Update corporate program.

A number of additional tools for implementation are defined. For the purposes of this constructability analysis guideline, it is assumed that these milestones have been reached and the constructability program has been implemented.

II. CONSTRUCTABILITY ANALYSIS AND REVIEW AIDS

It is advisable to be aware of known methods and procedures that are valuable in the definition of the Analysis and Review processes.

Further to those mentioned in section 3.3, other aids or tools are:

- A Matrix for Constructability and Review Analysis (See III below for an example);
- Audit results from reviews of earlier projects can be summarised to list often-recurring problems;
- A project journal, kept by an Engineer to log all lessons learned during previous projects, can be utilised to create a checklist for later projects;
- A list of seventeen “tools” is provided by the referenced “Constructability Implementation Guide”, published by CII, of which, several are useful for Analysis and Review; and
- A general checklist (see IV below).

III. MATRIX FOR CONSTRUCTABILITY REVIEW AND ANALYSIS [4]

	Part 1	Part 2	Part 3	Part 4
Section	Constructability review (Form set A1000)	Constructability analysis tools (Form set B1000)	Quality assurance (Form set C1000)	Review reports (Form set D1000)
Section 1 Client brief	• Building purpose • Fitness • Functionality	Decision support system (DSS) tool to ascertain building is "on strategy".	S1C1000 question set	S1D1000 report
Section 2 Design	• Buildable • Difficult elements • Uncompensated risks • Design risk • Resource risk • Load lift risk • Construction risk • Erection risk • Commissioning risk	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
Section 3 Site inspection	• Easements • Utility access • Location • Storage • Activity • Lay down • Boneyard • Hard arrival receival • Telecoms and comms • Traffic • Public	DSS to determine if all the activity can be performed on the site.	S3C1000 question set	S3D1000 report
Section 4 Drawings and plans	• Accuracy • Completeness • Nomenclature • Schedules and tables • Vendor-supplied bid documents • Utility or agency bid documents • Environmental documentation • Resource consent documents • Consent conditions • Complete geotech surveys	Schedule analysis to determine errors and omissions that lead to constructability and time delay issues.	S4C1000 question set	S4D1000 report
Section 5 GA, layouts, scope	• Nomenclature • Orientation • Locations • Floor elevations • Tilts, slabs, beams, columns • Fitout • Glazing • Piping and cables • Cable racking • machine platforms • HVAC systems standardised • Sizes standardised • Brackets and support structures standardised • Types rationalised • Translatable to subcontractor level with minimum instruction • Oriented to operations and maintenance • Oriented to commissioning	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

IV. GENERAL CONSTRUCTABILITY CHECKLIST [6]

1. Provide work areas when practical
2. Verify utility locations
3. Assure utility construction coordination with other Agencies
4. Are pay items in the bid tabulation covered by the specs?
5. Is all of the required work covered by pay items?
6. Provide access to work areas
7. Consider access for routine maintenance in design
8. Consider construction methods that "drive" the design
9. Is weather a factor?
10. Are materials available?
11. Keep design simple and flexible
12. Standardise design elements
13. Do specifications allow work efficiency?
14. Are specifications clear and conform to current practices?
15. Check local Agency requirements for environmental issues.
16. Which material is more economical?
17. Consider material type availability during staged construction.
18. Can access be constructed to remote locations?
19. Minimise restricted areas that eliminate normal equipment use
20. Minimise low production or hand work areas
21. Do Special Provisions fit the job?
22. Strive for simplicity in design
23. Minimise architectural details
24. Consider working area requirements around structures
25. Check for overhead utility conflicts
26. Consider access to structure site
27. Can traffic conflicts be reduced?
28. Are work zones large enough for equipment access?
29. Can emergency vehicles travel through without delays?

(From presentation by Brehm)