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EXECUTIVE SUMMARY

Constructability reviews are conducted in conjunction with Engineering Design Reviews to identify potential constructability problems with designs. Considering constructability within earlier stages of a project will allow for necessary corrective measures which may negatively impact on the construction works and/or place potential restrictions on the construction.

1. INTRODUCTION

A constructability assessment is a method for identifying potential problems with constructability of design or construction methodology/sequencing early enough in the project development to take corrective action. The assessment aims to recognise difficulties prior to the commencement of construction to reduce or prevent error, delays and cost overruns.

A constructability assessment allows the design team to study and become aware of every facet and intricate detail of the construction of a design. A properly conducted constructability assessment will identify potential construction difficulties and allows the construction methodology to be considered during the design phase of the project.

A constructability assessment will be beneficial to a project from a cost, time, quality and safety perspective; thereby adding value to a project. A constructability assessment is a more efficient method of solving potential construction related problems as opposed to realising construction constraints during the execution phase of a project.

2. SUPPORTING CLAUSES

2.1 SCOPE

This document provides the reader with a guideline for the execution of a constructability assessment and is limited to construction for civil and structural engineering works for new builds and modifications to existing plants. Other project stakeholders are required to participate and provide input into the assessment to determine the technically viable and cost effective solutions.

2.1.1 Purpose

The purpose of a constructability assessment during project development is to ensure the project is constructible, while bearing in mind time, cost, quality, risk and safety, and is maintainable through its life expectancy. These reviews are applicable to both Brown and Greenfields projects.

Constructability reviews involve the optimum use of design and construction knowledge, and experience in the planning and development of a project. This document provides the reader with a guideline for items which should be considered when conducting a constructability assessment; and review of construction drawings. The guideline also considers maintenance of risks and concerns which may have a negative impact on the project.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited divisions.

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] Occupational Health and Safety Act, 1993 (Act 6 of 1993),
[3] Mine Health and Safety Act of 1996,
[4] Construction Regulations 2014,
[5] 240-53113685 : Design Review Procedure,
[6] 240-4332798 : Engineering Policy,

2.2.2 Informative

[7] 240-56364545 :Structural Design and Engineering Standard

2.3 DEFINITIONS

Definition	Description
Brownfield Project	A project that requires modification or refurbishments of an existing plant.
Constructability	The ease and efficiency with which structures can be built.
Contractor	The party, if required, who carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project, or operation or maintenance of a facility. The Principal may undertake all or part of the duties of the Contractor.
Demolished material	Material as a result of demolition activity
Designer	The individual who defines the architecture, components, interfaces, and other system components
Detail design	The process of refining and expanding the preliminary design of a system or component to the extent that the design is sufficiently complete to be implemented
Greenfield Project	A new build project
Indicative programme	Programme indicating sufficient detail to determine the major milestones and target dates that have to be achieved during the construction process. The indicative critical path for the construction phase of the project should also be highlighted within the programme
Principal	The party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal
Shall	Indicates a requirement.
Should	Indicates a recommendation

2.3.1 Disclosure Classification

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

2.4 ABBREVIATIONS

Abbreviation	Description
CoE	Centre of Excellence
CTC	Civil Technical Committee
HVAC	Heating, Ventilation and Air Conditioning
LDE	Lead Design Engineer
PCM	Process Control Manual
SANS	South African National Standard
SCOT	Study Committee of Technology
TC	Technical Committee
Gx	Eskom Generation

2.5 ROLES AND RESPONSIBILITIES

2.5.1 The Role of a CoE

The role of the Engineering Centres of Excellence is to apply its expertise, skill and processes to produce a high quality output of exceptional standards in line with the organisational requirement.

2.5.2 The Lead Design Engineer

The role of the Civil and Structural LDE is to ensure that this document is applied to all projects with Civil and Structural scope and must have input from LDE's from all disciplines involved.

The LDE is responsible for ensuring that a constructability assessment report is compiled.

2.5.3 Constructability Assessment Report Signatories

Complied by: LDE/Engineer appointed by the LDE

Functional Responsibility/Approved by: Senior Engineer/Chief Engineer

Authorised by: Corporate Specialist/CoE Manager

2.6 PROCESS FOR MONITORING

This document will be updated periodically in response to developments in technology, experience as well as the inspection findings/possible trends. The 'Technical Custodian', or an appropriate competent person nominated by the Structural Design Engineering Manager, should be consulted on any proposals for modifications or improvements to this document, including feedback on experience from any application in service.

2.7 RELATED/SUPPORTING DOCUMENTS

240 – 53114002: Engineering Change Management Procedure

240 – 53114026: Project Engineering Management Procedure

3. CONSTRUCTABILITY ASSESSMENT OVERVIEW

During a constructability assessment, risks which may impact on the construction are identified. Mitigation measures or workable solutions are proposed to address the identified risks. Examples of adverse impacts include method or means of construction that may escalate the cost of a project, cause disruptions to plant operations and exhaust the planned construction period which may result in project delays.

Constructability considerations in design should be implemented as early as possible within the design progression. This is done to ensure the constructability components are maintained as the influence of the designer reduces closer to project execution. This ensures that any changes to the design are made during the early design phases of a project.

3.1 CONSTRUCTABILITY ASSESSMENT REQUIREMENTS

In order for a constructability assessment to be properly conducted, the following must be available:

- Access to site for inspection
- Geotechnical overview
- Scope of works
- Required Operational Capability Report (ROC) and Stakeholder Requirements Definition (SRD)
- Arrangement design, depicting layout and 3D model of plant (Brownfield or Greenfields) to identify clash detection.

- For modifications to existing plants, it is recommended that the 3D model be based on a 3D scan of the existing plant to ensure that all relevant information is captured.
- Power station representation (i.e. Gx), including maintenance personnel; this is of particular importance when a modification or refurbishment to existing infrastructure or plant is required.
- Survey showing underground utilities

3.2 BENEFITS

Benefits of a constructability review process include:

- Identification of time and cost saving situations
- Identification or proposal of alternative designs
- Identification of potential risk
- Identification of alternative methods of construction or prioritisation of activities

4. PROJECT CONSTRUCTABILITY ENHANCEMENT DURING PLANNING PHASE

a. Despite this document being limited to Civil and Structural Engineering, it is advisable that all project stakeholders be involved in the constructability assessment. Alternative solutions proposed must have input from all relevant disciplines. This is conducted with particular emphasis of potential impacts to or by existing or proposed service routes.

b. A project team comprising of experienced representatives of the client, stakeholders external to engineering and engineers must be established. This is done in order to consider constructability components from the onset of the project and throughout all its phases.

c. To facilitate ease and efficiency of on-site operations, all major construction methods must be discussed and analysed as early as possible to direct the design according to these methods.

d. Individuals with relevant construction knowledge and experience must be involved in design works at the early stages of project planning to identify construction considerations which pose potential risks. This will aid in developing a well thought out construction methodology that addresses the identified risks.

e. The construction methods and interfaces between multiple contracts must be taken into consideration when choosing the type and the number of contracts required for the execution of projects.

f. The Project manager’s indicative programme indicating key dates and possible milestones must be produced at tender stage and included in the tender documentation. This is even more important if it is planned to have more than one contractor working at the same time on the same site. The programme ensures that interface management between multiple contractors can be maintained, as individual schedules can be aligned to milestone dates.

g. Site layout and underground utilities must be studied carefully to ensure that the construction, operation, and maintenance proceeds efficiently, and to avoid any interference between the operations performed during these phases. Existing drawings must be verified to be a true representation of what is on site if required.

h. Impacts on existing structures in close proximity to the proposed construction must be assessed and measures or alternative solutions developed accordingly. The possibility of relocating the proposed plant or structure must be evaluated.

i. Impacts on current operations and the necessary measures that would have to be implemented to mitigate these impacts would have to be work-shopped and solutions or alternative construction methodologies developed.

5. CONSTRUCTION PLANNING CONSIDERATIONS

During the planning aspect of the Planning and Design Stage of a project, focus must be placed on the range of criteria, requirements or tolerances that are applicable to the project. This allows the planning process to be undertaken in a concise manner. The following are examples of these planning considerations:

5.1 SITE:

5.1.1 Geotechnical Considerations:

When assessing the location of the site for construction, it is advisable that a desktop study be carried out based on available historical data. A geotechnical investigation should be conducted to establish the relevant input parameters required for the civil engineering design of structures and footings. The site must be evaluated to determine whether the preferred founding method is practical or economical. The following points must be considered:

- What site restrictions prefer a piling solution?
- What impact (both financial and methodological) would large excavations have on construction activities or existing facility operations?

5.1.2 Environmental considerations:

An environmental impact assessment must be conducted based on the concept designs produced, and the following must be considered, but not limited to:

- Environmental Effects: effects on the natural environment including aesthetics, topography, vegetation and water resources. Effect of increased run-off, seepage and infiltration often the consequence of land clearing and deforestation.
- Socio-Environmental Effects: effects on the living environment such as noise, vibration, air and water pollution. Effect during construction including noise, vibrations, pollution, dumping of earth material, settlement, landslides and soil erosion

5.1.3 Structure Orientation

After selecting the building site and all the analyses related to the location have been completed, consideration must be given to the orientation of the building on the site taking into consideration the type of building and occupancy. For example, an administration building should be orientated to take advantage of the natural vistas, micro-climates, natural drainage, natural lighting and topography.

5.2 STRUCTURE DIMENSIONS

Thought must be given to the size and scale of structures located in the area when determining the maximum height of the structure. There may also be statutory limitations that must also be considered with particular regard to the National Building Regulations. When considering building heights, one must also consider:

- Access heights, including maintenance operation
- Crawl beam heights
- Gantry crane heights
- Equipment heights
- HVAC ducts

- Small power and lighting
- Nearby Airports
- Building regulation limiting the construction height
- Clearance heights (in consideration of electrical servitudes)

5.3 STRUCTURE SETBACKS

The regulations of the various municipalities will dictate the minimum building line restrictions of a property relating to the positioning of any structure. This is also dependent on the type of structure and location.

5.4 CONSTRUCTION TOLERANCES

Construction tolerances must be clearly communicated to the contractor to ensure the design requirements are achieved, however these requirements should be evaluated to determine if these are achievable taking into consideration site conditions or envisaged methods of construction. To avoid unnecessary claims or compensation events, designs must be revisited in order to ensure that the required tolerances can be achieved employing cost efficient methods of construction.

5.5 ACCESS WAYS:

5.5.1 Vehicular Access

Consideration on how vehicles will enter and exit the proposed site must be made taking into account i.e. access to minor and major roads. For example, where a building is located on a corner plot between a minor and a major road, access off the minor road is preferable. Right of way, road signs and traffic light considerations must be considered and authorisation obtained from the relevant local authority. Easy accessibility will minimise the chance of accidents, and save time in manoeuvring to arrive and leave the site. Proper planning is required to layout the roads leading from the nearest highway. The provision of internal access roads should be based on the operational conditions or requirements of the plant or facility. The relevant parties should be involved in the constructability assessments to provide the necessary input should there be risks or concerns raised about the location of these roads. Solutions tabled should meet with the approval of all parties.

5.5.2 Vehicular Access during construction

The placement of construction equipment such as tower cranes must be assessed such that primary and secondary access ways are not obstructed. In the event an access way is obstructed, the necessary traffic accommodation measures or detours should be assessed and implemented to suit construction activities. If a road is temporarily unavailable, road barricading equipment must be used to indicate closure of road. Internal access road closures must be authorised by the management of the facility. Similarly, any works impacting on municipal, provincial or national roads must be authorised by the relevant authorities inclusive of any traffic accommodation measures. When considering vehicular access during construction, one must look at other active projects on site and the sharing of work space.

5.5.3 Pedestrian Access

Entrances and exits of a building must be designed so as to provide convenient access to parking areas, walk-ways and adjacent streets, with particular attention being given to the needs of the physically handicapped. The impact of construction activities on existing pedestrian accesses should be assessed and the necessary accommodation or safe making measures should be evaluated for implementation.

5.6 DEMOLISHED MATERIAL

Projects may require demolition of existing structures and infrastructure. The demolished material can be transported directly to a dump or temporarily stored on site and transported later to a waste disposal facility. In both cases; prior to storage or transport; the demolished material must be assessed to determine if the spoils are contaminated. If the materials are contaminated, storage on site is prohibited and the materials must be dumped in specialised dumps. The vicinity of existing dumps must be assessed and costs taken into account if demolished material must be transported off site.

5.7 SAFETY AND SECURITY

When performing a constructability review, one must assess the potential safety and security risks associated with a design. If a design does not adequately address these risks, this could lead to unsafe working conditions. Ultimately the design will have to be revisited and these risks addressed.

When considering safety in a design, one must also note safety issues when performing construction in confined spaces.

5.8 SPACE CONSIDERATION, FOR ON SITE TEMPORARY LAYDOWN AREA

During the planning phase it is important that the construction site layout is identified and defined taking into consideration working space, laydown areas, site offices, stores and workshops and any other facility required for the construction. If required, construction roads must also be studied and built prior the contractor taking possession of the site. If there are existing roads within the plant, it is then necessary to define the construction vehicle route.

It is also necessary to assess if a concrete batch plant is necessary or ready mix concrete can be transported from commercial source. This should be based on the amount of concrete necessary for the construction, the availability of the commercial sources, and their distance from site. If both solutions are possible the economic study will determine which one to be adopted.

The site layout will be studied and allocated by the client defining both the construction boundary and the laydown areas. The Contractor will propose a site layout plan which should fit within the boundaries. For safety and security reasons, the construction site and laydown area must be fenced.

Without a defined site layout the Contractor may refuse to work for safety and security reasons. The proposed laydown area site/s will require an environmental impact assessment. Preliminary desktop studies will be required to determine if an environmental impact will be triggered. Should there be any environmental risks then these should be addressed in the works information.

5.9 PROJECT CONSTRUCTABILITY ENHANCEMENT DURING DESIGN

At the outset of every design, after the evaluation of clients' needs and the installation site, the most appropriate construction option must be designed, namely onsite construction or a combination of onsite and modularized construction.

Modularisation of elements

Consideration must be given to structures that could be built by modularised or preassemble elements by carrying out a structural and cost analysis study. This study should include, but not limited to:

a. Constructability, i.e. can the plant be constructed with modularised elements? If yes, then:

b. The size and weight of the modular sections must be determined in relation to functionality, transportation, storage, crane capacity, erection etc.

c. The adoption of onsite workshops should be evaluated in order to eliminate road transportation costs and time, and to facilitate construction. The evaluation should include consideration of transportation of material and equipment to on-site workshops as well as electrical requirements.

d. For existing plants, a study needs to be conducted to ensure that the modularisation can be economically and structurally applied to the existing plant also taking into consideration point a, b and c.

e. In addition, the constructability methodology must be reviewed to ensure that any construction concerns are met and that the scheduled sequence of module fabrication matches the preferred erection sequence on site.

6. STAGES OF CONSTRUCTION FOR CONSTRUCTION ON EXISTING PLANT

The constructability assessment for construction in an existing power plant needs to be broken down into three distinctive stages:

- Pre-outage stage – Any construction activities that will have no impact on the normal operation of the plant can be carried out during this stage;
- Outage stage - All construction activities that cannot be constructed whilst the plant is in operation;
- Post-outage stage - Any construction activities that will not impact on the normal operation of the plant.

In order to maximise time utilisation, construction must as far as possible be scheduled to take place in parallel activities, not neglecting safety of personnel.

7. INTERFACE WITH ACCOMPANYING PROJECT PACKAGES

Interface management plays a significant role in construction management, hence all concurrent projects on the construction site must be considered in the Project Manager's indicative programme. This programme should be developed by studying how the other projects may affect each other, developing the correct interface between the various projects by studying how they are affected by other activities. An integration engineer or manager should be appointed to ensure that the various contractors interface with each other as per the programme.

Key points that must be considered:

- Time line of construction, when will the interface occur
- The need for different contractors to be sharing a working area and the impact they may have on each other's activities. The works information/scope of work must ensure that each contractor working on the site are identifiable and has their working area clearly demarcated
- Every contractor is responsible for his own safety file. It is the Employer's safety officer's/representative's responsibility to manage between the various contractors
- The effect of construction plant and equipment on other contractors working space and activities.

Interface events may impact the project negatively with regards to time, cost, quality and safety, thus effectively managing and tracking interfaces of the construction is necessary. In practice, clear communication via a collaboration meeting is a good approach for addressing interface issues.

Where interfaces exist with other construction packages, such should be well documented in all relevant interfacing Works Information/ Scope documents to clearly indicate to the various contractors that tie in points with others. A Terminal Point register is the tool used in Eskom to manage such interface points.

The overall works need to be scheduled such that all Contractors do not impede on each other's Works including quality, health, safety and schedule. Managing these interfaces form an integral part of the constructability assessment and is based on the Contractors method statements and the construction schedule which are both managed by Project and Construction Management with input from Engineering. Such should be coordinated and reviewed to ensure that the interfacing Contractors do not hinder the Works of the other, nor affect existing plant, temporary works incl. cranes and contractor yards of Others.

Interfaces between subcontractors shall be managed by the main Contractor and are not required to be part of the Constructability assessment.

8. CONSTRUCTION PLANT AND EQUIPMENT

Depending on the nature of the works, all construction plant and equipment, necessary for the execution of the works, must be determined during the design phase. It must be assessed if the required construction plant and equipment are able to access the site of the construction activities.

8.1 EXAMPLES OF PLANT AND EQUIPMENT THAT MUST BE CONSIDERED

8.1.1 Tower cranes

The following criteria must be taken into account in selecting and sizing of the cranes:

a. Boom length and Trolley travel

- The boom must be able to swing 360 degrees unless it is possible to secure the boom against wind force during standby.
- The crane hook must be able to reach all areas of the works without interference to the existing structures.

b. Boom height

- The height of the crane must be sufficient such that no interference to the existing structures occurs.
- An assessment must be completed to establish if more than one tower crane is required. In the event that multiple tower cranes are required, the boom heights of each individual tower crane must be staggered to allow for a 360 degree swing of the boom unless the option of securing the boom against wind is available.

c. Load capacity

- During design, if modularisation and preassembly for project elements are required, the weight of the element must be communicated to ensure the required crane capacity is available.

d. Tower Crane erection

- It must be assessed if it will be practical to erect the required tower crane(s) with the use of mobile cranes. Careful attention must be paid to congested areas.

8.1.2 Mobile crane

In the event it is not possible for a tower crane's boom to access a required working area, the use of a mobile crane may be utilised to supplement the tower crane.

8.1.3 Other Typical site construction equipment

Apart from the cranes, other site construction equipment may cause congestion on site and must be considered when completing a constructability assessment. These equipment include, but are not limited to:

- Scaffolding
- Forklifts
- General trucks
- Scrap low-bed trailers
- Cherry picker
- Bosun's chairs
- Lifting equipment
- Power handheld tools
- Welding & gas cutting equipment and machines.
- Support light delivery vans (LDV's)
- Piling equipment
- Excavation Plant
- Nicolas trailers

It must be noted that some of these equipment may belong to other contractors.

9. CONSTRUCTABILITY REVIEW CHECK LIST

In addition to the above guidelines, a checklist is provided to assist in assessing the projects readiness for construction. The checklist is located in appendix A. This check list must be complete and addressed before drawings are issued for construction.

A constructability assessment report must be produced during each design phase and when applicable this check list must accompany the constructability assessment report.

10. AUTHORISATION

This document has been seen and accepted by:

Name & Surname	Designation
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11. REVISIONS

Date	Rev.	Compiler	Remarks
March 2016	0.1	Avesh Haricharan	Draft
March 2016	0.2	Avesh Haricharan	Draft Document for Comments Review
April 2016	1	Avesh Haricharan	Final Document for Authorisation and Publication

12. DEVELOPMENT TEAM

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

- Corporate Specialist - Bruno Marrai
- Structural Design CoE Manager – Tejas Naidoo
- Civil Engineer - Avesh Haricharan

13. ACKNOWLEDGEMENTS

- Denise Govender – Civil Engineer
- Gareth Macintosh – Civil Engineer
- Kameel Burath – Civil Engineer

APPENDIX A: CONSTRUCTABILITY REVIEW CHECK LIST

DRAWINGS	Yes/ No - Comments
Verify that the intent of drawings and specs on drawings are clear. Are all of the views to be constructed provided, such as plans, elevations, sections, bending schedules, and details?	
Are all symbols and abbreviations provided in the appropriate legends?	
Are all scales correctly shown where applicable?	
Are the title blocks complete and current?	
Is the drawing-layering, sequencing and numbering correct?	
Are all of the drawn by and checked by blocks been initialled?	
Are the drawings that are initialled been carefully checked?	
Are all of the dimensions, angles, radii, datum levels, coordinates depicted clearly?	
Are the site grade elevations, finish floor elevations and building location footprints coordinated with all disciplines within the project?	
Will all of the construction systems and assemblies fit within the available spaces leaving all of the necessary clearances and tolerances for operational, maintenance and replacement access?	
Are all dimensions as simple as possible? - Do they all close or can they be easily checked against overall dimensions? - Are the start points and end points of every dimension unmistakably clear? - Have derivation dimensions been avoided or minimized?	
Have all drawings that show a graphic scale been drawn at that scale?	
CIVIL & STRUCTURAL	
Are all relevant controlling property lines, building lines, existing servitudes, existing and proposed contours, and limits of construction been indicated?	
Do all exposed surfaces have positive drainage to move water away from potential incursion zones and towards catchments or drain locations?	
Are all profiles coordinated with the plan views? Are all relevant utilities shown on profile sheets where they run close or cross each other?	
Are all substructure, on-grade, superstructure, secondary structural elements, surface treatments shown, sized,	

scheduled, detailed and coordinated to the extent necessary to construct.	
Are all primary utility assemblies coordinated with all below grade structural foundation and wall conditions shown clearly?	
Have all of the relevant equipment loads and supports been structurally accommodated and detailed? (NB: it is important that all loads on structures be denoted on the drawing. This may be required in future for refurbishment)	
Will the expansion and control joint designs and locations handle the differential movements? Are they coordinated with all the other effected disciplines?	
Check arrangement design, to ensure no clashes with existing plant/ other structures/ contractor yards/ cranes/ temporary infrastructure etc.	
ARCHITECTURAL	
Do the interior and exterior functions, massing, spatial organisations, circulation, future expansions, schedules (windows, finishes) appearance addresses the client's requirements?	
Do all of the structural perimeter overhangs match the architectural specifications, for example roof overhangs and projections?	
IMPLEMENTATION PLANNING	
Verify assumptions relative to sequencing construction activities.	
Verify that requirements necessary to achieve assumed sequencing are included in the contract documents.	
Verify that implementation plan addresses environmental issues and assumptions.	