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The 9 Stages of Complex Engineering Projects
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Clarity in Complexity

Introduction

The whitepaper titled ‘The 9 Stages of Complex Engineering Projects’ provides a comprehensive exploration of the critical phases involved in managing complex engineering projects. Authored by information scientist and industry expert Arno van Vulpen, the whitepaper draws on over 30 years of expertise. It offers detailed insights into how document management systems (eDMS) can support each stage of a project, from feasibility studies through to final handover.

The aim is to optimize project outcomes by ensuring efficient documentation control and management, which are vital for the successful execution of complex projects. This whitepaper is essential reading for professionals involved in large-scale engineering projects, offering practical guidance on how to streamline processes, minimize risks, and ensure that all project documentation is accurate, up-to-date, and accessible to all stakeholders.

Summary

The whitepaper divides the project lifecycle into nine critical stages, each requiring specific strategies for document management and control. Below is a summary of each stage:

1. Feasibility Study

This initial stage assesses whether the project is worth the investment, considering technical, economic, legal, and operational factors. Early consideration of an eDMS is recommended to ensure smooth transitions in later stages.

2. Conceptual Design

Following a positive feasibility outcome, this stage marks the beginning of the design process. Engineers develop design ideas and evaluate them based on cost, feasibility, and potential returns. An eDMS can help manage the increasing volume of documentation and support collaborative reviews and approvals.

3. Pre-FEED (Preliminary Front-End Engineering Design)

This stage refines the selected concept into a detailed design basis and scope of work for the next phase. Document control becomes crucial as the number of deliverables increases, and an eDMS ensures that all documents are properly managed and traceable.

4. FEED (Front-End Engineering Design)

FEED further details the design and produces the “FEED Package” for contract bidding. The accuracy of cost estimates improves, and a final investment decision is made. An eDMS is essential for managing the large volume of deliverables and ensuring that all documents are up to date and properly approved.

5. Detailed Design

At this stage, the design is completed to 100%, allowing for procurement and construction to begin. The number of stakeholders and activities peaks, making document control a critical success factor. An eDMS helps prevent delays and ensures that all deliverables are completed and approved on time.

6. Procurement & Fabrication

Following Detailed Design, this stage involves acquiring materials and services and assembling them into finished products. An eDMS supports efficient information exchange with vendors and contractors, helping to keep the project on schedule and within budget.

7. Construction & Installation

This stage involves assembling the components on-site to create the final asset. As-built documentation is created to reflect any changes made during construction. An eDMS mitigates risks such as cost overruns and schedule delays by ensuring that all project documentation is accurate and accessible.

8. Pre-Commissioning

Before the facility is put into operation, precommissioning ensures that all systems and components are correctly installed and functioning. Checklists and punch lists are used to track progress, and an eDMS helps manage these documents to ensure a smooth transition to operations.

9. Handover

The final stage involves formally transferring the completed project to the operations team. This includes handing over all relevant documentation, which must be properly approved and organized. An eDMS streamlines this process, ensuring that all necessary documents are handed over efficiently and securely.

Each stage of the project lifecycle presents unique challenges that can be effectively managed with the right document control strategies. The whitepaper emphasizes the importance of early implementation of an eDMS to ensure that all project documentation is well-organized, traceable, and accessible throughout the project lifecycle. By doing so, projects can be completed more efficiently, safely, and within budget, ultimately leading to successful outcomes.

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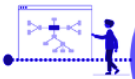
THE 9 STAGES

OF COMPLEX ENGINEERING PROJECTS

1 The Feasibility Study
To determine whether the project is worth the investment for the owner/client.

The right time to consider an eDMS!

2 Conceptual Design
To produce a conceptual design that provides enough input to make a decision on proceeding with pre-FEED.



Starting the design process

3 Pre-FEED
To define and further detail the selected concept, resulting in "design basis" and scope of work (SoW) for FEED.

Creating the design basis

4 FEED
To deliver the FEED Package as the final result. It serves as the basis for contract bidding for the Execution phase.

Front-end engineering design

5 Detailed Design
To fill in all design and vendor details, which are required in order to facilitate procurement and construction.

Completing the engineering puzzle

6 Procurement & Fabrication
To acquire materials, equipment, services needed for construction, and the actual manufacturing.

From theory to reality

7 Construction & Installation
To assemble all of the components and materials to create the finished project/asset.

Putting it all together

8 Pre-Commissioning
To ensure the facility is ready for safe and efficient operation and identify and resolve any issues.

Getting ready for operations

9 Handover
To get all required/relevant documents and drawings across to operations.

From project to operations

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50+ page E-book: The 9 Stages of Complex Engineering Projects

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Feasibility Study: the right time to consider an eDMS!

1.1 The feasibility study in a nutshell

The feasibility study is the first phase of an engineering project. Its main objective is to determine whether the project is worth the investment for the owner/client. This could be new development or extension of an asset (greenfield and brownfield projects) – for example a refinery, FPSO, offshore wind park, solar farm, carbon capture & storage, mine, or infrastructure.

A feasibility study helps determine if the project is viable and justifiable. Not only technical and economic feasibility is evaluated, but also legal, planning, and operational feasibility, as well as an assessment of the project's environmental, social, economic and political impacts.

The duration of this project stage depends on the nature, location, size and complexity of the project. Completing this stage is a key milestone for any project and the gateway to the Conceptual Design stage (or: Concept Definition). Not all project ideas turn out to be feasible or viable, which is exactly why this stage is so important.

1.2 Who is involved in the feasibility study?

This study often involves a wide range of specialists, such as engineers from different engineering disciplines, geologists, and policy experts. The team size and expertise required also depend on the nature, location, size and complexity of the project. In this stage, the team of engineers is relatively small compared to later stages, because the study provides a high-level evaluation of options and not an actual design yet. External expertise might be hired by the client/project owner, but contractors usually only come into the picture in later stages.

1.3 When is the right time to consider a Document Control strategy?

It's never too early to consider a Document Control strategy. The decisions made in this phase have an impact on all subsequent project phases. It does not involve a lot of work and can be kept high-level (like the feasibility study itself) but it's recommended to already consider the following:

- That the project will need an eDMS after passing this stage and could already benefit from an eDMS right now.

- That a top-quality, properly configured eDMS – with true, out-of-the-box Document Control functionality – is a critical success factor (CSF) for any engineering project.
- That experienced Document Controllers can bring much added-value to a project.
- That a proper Document Control process will ensure effective and unique reference numbers from the start, prevent loss of any project documentation and time waste searching for them, and prevent the use of outdated documents or information by any stakeholders.
- What would be the most effective Document Control process, numbering structures (e.g. for documents, drawings, correspondence), revision coding, reference data (e.g. discipline codes and document types) and access requirements.

1.4 When is the right time to consider selecting an eDMS?

While selecting an eDMS often receives a lower priority early in a project, it is very useful to consider early on. This is all too often initiated too late, which means having to select and configure an eDMS under pressure – while the risks and consequences of not having an eDMS start to become apparent – and it distracts from core project activities. As more documents, people and external parties get involved, having an eDMS in place becomes more crucial. Choosing the right eDMS is a strategic choice, in which all the pros and cons of solutions should be evaluated.

Choosing the right eDMS is a strategic choice, in which all the pros and cons of solutions should be evaluated.

There are many different eDMS solutions on the market, but few are tailored to and capable of supporting (complex) engineering projects out-of-the-box, plus not to forget: your project's requirements, standards and business processes. This makes it quite important to carefully select the right eDMS for your project.

Having a high-quality eDMS in place that meets the project's needs will not only help to keep things well-organised in the current project stage, but also enable a smooth transition into next project stages – which can benefit from the already configured eDMS and an easy handover of relevant documents from the preceding stage (with proper document numbering and revisioning).

1.5 How Assai supports the feasibility study

Assai provides out-of-the-box support for all project stages (and operations), based on over 30 years of experience. While the feasibility study may not involve so many documents and people/parties yet, it is already important to have a clear "single source of truth" for your project deliverables, such as documents and correspondence, with unique reference numbers. Plus to keep track of planning dates, responsibilities, actions, changes, access levels and what more is relevant to record in this stage.

As a result, all people and organisations involved will have easy and ubiquitous access to the right and latest information. Stakeholders that need to create documents in Assai can easily do so, with efficient quality-check and review options, as needed.

Compliance is also guaranteed by the out-of-the-box (and customisable) authorisation structures, user roles & permissions, and traceability of any document file downloads, review & approval history and any changes.

Within days you could have your own Assai Cloud environment – or on-premises/Azure Stack if preferred – to accommodate any number of projects, documents and users. Configuration is a breeze and can be maintained without the help of Assai consultants. Our experts in document management and document control are there to advise you on best practices and how Assai could optimally support your project. This includes (Power BI) reports and dashboards, with many readily available templates and endless customisation options.

2

Conceptual Design: starting the design process

2.1 Conceptual Design in a nutshell

The Conceptual Design stage – sometimes 'Concept Selection', 'Conceptual Engineering' or 'FEL-1' (if FEL project planning is used) – starts after a positive outcome of the Feasibility Study: the project seems technically achievable and commercially viable. This next stage marks the start of the design process, and the three subsequent stages (Pre-FEED, FEED/Front-End Engineering Design, Detailed Design) will each go a level deeper, expanding the design with more details and more accuracy.

In this stage, engineers analyse the engineering challenge to come up with (realistic) requirements and solutions. First, design ideas are generated on how the project could be implemented ('ideation'). Next, gathered design ideas and alternatives are evaluated ('concept evaluation') – on their strengths, weaknesses, cost and benefits – to decide on the optimal solution, which meets the requirements and maximises profits for the client/owner. Cost estimates (on CAPEX/capital expenditures and OPEX/operational expenses) are still quite rough at this stage; easily +/- 50%.

The main objective of this stage is to produce a proper conceptual design that provides enough detail and quality input for management to make a decision on proceeding with pre-FEED (or FEED / 'Define' / 'FEL-3', if Conceptual Design and pre-FEED are combined as 'Select' phase). Fundamental design choices in this stage will have a big impact on the rest of the project. The duration of this stage varies depending on the nature, location, size and complexity of the project.

2.2 Who is involved in Conceptual Design?

The client/owner may assign own engineers and/or involve an engineering company at this stage (and a process licensor, if applicable). Engineers from various disciplines are involved to come up with design ideas and elaborate them, in their respective areas of expertise. Project management becomes more crucial now to manage planning & progress and ensure timely completion of all required activities & deliverables.

A dedicated Document Controller is usually not required at this stage but could be valuable. Having an eDMS application will help team members and external parties to find, store & share all project deliverables centrally, define standards, collaborate, review & approve, track actions, plan and report.

Once the conceptual design is ready, management (e.g. a board of directors) will decide – based on all relevant information and expert advice – whether or not to move on to pre-FEED or FEED. The outcomes of design analyses (e.g. economics) or changes to internal/external factors and circumstances can also influence this go/no-go decision.

2.3 Key deliverables & outputs

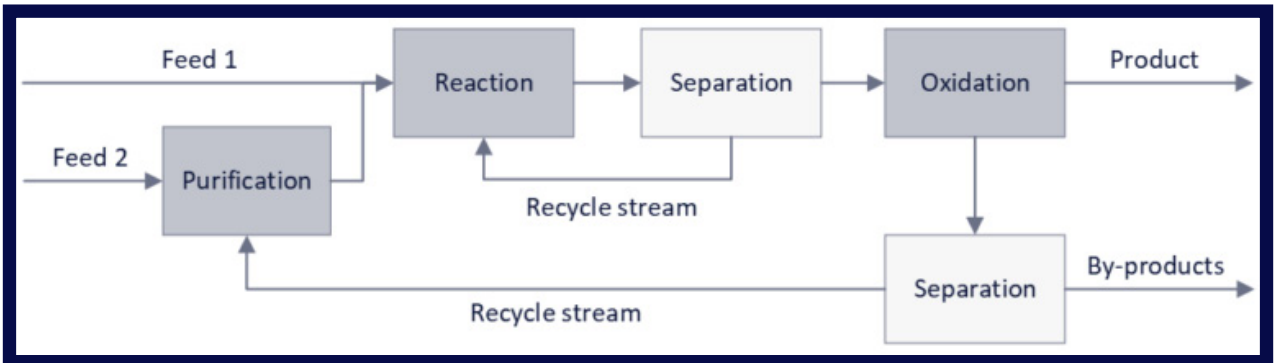
More types of deliverables are produced now by qualitative and quantitative engineering analyses, design activities, cost estimation, studies and meetings.

Typical deliverables of this stage may include:

- Functional requirements (FR)
- Preliminary design basis
- High-level design drawings and diagrams (e.g. plot plan)
- Models and simulations (e.g. thermal simulation)
- Technical analyses (e.g. mechanical/structural)
- Commercial analyses (economics/financial)
- Risk register

Typical deliverables for projects involving (chemical) processes:

- Block Flow Diagram (BFD) – A simplified and more informal overview than a Process Flow Diagram (PFD), providing a high-level logical overview of the process structure and streams.
- Material Balance – Overview of materials involved (input and output).



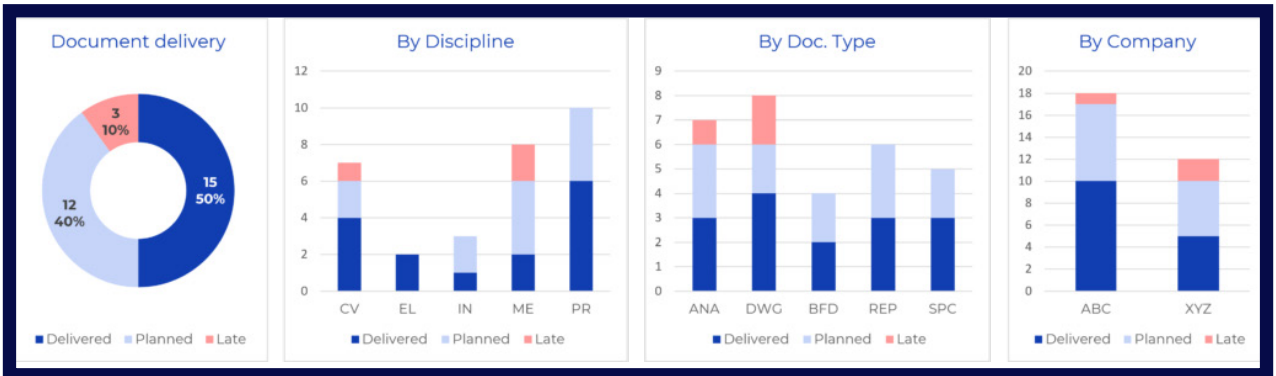
An example of a simple Block Flow Diagram (BFD).

Some of the deliverables created during Conceptual Design will be handed over to the next project stage (pre-FEED or FEED) – as essential input to take the design to the next level. Among the other deliverables, a selection may need to be retained as-is, for future reference or to meet regulatory/audit requirements.

2.4 How Assai supports Conceptual Design

During Conceptual Design, the number of deliverables, companies, people and actions starts to increase. Having an eDMS in place helps to keep everything well-organised, efficient, secure and compliant.

- Assai provides out-of-the-box support for all project stages (and operations), with over 30 years of experience. The following Assai features are key in supporting the Conceptual Design stage:
- Powerful document search & folder trees (automated + custom)
- Easily give engineers and other groups the access and options they need
- Checkout and upload options for engineers, automatic PDF conversion
- Collaborative reviews with integrated redline markup commenting
- Clear roles & responsibilities, review & approval flows
- Custom workflows (e.g. document creation, correspondence handling)
- Digital Signature integration (with DocuSign®)
- Automated e-mail notifications about any (late) actions
- Records management for records to be frozen and retained
- Create a vault per project stage or continue within the same
- Official online handover from one project stage to the next
- Many standard reports and clickable dashboards, Power BI reporting



Assai reports and dashboards provide live insight and overview at any level

Plus as mentioned in the previous article:

- Assai is a proven, reliable, user-friendly and secure “single source of truth” for all your project deliverables, such as documents, drawings, correspondence and technical queries. Everything is traceable and can be reported on.
- Setup & configuration of an Assai Cloud (SaaS) environment – for any number of projects, documents and users – is a breeze.

3

Pre-FEED: creating the design basis

3.1 Pre-FEED in a nutshell

The pre-FEED stage (pre-FEED is short for preliminary Front-End Engineering Design) – sometimes referred to as 'Design Basis' or 'FEL-2' phase – comes after Conceptual Design and before the FEED stage. It is the final part of conceptual engineering. The selected concept will be defined and detailed further to come to a "design basis" and scope of work (SoW) for FEED, which could be given to a FEED contractor for bidding.

By the end of pre-FEED, key design decisions have been made, risks are clear and mitigated where needed, there is a clear approach for the execution phase, and cost estimates are more precise (CAPEX +/- 30%). Engineering is often 4 to 8% complete by that time. The duration of this stage varies depending on the nature, location, size and complexity of the project.

3.2 Key deliverables and outputs

The two main deliverables of the pre-FEED stage are:

- Basis of Design (BOD) document (lists the principles, requirements, criteria, assumptions and reasoning on which design calculations and decisions are based)
- FEED Scope of Work (SoW) (summarises the project scope, schedule & objectives, interfaces, and the work to be done by the FEED contractor)

Other typical deliverables of the pre-FEED stage include:

- PFD drawings (Process Flow Diagrams; high-level process overviews, more detailed and formal than a Block Flow Diagram (BFD) from Conceptual Design, and less detailed than a P&ID drawing)
- Heat and Material Balance, or Heat and Mass Balance (HMB; process overview with major equipment and amount of heating/cooling required, normal operating conditions and flow rates of process streams)
- Initial P&ID drawings (Piping & Instrumentation Diagrams; process overviews with all crucial equipment, piping and instrumentation)
- Preliminary plot plan or field architecture
- Main equipment list
- Economic assessments (CAPEX, OPEX, ABEX = abandonment expenditure)
- Start of EIA or ESIA (Environmental (and Social) Impact Assessment)
- Risk mitigation plans
- Enhanced project schedule

3.3 The importance of Document Control

During pre-FEED, the number of documents, drawings, people and activities increases further, as seen above. There will be more official document reviews and approvals, often multiple revisions per document, a larger team, perhaps multiple companies, and usually tighter timelines – and thus higher risks of mistakes, inefficiency, re-work, information security issues and project delays.

This makes it highly beneficial, if not vital, to have a professional eDMS and Document Control business function in place, or to start setting this up now. This needs to be able to accommodate the project's requirements, standards and procedures. The eDMS should be a reliable central repository where everyone can easily find all latest information, but also have solid Document Control features, such as document numbering and revisioning based on project standards, efficient distribution (standardised and automated), integrated review & approval flows, clear roles & responsibilities, and full traceability. This sets a major step toward the timely and successful completion of the pre-FEED stage.

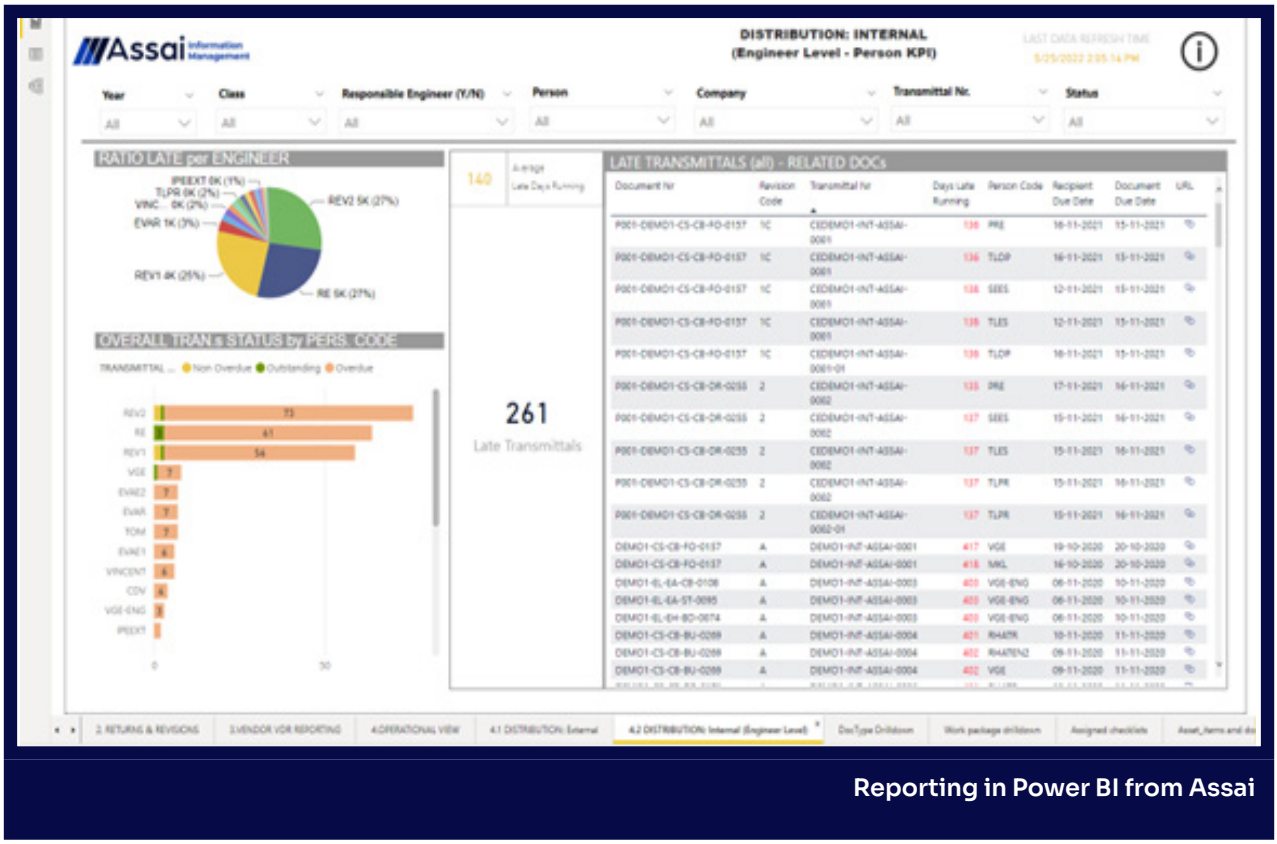
Our advice: select an eDMS in time! Doing this in the busy FEED stage can lead to a less fit or poorly configured eDMS solution, making this a liability instead of a valuable asset. An eDMS is best implemented during pre-FEED or earlier.

3.4 How Assai supports pre-FEED

Assai provides out-of-the-box support for all project stages (and operations), with over 30 years of experience. The following Assai features are key in supporting the pre-FEED stage and a paperless office:

- Powerful document search & folder trees (automated + custom)
- Easy maintenance of numbering standards and reference data lists
- Easy preloading of the MDR (Master Document Register)
- Planning, progress & forecasts at any level: document, work package (WBS) and project
- Built-in review & approval flows; highly configurable

- Distribution matrix with (pre-)defined roles & responsibilities
- Assai Portal for sharing & collaboration with external parties
- Extensive automation and self-service opportunities
- E-mail notifications about changes and (new or overdue) actions
- Easy digital document handover from pre-FEED to FEED
- Standard reports and dashboards, Power BI reporting



Reporting in Power BI from Assai

Plus as highlighted in previous phases:

- Assai provides a proven, reliable, user-friendly and secure “single source of truth” for all your project deliverables, no matter the project size or complexity. Everything is traceable and can be reported on.
- Assai Cloud (or on-premises) is a flexible, turnkey solution with full support for engineering projects, operations, maintenance & modifications, and integration options with Digital Twin environments and Common Data Environments (CDE).

4

FEED: Front-End Engineering Design

4.1 FEED in a nutshell

The FEED or FEE stage (Front-End Engineering Design) – sometimes Basic Engineering, 'Define' or 'FEL-3' phase – usually follows after the pre-FEED stage (or the 'Select' / 'FEL-2' phase). Based on the pre-FEED deliverables (mainly the Basis of Design and FEED Scope of Work), Basic Engineering will be completed with the "FEED Package" as a final result. The FEED Package forms the basis for contract bidding for the 'Execution' phase: Engineering (Detailed Design), Procurement and Construction – often carried out by one main EPC contractor.

While the FEED stage on average "only" represents 2% of the total project execution cost, it can save up to 30% on further design and execution cost if done well. With the end in mind, it is also wise to involve construction and operations teams early on.

Cost estimate accuracy in the FEED stage is typically around +/- 15 to 20% (CAPEX). By the end of this stage, engineering is generally 12 to 20% complete (depending on the amount of detailing needed to consider the project ready for Detailed Design and on the type of EPC contract).

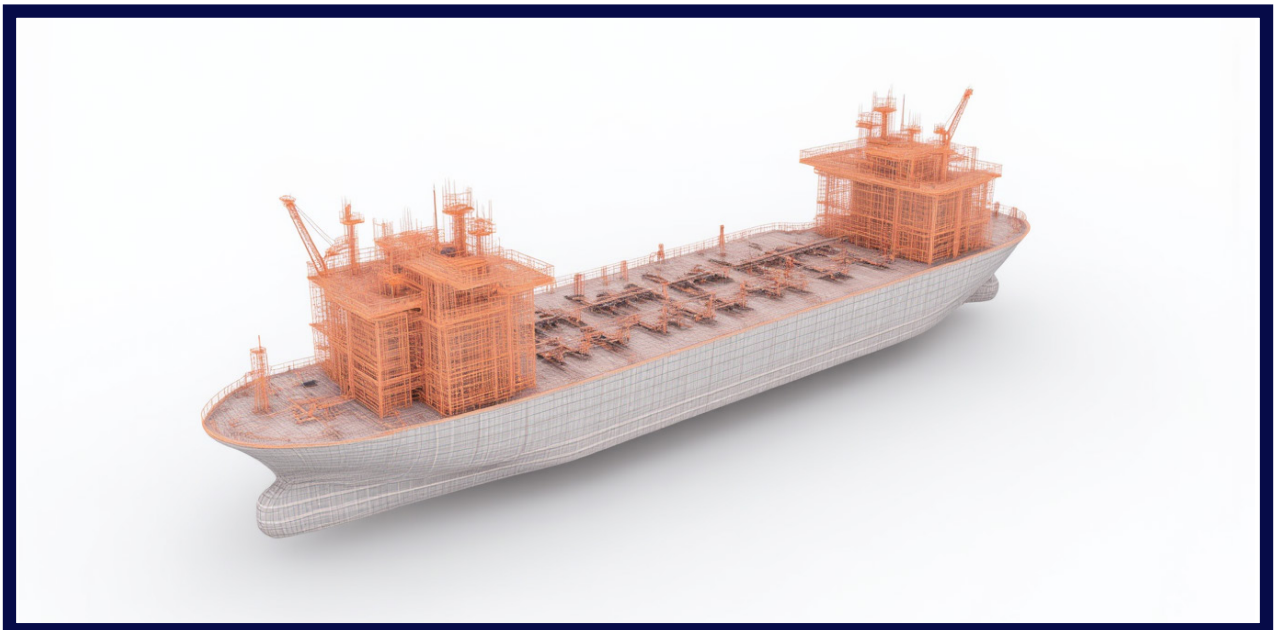
By the end of the FEED stage, a final investment decision (FID) needs to be made for the engineering project. At this point – with a clear picture of the project scope and cost, and a relatively small part of overall budget spent – there is still a chance to abandon the project if not economically viable or cost-effective after all.

4.2 Key deliverables and outputs

The main deliverable of the FEED stage is the FEED package. This contains a wide variety of deliverables and forms the basis for EPC contract bidding. Typical FEED stage deliverables include:

- Operating philosophy
- Project Execution Plan
- Master document register (MDR)
- HAZOP or SIL reports (process safety studies)
- Specifications and standards
- Final Plot Plan
- P&ID drawings (Piping & Instrumentation Diagrams)
- Equipment Lists & Specifications (though no equipment is procured yet)
- Line Lists
- Mechanical Data Sheet (MDS)

- Electrical Data Sheets (EDS)
- Instrument Index
- Cause & Effect Diagrams
- Material Selection Diagram (MSD)
- Start of BOM list (Bill of Materials)
- Start of 3D models
- Vendor list
- Licensor selection



Initial 3D model of a tanker

4.3 Selecting a contractor

The subsequent project stages – Engineering, Procurement & Construction (EPC) – are often performed by an EPC contractor. Selecting a contractor usually happens through a tendering process, where multiple companies may submit a bid to win the contract, based on the contents of the FEED Package. The FEED Package needs to be sufficiently detailed and specific to receive proposals that meet the project's requirements and expectations and are easy to compare, but not so specific or demanding as to restrict the options for bidders or even prevent them from bidding at all.

Outsourcing EPC work to a contractor allows client companies to scale up and down (specialised) resources as required, and make use of their extensive project experience and expertise. Contractors can provide specialists for many different project roles and engineering disciplines;

e.g. Process, Process Safety, Civil, Structural, Mechanical, HVAC (Heating, Ventilation and Air Conditioning), Piping, Electrical, Instrumentation and HSE (Health, Safety & Environment).

The next article in this series (on Detailed Design) will cover some common contract models (e.g. EPC, EPCM, EPCI, BOT, BOOT, DFBO).

> **Assai makes it extremely easy for contractors and other externals to receive and submit documentation, after just 30 minutes of training. The level of automation is remarkable. This has saved our projects a lot of time and resources.**

4.4 How Assai supports FEED

Assai provides out-of-the-box support for all project stages (and operations), with over 30 years of experience. The following Assai features are key in supporting the FEED stage and getting everything 'AFD' (Approved for Design) in time:

- Powerful document search & drilldown options
- Never any doubt about the latest revision or latest information
- Always clear who has responsibility or actions to complete
- High level of automation for engineers and Document Controllers
- Out-of-the-box, flexible workflows for review & approval
- Collaborative reviews and redline commenting
- Generate corporate file templates with pre-populated information
- Digital stamping and signing of documents
- Automated e-mail notifications of new and overdue actions
- Planning & progress at any level; document, work package or project
- Assai Portal optimizes collaboration with external parties, saves resources
- Store official correspondence with the right access control
- Dedicated technical query module to handle any type of query
- Assets module: link documents to tags for benefits in next project stages
- Simple user account management & access control, Single Sign-On
- Records management for records to be frozen and retained.
- Mark & track documentation required for handover (to EPC), fully digital
- Extensive report & dashboard features, Power BI reporting

Plus as highlighted in previous phases:

- Assai offers a proven, specialised, user-friendly and secure eDMS for engineering projects of any size and complexity. Everything is traceable and can be reported on.
- Assai Cloud (or on-premises) is a flexible, turnkey solution with out-of-the-box support for engineering projects from start to end, plus operations, maintenance & modifications.

5

Detailed Design: completing the engineering puzzle

5.1 Detailed Design in a nutshell

The Detailed Design stage follows after the FEED stage (Front-End Engineering Design). The basic design (with typically 12 to 20% of engineering completed) will be refined to 100% – usually by a contractor (e.g. EPC, EPCM or PMC; see below for more) – to enable procurement and construction. This is an iterative process, as different design activities can influence each other; for example, equipment design by vendors or routing of pipes may cause changes to the plant layout design. Cost estimate accuracy in this stage has improved to around +/- 10%. The duration of this stage varies depending on the nature, location, size and complexity of the project.

In Detailed Design, larger equipment and long-lead items are already procured from vendors and suppliers, to allow integrating equipment dimensions and specifications into the design. Supplied equipment can come with all many kinds of vendor documentation, such as layouts, datasheets and manuals. In-time delivery of all vendor documentation by a (large) variety of equipment suppliers can be a major challenge and risk for engineering projects. It helps to have a clear, accessible, up-to-date Vendor Document Requirements list (VDR, VDRL or SDRL) with links to the related equipment and vendors/suppliers, and clear due dates to enable tracking & expediting of this documentation category.

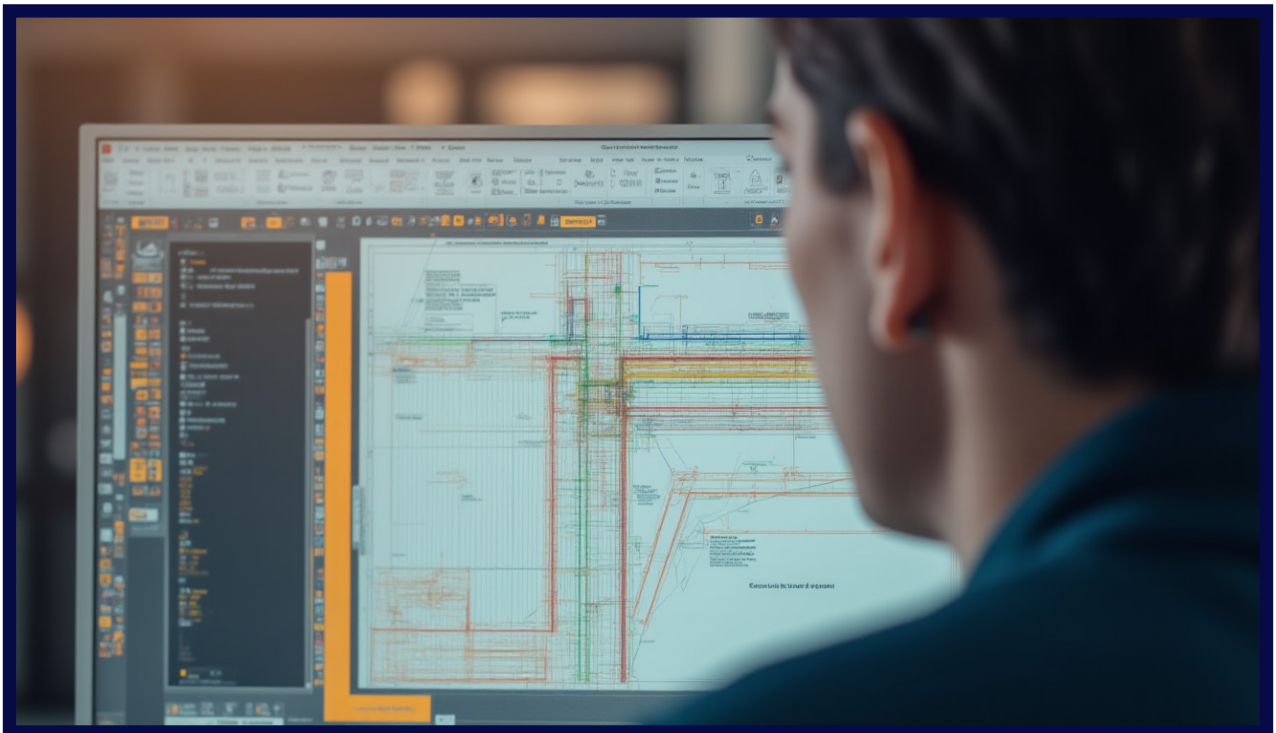
The number of deliverables, stakeholders and activities is at its peak in the Detailed Design stage. Staying on top of things now demands a continuous, dedicated Document Control effort, and a suitable eDMS that meets the project requirements. This is crucial for achieving a timely completion and approval of all project deliverables, and prevent costly project delays or other (unplanned) deviations.

5.2 Key deliverables and outputs

A selection of typical deliverables of the Detailed Design stage:

- Scope of Work
- Project Schedule
- Constructability Review
- HAZOP report (hazard and operability study)
- Process Flow Diagrams (PFD)
- Pressure Safety Valve (PSV) study
- 2D models
- 3D models
- Detailed designs that can be used for construction and installation

- Detailed piping drawings such as isometrics
- Pipe support details
- Approved vendor drawings and P&ID's
- Vendor Data Sheets
- (Equipment) Process data sheets
- Equipment List
- Valve List
- Line List
- Tie-in List
- Instrument Index
- Single-Line Diagrams (SLD)
- Material Take Off (MTO; list of materials required for construction)
- Start up, operating & commissioning procedures
- Emergency shutdown (ESD) philosophy
- Demolition drawings



Detailed Design results in highly detailed CAD drawings

5.3 Key deliverables and outputswww

The previous article in this series (on the FEED stage) described that clients generally contract out at least the EPC work to EPC contractors. There are many more contact types than the well-known “EPC contract”, some of which extend the responsibilities or ownership of the contractor. The contract type chosen mainly depends on the amount of control desired by the client/owner, the amount of risk accepted/preferred, how clear and precise the Scope of Work is, and the expertise, experience, resources, time and budget available at the client.

Common EPC contract variants:

- **EPC:** full outsourcing of all EPC work to the contractor; a single contract and single point of contact for the client; requires an extremely well-defined project brief, plans and specifications; takes longer to establish; fixed CAPEX (but extra cost for deviations from the Scope of Work); usually significant higher project cost than the EPCM model; less involvement and resources needed from the client; less suited for highly specialist or innovative projects with too many variables.
- **EPCM** (with M for Management): the client is involved in management in all stages; more flexibility (to change the scope); all contracts with third parties (e.g. construction contractors, suppliers and vendors) are directly with the client; engineering (design) and procurement are handled by the EPC contractor; more control for the client; easier to establish; usually lower costs (less risk mitigation needed); more involvement and resources needed from the client; suited for less well-defined projects or with more variables.
- **PMC** (Project Management Consultant): similar to EPCM but the PMC contractor only takes care of engineering management and also overall project management; the client has direct contracts with engineering contractors (besides construction contractors as in EPCM); this splits the responsibility for engineering and project management (PM) between two contractors; suited when the combination of required engineering and PM capabilities is difficult to find in the market.
- **EPCI** (with I for Installation): similar to EPC and often related to offshore construction; the contractor takes care of the full installation on-site.
- **EPCC, EPCIC, or EPIC** (with I for Installation and C for Commissioning): similar to EPC/EPCI but ‘turnkey’ (LSTK – Lump sum turnkey) for the client: the contractor is also responsible for commissioning.

In some sectors and industries the EPC model is no longer the dominant one, and new (public-private) models with more even risk distributions have become more regular. For instance the BOT (Build Operate Transfer) model which combines public and private resources, whereby the private party receives operating rights (a concession) for an extended period of time. Other

variants seen include BOOT (Build Own Operate Transfer), DBOT (Design Build Operate Transfer), or ones where the asset does not get transferred eventually (e.g. BOO without the 'T' or DBFO: Design Build Finance Operate).

Detailed Design involves close collaboration between a wide variety of disciplines and companies

5.4 Project control with Document Control

Document control – simply stated: being and staying in control of all project documentation – can make or break any engineering project, especially in the hectic Detailed Design stage. When actions are not clear or get missed, planning dates or due dates are exceeded, or information gets lost, that can easily cause a (costly) domino effect for a project, with one delay leading to another. Project milestones cannot be reached if project documentation is not progressing as planned, or if not correctly, timely and fully approved.

If on the other hand, document control is well-organised with an appropriate eDMS system – one that facilitates all stakeholders, allows to find latest information fast, keeps everyone aware of actions and due dates, supports efficient and effective collaboration, covers risks and future liability, and gives comprehensive insight into progress and potential bottlenecks at all times –

then this suddenly becomes an invaluable enabler for project control (and a cost-saver for the project too).

> **Many expensive software companies have promised to support our project requirements, and some tried long and hard, but failed to deliver. Assai have delivered everything they promised in sales presentations and are of great added value.**
>
> - **IM/DC department of a major project with ca. 600K documents**

5.5 How Assai supports Detailed Design

Assai provides out-of-the-box support for all project stages (and operations), with over 30 years of experience. The following Assai features are key in supporting clients and contractors during Detailed Design and making sure everything is 'AFC' (Approved for Construction) in time:

- Easy, unambiguous access to relevant information for all project roles
- Highly efficient information exchange with external parties: Assai Portal
- Never any doubt about the latest revision or latest information
- Store any file type; integrated file viewer (with redline markup capability)
- Out-of-the-box, flexible workflows for review & approval
- Distribution matrix to simplify and automate document distribution
- Full action tracking, with (proactive) automatic and manual reminders
- High levels of automation for engineers and Document Controllers
- Dedicated planning module; organise deliverables in a WBS
- View progress and forecasts at any level: document, work package, project
- Vendor document control features (easy VDRL tracking & expediting)
- Store Purchase Orders (PO) and associate with documents
- Assets module: associate documents with tags, equipment etc. for Operations
- Technical query module to handle change requests and more (RFC, RFI)
- Correspondence module to centrally store official letters
- Easy preparation of construction work packages
- Easy management of roles, responsibilities and user/group access
- Detailed audit trails; coverage against liability

- Many standard reports & dashboards, Power BI reporting
- Extensive REST API integration options

Plus as described in previous phases:

- Assai offers a proven, specialised, user-friendly and secure eDMS for all project deliverables, no matter the project size or complexity. Everything is traceable and can be reported on.
- Assai Cloud (or on-premises) is a flexible, turnkey solution with out-of-the-box support for engineering projects from start to end, plus operations, maintenance & modifications, and Digital Twin environments.

6

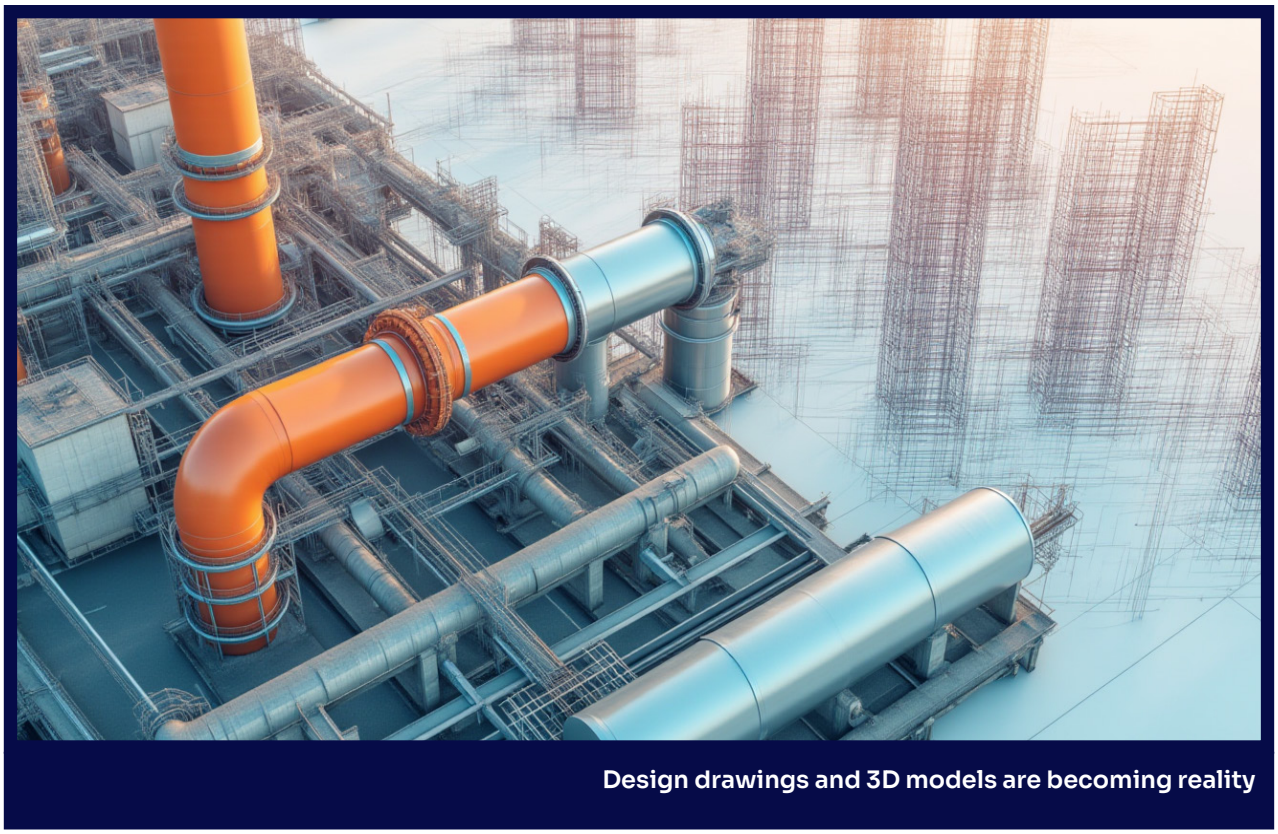
Procurement & Fabrication: from theory to reality

6.1 Procurement & Fabrication in a nutshell

After successful completion of the Detailed Design stage, procurement and fabrication come next. This happens based on the final, approved design documents and “Approved for Construction (AFC)” drawings.

Procurement involves the acquisition of materials, equipment, and services needed for construction. This may include activities such as identifying vendors, requesting bids or proposals (bidding & tendering), and negotiating contracts. Sometimes preferred suppliers have been listed upfront.

Fabrication, on the other hand, involves the actual manufacturing or assembly of materials and components into finished products, which can be put together on-site. This can involve cutting and shaping materials, welding and assembling parts, and testing the finished product to ensure that it meets the required specifications. Together, procurement and fabrication are crucial steps in the successful completion of any engineering project.



Design drawings and 3D models are becoming reality

6.2 Who is involved in Procurement & Fabrication?

Procurement and fabrication are usually carried out by different teams or departments. The procurement team is responsible for acquiring the materials and services needed for the project, while the fabrication team is responsible for ensuring that the materials are manufactured or assembled according to the project specifications.

In some cases, the same company or organisation may be responsible for both procurement and fabrication. For example, a construction company may have its own procurement team that cquires materials from suppliers, and a fabrication team that assembles those materials into finished products. In other cases, the procurement and fabrication processes may be carried out by separate companies. For example, a construction company may hire a subcontractor to fabricate certain components of a project.

Overall, the key players involved in procurement and fabrication include the project owner or client (providing the overall direction and funding for the project), the engineering design team, procurement teams, fabrication teams, and vendors or suppliers of materials and services. Also involved may be consultants who provide advice and expertise on procurement and fabrication, and regulators or government agencies responsible for overseeing the procurement process.

6.3 Typical challenges for Procurement & Fabrication

Challenges for procurement include identifying and sourcing the right materials and equipment for the project, negotiating contracts with suppliers, and ensuring that all materials and equipment are delivered on time and within budget. Another challenge can be coordinating the work of different vendors or contractors, as well as managing any changes to the project scope that may affect the procurement of materials and equipment. Furthermore, there can be challenges related to document control, such as ensuring that all project documentation is accurate, up-to-date and easily accessible to all stakeholders.

Challenges for fabrication include coordinating the fabrication of many different components, ensuring that all work is completed on time and within budget, and managing changes to the project scope that may affect the fabrication process. The same document control challenges as for procurement apply here as well. Other potential challenges include managing the work of

different contractors or vendors, and ensuring that all work is done in accordance with relevant safety and quality standards. Furthermore, there may be challenges related to the logistics of transporting and assembling fabricated components on site.

6.4 How Assai supports Procurement & Fabrication

The cutting-edge document control system Assai helps to ensure that all project documentation is accurate, up-to-date, and easily accessible to all team members and stakeholders. This is particularly important for procurement to source and purchase the right materials and equipment, or to provide fabrication with the right drawings and instructions. Assai also streamlines communication and collaboration among team members, and provides a centralized location for storing and organizing all project documentation. This reduces the risk of errors and delays for the project.

Key Assai features that support Procurement & Fabrication:

- Central repository for all relevant documents and drawings
- Organise documents in packages and (custom) folder trees
- Vendor document control module (SDRL / VDRL tracking)
- Asset breakdown structure to quickly find documentation by tag or equipment
- Assai Portal to exchange documents and drawings with vendors and contractors
- Technical Queries module to process any kinds of requests or deviations
- Correspondence module to manage official letters and communications
- Integration options with procurement systems (using REST API)
- Power BI reporting interface

Plus as seen in previous phases:

- Assai offers a proven, specialised, user-friendly and secure eDMS for all project deliverables, no matter the project size or complexity. Everything is traceable and can be reported on.
- Assai Cloud (or on-premises) is a flexible, turnkey solution with out-of-the-box support for engineering projects from start to end, plus operations, maintenance & modifications, and Digital Twin environments.

7

Construction & Installation: putting it all together

7.1 Construction & Installation in a nutshell

The Construction & Installation stage follows after Procurement & Fabrication. Construction and installation involve putting all of the various components and materials that have been procured and fabricated together on-site to create the finished project/asset – based on the final approved documents and drawings. This typically includes activities such as assembling structures, installing mechanical and electrical systems, and testing the completed project to ensure that it meets the required specifications.

In practice, it may not always be possible to construct and install everything exactly as designed, which is why this stage is concluded with the "as-building" process to align all drawings with the reality where deviations were required (see below).

Construction and installation are the final steps in the engineering project process, and they are typically overseen by a construction manager or project manager. Completion of this stage is often referred to as "mechanical completion". This is traditionally the end of the EPC contract scope, but depending on the contract model, the responsibility of the EPC contractor may extend further, e.g. to also cover pre-commissioning and commissioning.

7.2 As-building

For various reasons, engineering designs on paper cannot always be constructed and installed exactly as designed. For instance due to physical limitations or later design variations, pipelines or cables may have been routed or connected differently than shown in the latest "approved for construction" (AFC) drawing.

To enable safe and efficient operations, it is important that all drawings in the eDMS are matching with the real situation on-site. This requires engineers to do site walks, highlighting differences between the design drawings and how things have been constructed in reality. This is typically done by marking up drawings (redlining, red-blue markups), either physically or digitally, which then need to be updated by a designer using CAD tools or other software.

After checking a drawing and incorporating any markups into a new revision, its status in the eDMS can be updated to reflect this: As-built (AB or ASB). Standards for revision codes and statuses can vary per project and organisation.

Construction and installation based on detailed design drawings

7.3 Project risks during Construction & Installation

There are several risks that can arise during the construction & installation phase of engineering projects, and need to be addressed, including:

- **Cost overruns:** The cost of materials, labour, or other expenses can exceed the original estimates, resulting in higher costs than expected.
- Schedule delays: The project may take longer than expected to complete, leading to delays and potential loss of revenue.
- **Quality issues:** Poor workmanship or defective materials can lead to subpar quality, which can affect the safety, performance, and durability of the project.
- **Health and safety risks:** Construction sites can be dangerous environments, and workers and the public may be at risk of accidents or injuries.
- **Environmental impacts:** Construction and installation activities can have negative impacts on the environment, such as air and water pollution or destruction of natural habitats.
- **Changes in project scope:** The scope of the project may change during construction and installation, leading to additional costs or delays.
- **Legal issues:** Disputes or claims related to contracts, permits, or other legal issues can arise during construction and installation, potentially leading to costly delays or legal liabilities.

7.4 How Assai supports Construction & Installation

Assai offers a comprehensive, user-friendly, centralised (cloud) platform for accessing and controlling unlimited amounts of project documentation. It offers advanced (automated) distribution features, access control, detailed audit trails, and supports a fully digital, paperless working environment. Assai streamlines and improves collaboration and communication, and helps to mitigate the many risks associated with construction & installation.

Assai provides out-of-the-box functionality for each project stage (and operations), based on more than 30 years of experience. Key Assai features supporting Construction & Installation include:

- Easy access for all stakeholders to required project documentation
- Excellent version control with latest revisions always on top
- Digital Construction Work Packages (CWP)
- Easy online exchange of documents and drawings with contractors (Assai Portal)
- Track official distribution and stakeholder actions with transmittals
- Flexible asset breakdown structures to find documentation by system, unit, tag or equipment
- As-building made simple with integrated redline markup (RLMU) file upload and digital redlining on tablets (Assai Mobile)
- Process redline markup files to get all drawings to as-built status
- Empower authorised engineers or designers to check out and revise/update drawings
- Grant access to source / native files only for those who need this
- Digital (bulk) stamping and electronic signatures
- Technical Query module to handle any kind of request or deviation
- Live progress and bottlenecks with Assai's advanced planning & reporting features
- Extensive REST API library to integrate/interface with other systems

Plus as seen in previous phases:

- Assai offers a proven, specialised, user-friendly and secure eDMS for all project deliverables, no matter the project size or complexity. Everything is traceable and can be reported on.
- Assai Cloud (or on-premises) is a flexible, turnkey solution with out-of-the-box support for engineering projects from start to end, plus operations, maintenance & modifications, and Digital Twin environments.

8

Pre-Commissioning: getting ready for operations

8.1 (Pre-)Commissioning in a nutshell

The pre-commissioning (or pre-comm) stage of engineering projects is a critical phase that occurs after construction & installation and before the facility/asset is put into operation. It involves both the contractor and the operator.

The purpose of pre-commissioning is to ensure that the facility is ready for safe and efficient operation, and to identify and resolve any issues that may have arisen during construction. It involves a series of activities which aim to ensure that all systems and components of the facility are properly installed, tested, and prepared for the Operations phase (see next section).

After pre-commissioning follows commissioning. The main difference is that during pre-commissioning, dry runs and trial runs with test fluids (e.g. water) may take place, but during commissioning, actual process fluids are introduced to process equipment. So both may involve testing control systems, starting up equipment, and conducting trial runs. After all required pre-commissioning and commissioning checks have been passed successfully, start-up (SU) can take place with a handover from the engineering project to Operations.

8.2 What happens during Pre-Commissioning?

Firstly, Mechanical Completion (MC) verification is an important interface between construction and pre-commissioning. This can stand on its own or be part of pre-commissioning. MC verification confirms that the construction and installation of all components (e.g. equipment, piping, cabling, electrical and mechanical components, instrumentation) are physically complete, inspected, tested and have all required documentation. This results in a Mechanical Completion Certificate (MCS).

Other typical activities during pre-commissioning include:

- **Flushing and cleaning of systems:** the piping and process systems need to be cleared of any debris or contaminants that may have been introduced during construction.
- **Leak testing:** all piping and equipment are tested to ensure there are no leaks or other issues that could cause problems during operations.
- **Testing of safety systems:** safety systems, such as fire protection and emergency shutdown systems, are tested to ensure they are functioning properly.

- **Testing of control systems:** control systems, such as SCADA (Supervisory Control and Data Acquisition) systems, DCS (Distributed Control Systems) and PLC (Programmable Logic Controller), are tested to ensure they are properly configured and able to control and monitor the various systems and equipment in the facility.
- **Commissioning of utilities:** utilities, such as electricity, water, and gas, are commissioned to ensure that they are available and functioning properly.
- **Training of personnel:** training people on the operation and maintenance of the facility.

8.3 (Pre-)commissioning checks & checklists

As mentioned, (pre-)commissioning involves many checks on many different components. Organising check points into checklists helps engineers or other specialists in the efficient, correct, safe and timely completion of all required checks. If there are follow-up actions or open ends, punch lists may be needed to keep track of any remaining items to close out a checkpoint. All of the activities mentioned earlier can be supported by (pre-)commissioning checklists. Individual systems or equipment (types) may also have their own (detailed) checklists to check if they are functioning properly.

Some example check points to illustrate:

- Visually check equipment for defects.
- Ensure correct equipment assembly based on the vendor P&ID drawing.

Construction and installation based on detailed design drawings

- Equipment grounding is properly installed.
- Access ladders are properly fitted and fastened.
- Remove all temporary construction materials.
- Operating blinds are installed as in the drawing.
- Platforms allow safe access to valves and instrumentation on the skid.
- Pressure Safety Valves (PSV) inlet and outlet open; by-pass valves closed.
- Check all drain and vent valves.

8.4 How Assai supports Pre-Commissioning

Assai provides out-of-the-box functionality for all project stages (and operations), based on more than 30 years of experience. Key Assai features supporting Pre-Commissioning and Commissioning include:

- Easy access to the latest project documentation for all stakeholders
- Checklist module: flexible, unlimited checks, grouped as checklists and automatically assigned to systems or equipment
- Distinguish between mandatory and optional checks
- Complete checklists on-site on a tablet, with Assai Mobile
- Create (upload) and complete punch lists online
- Asset Management module with asset hierarchy and commissioning stages
- Restrict commissioning stage changes for components if mandatory checks are pending
- Technical query module to process any type of request, deviation or issue, also on-site with Assai Mobile
- Find documentation and technical queries by system, unit, tag or equipment
- Dedicated reports on (pre-)commissioning progress. See bottlenecks before they become a problem or cause delays.
- Advanced reporting capabilities with Power BI (and integrated reports)
- Comprehensive REST API library to interface with other applications

Plus as seen in previous phases:

- Assai offers a proven, specialised, user-friendly and secure eDMS for all project deliverables, no matter the project size or complexity. Everything is traceable and can be reported on.
- Assai Cloud (or on-premises) is a flexible, turnkey solution with out-of-the-box support for engineering projects from start to end, plus operations, maintenance & modifications, and Digital Twin environments.

9

Handover: from a project to operations

9.1 Handover (and start-up) in a nutshell

After pre-commissioning and commissioning are completed, the built facility can be started up (start-up or SU phase). This may involve a series of complex actions and evaluations of different scenarios and configuration settings. The various systems and components are slowly ramped up to normal operating levels, while checking for any issues and optimising performance.

Eventually, the facility needs to be formally handed over from the project team/contractor to the team or organisation responsible for operating the facility, often an owner-operator. The handover from a project to operations is sometimes abbreviated as P2A (project-to-asset). This is normally not just a date but a process of transition, which may already be started earlier in the project by involving operations staff there (e.g. in pre-commissioning or even earlier).

Once the operations team has received the required information, training and tools (Operational Readiness), and performance requirements have been met, official acceptance certificates tend to be issued to the project team (or contractor). First a Provisional Acceptance Certificate (PAC), followed by a Final Acceptance Certificate (FAC) after passing a performance guarantee period. This marks the end of the project and the transfer of all responsibilities from the project to operations.

9.2 Documentation handover

A key aspect in any handover, is getting all required/relevant documents and drawings across to operations (e.g. metadata, native files, PDF renditions). These deliverables need to have the required approvals – perhaps accompanied by stamps or digital signatures inside the files – and to have reached the required status (e.g. ASB – “As-Built” for drawings, and IFU – “Issued for Use” for documents).

A handover requires careful preparation, deliverable selection, and keeping track of what was or still has to be handed over. Depending on the size and complexity of the asset, planning timelines and corporate policies, the documentation handover schedule may vary. It may be done all at once or in batches, e.g. weekly or whenever deliverables are ready to be handed over (‘progressive handover’).

Earlier in the project, there may already have been (documentation) handovers between project stages, where one party transferred information and responsibilities to the party responsible for the next project stage. Or perhaps just making a selection of project deliverables which should be carried forward into the next project stage (e.g. from FEED to Detailed Design). Although this

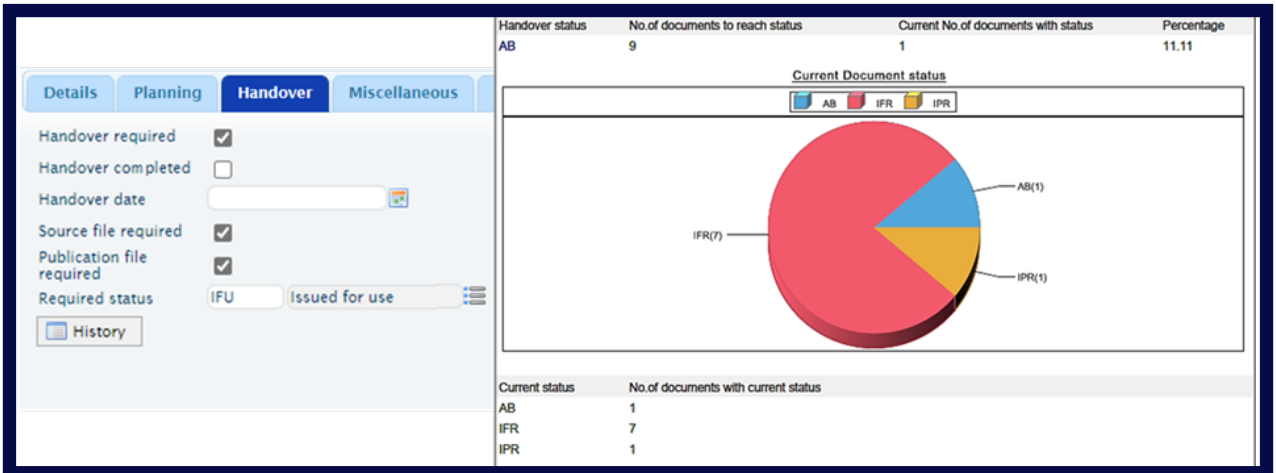
article focuses on the final handover from a project to operations, most principles of using an eDMS like Assai to support handovers also apply to the handovers between project stages.

The Operations phase (with Maintenance & Modifications) is out of scope for this article series. However, Assai support for the asset lifecycle does not stop there. Assai also provides strong support and dedicated functionality for Operations environments and related organisational roles, such as: chief operation officer (COO), plant management, operations support manager, change (MOC) manager, supply chain officers, quality control, maintenance reliability engineers, and operations engineers.

9.3 How Assai supports Handover

Assai provides out-of-the-box functionality for all project stages (and operations), based on more than 30 years of experience. Key Assai features supporting handover include:

- Special handover attributes on individual documents (e.g. handover required, handover completed, handover date, required status; all updatable in bulk)
- Digital (bulk) stamping and electronic signatures (DocuSign®)
- Create an Operations environment in minutes, in line with project standards & procedures
- Digital handovers within Assai, between project stages or from projects to operations
- Easily filter out the documents and drawings required by operations
- Easily filter out documents and drawings that are ready to be handed over
- Hand over latest revisions only or include older revisions too
- Include native files by default or only where required for the individual document
- Select which metadata attributes to include and exclude



Handover preparation, tracking and reporting in Assai

- Automatic population of handover date and “handover completed” flag
- Progressive handovers, using the “handover completed” flag and related properties
- Alternatively, bulk-export metadata and files from Assai for importing into other systems
- Detailed handover history for both sides; optional transmittals for additional tracking
- Dedicated reports to keep track of handover readiness and handover progress
- Records Management module for records to be frozen and retained
- Detailed audit trails; coverage against liability
- Advanced reporting capabilities and Power BI integration

Plus as seen in previous phases:

- Assai offers a proven, specialised, user-friendly and secure eDMS for all project deliverables, no matter the project size or complexity. Everything is traceable and can be reported on.
- Assai Cloud (or on-premises) is a flexible, turnkey solution with out-of-the-box support for engineering projects from start to end, plus operations, maintenance & modifications, and Digital Twin environments.

Conclusion

Engineering projects are never just about design and construction - they are about orchestrating people, processes, and information across nine critical stages. When each phase is supported by structured document control and clear collaboration, complexity turns into clarity, risks are reduced, and outcomes improve. Success isn't defined by finishing a project; it's defined by handing over a safe, compliant, and well-documented asset that stands the test of time.

If you want every stage of your project to move forward with confidence, discover how Assai's eDMS empowers teams to manage complexity with ease. Schedule your demo today and transform the way you deliver engineering projects.

About the author

Arno van Vulpen, with a strong background in information science and a specialization in user experience, finds his greatest inspiration and energy in staying closely connected to his scientific roots. This solid foundation fuels his mission to continuously grow, challenge himself, and drive significant progress in his field.

Since 2013, Arno has been an integral part of the Assai team. He began his journey as an all-around consultant, quickly advancing to the roles of product owner and, eventually, product manager. In this capacity, he now stands at the forefront of all innovations and enhancements in Assai's document management software. Arno takes great pleasure in simplifying complex issues, and with Assai, he has been instrumental in bringing significant strides forward. Although the

software was already a market leader, the development of the new Assai Connect user interface represents an iconic breakthrough, setting new standards in the industry.

Arno is passionate about the often-underestimated importance of software in engineering projects and opeations. He advocates for its early involvement in projects, recognizing the immense value it brings. Drawing on the extensive knowledge he has accumulated over the past twenty years in various roles, Arno shares his insights to raise awareness in the industry about the critical role of document control software. A key aspect of Arno's philosophy is the alignment between project teams and document controllers. He firmly believes in bringing everybody on the same page, with clear roles & responsibilities and access to the latest information. This alignmentis is more crucial the further projects progress and afterward in the maintenance and management phases. Having quick access to the necessary information is paramount in all circumstances.

His journey with Assai began while he was still on the client side, where he and his colleagues struggled to manage an overwhelming volume of documents, losing track of important information. Assai provided a solution that immediately resonated with Arno. When the company's then-owner approached him about joining Assai, Arno didn't hesitate, especially since it combined with another of his passions – travel. With clients worldwide, Assai offers Arno the global stage he always envisioned.

Arno is driven by a desire to make a meaningful impact through his work. He aims to improve people's quality of life – both professionally and personally – and contribute to making the world a better, safer, and more sustainable place.

About Assai

At Assai, we bring clarity and control to complex, asset-heavy industries. Our AI-powered engineering data platform supports teams across the entire asset lifecycle - from design and construction to operation and decommissioning.

Assai provides a single source of truth for all engineering documents and data, enabling organizations to unlock, integrate, enrich, and govern their technical information. With this foundation, project teams make better decisions, execute faster, and achieve stronger outcomes.

Trusted by global leaders in energy, utilities, petrochemicals, and other asset-intensive sectors, Assai helps organizations save time, reduce risk, and stay fully in control of their projects and operations.

assai

Clarity in Complexity

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