Facility Lifecycle 3D Model Standard (FL3DMS)

Lifecycle Management Guide

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Shell, BP, TOTAL, ExxonMobil, FLUOR, Norsok, Aveva and Cohesive Group.

The Lifecycle Guide Team is part of the Facility Lifecycle 3D Model Standard (FL3DMS) group organized by USPI-NL with participating members:
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Foreword

The Facility Lifecycle 3D Model Standard (FL3DMS) is an industry-standard that provides a specification developed to standardise how 3D models are configured, its content, and what is to be handed over to optimize the return on the investment in a 3D model.

The Lifecycle Management guide is being developed collaboratively by Principal (Owner/Operator) companies, EPC contractors and software providers, to provide information on the development of 3D models for the lifetime of a facility.

FL3DMS is a practical, application neutral, specification for the structure and content of 3D Models, designed to guide the creation and maintenance of 3D models in capital projects and assets.
It is based on existing company standards and best practices of the FL3DMS participants and includes technical requirements for the creation and handover of 3D models to enable use-cases in projects and operations. These include 3D model design integration, Advance Work Packaging (AWP), Digital Twins and replication of 3D designs.

The first version of the 3D specification was issued in 2021, and member organizations are now implementing it and identifying improvement opportunities for the next version.
To accelerate adoption of the standard, and its maturation via feedback, it is available for the public to download.

FL3DMS Download

You can request a download of FL3DMS from USPI by contacting us at stichting@uspi.nl.
USPI FL3DMS requests a voluntary contribution of €500 to download the specification, cover the cost of administration, hosting and sharing the standard.
If you pay this contribution, you will receive perpetual updates of the standard and associated documents, such as the business case for maintaining the 3D Model as Built and the FL3DMS implementation guide. You will also be invited to provide feedback to influence future updates of the standard. USPI members can request the standard free of charge.

By downloading the FL3DMS Specification you agree to use the specification within your own organization and within the projects that are execute by it only.
You agree not to share the specification with other organizations outside this scope. The intellectual property of the standard remains with USPI.

Full FL3DMS membership is encouraged very much in view of the need to create critical mass and accelerate the standardization of the process industries.

If your organization wishes to contribute to the development of the FL3DMS specification, you are invited to join USPI and FL3DMS as a member.
Your company representatives will get full access to all USPI and FL3DMS members meetings, working group meetings and to the FL3DMS SharePoint or Teams (Microsoft) site where all project information is stored and can be accessed.

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1 Introduction

The name of the Specification, Facility Lifecycle 3D Model Standard, indicates that the content is focused on the lifecycle use of 3D models.
The 3D model referenced in this guide, is a comprehensive three-dimensional representation of the complete energy/process facility.
The objective of this Lifecycle Management guide is to enable owners of 3D models to manage and use their 3D models for the full facility lifecycle, thereby optimizing the business value generated from the 3D model.
The guide provides information on the development and maintenance of 3D models for the lifetime of a facility, from ‘cradle to grave’.

In the remainder of this Introduction, the scope and intended use (section 1.1), and the content (section 1.2) of the guide are explained in more detail.

1.1 Scope & Intended Use

This guide outlines options for the development of 3D models such that the Company can make an educated decision as to what they require for the 3D model of their facility.
This includes:

- 3D model application selection.
- 3D model ownership, hosting and support.
- Contracting strategy impact.
- 3D model deliverables development, review and data validation.
- Construction and as-built processes for evergreening the 3D model.
- Operational use of the 3D model.
- Benefits of an evergreen 3D model.

The intention of this document is to help identify the 3D model scope for a project, based on the requirements for the initial concept, the detail design, fabrication and construction, through the facility operational life, to the decommissioning phase.

Out of scope of this guide are procedural steps for developing or maintaining the 3D model, specific application tools for 3D model development, or how it will be integrated with other software applications and data repositories.
Please refer to the L3Dex Implementation guide and Data Model guide for further information on these topics.

1.2 Content

This document identifies the options to be specified when creating a 3D model for the layout and construction of a project, through the operational life to decommissioning. This may be a new Greenfield project or a Brownfield modification project on an existing facility.

2 References

2.1 Normative References

- **Capital Facility Information Handover Specification (CFIHOS)**: The aim is to offer practical standardized specifications for information handover that work for:
  - Anyone involved in making, operating, maintaining, or decommissioning industrial facilities.
  - Everyone in the information supply chain – Operators, contractors and equipment manufacturers, and suppliers.

  It organizes data and documents in a structured way so users:
  - Have the information they need to operate, maintain and decommission a facility.
  - Can share information easily with other users/systems.
  - Can find information quickly.

2.2 Informative References

- **ISO 19650**: It is titled: "Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling." The purpose of ISO 19650 is to provide recommendations for a framework to manage information, including exchanging, recording, versioning, and organizing for all actors. An interesting aspect of ISO 19650 is that it includes a lifecycle perspective regarding the detail, granularity, content, and structure of the engineering and design data, including 3D models.

- **DEXPI P&ID Specification**: This specification by the DEXPI group (Data EXchange for the Process Industry) provides a general method for data exchange, data interoperability, and data integration for the process industry covering all phases of the lifecycle of a (petro-)chemical plant, ranging from specification of functional requirements to facilities in operation. It covers both formats and content.

  The underlying DEXPI information model is a conceptual model that describes the objects that appear in a P&ID from an engineering point of view.

  P&ID's and 3D models are important elements in the development of facilities. The process-related objects represented in both models should be aligned.

  The DEXPI P&ID Specification is relevant for FL3DMS for cross-referencing purposes (e.g., in Digital Twin environments), cross-checking purposes, or object recognition purposes (creating object-oriented 3D model from point cloud from laser scanning).

3 Abbreviations, Terms & Definitions

3.1 Abbreviations

	Description
AR	Augmented Reality – the real world environment overlaid with a computer generated one.
CAD	Computer-Aided Design: The use of computers to aid in the creation, modification, analysis, or optimization of a design
CAPEX	Capital expenditure
CFIHOS	Capital Facilities Information Handover Specification. It aims to make information handover quicker, easier and safer for operators, contractors, equipment manufacturers, and suppliers by using standardized specifications and changing how projects and facilities manage their data. The goal of CFIHOS is to give you the tools to get the right information to start, operate, maintain
DEXPI	Data EXchange in the Process Industry
EPC	Engineering, Procurement, and Construction
FL3DMS	Facility Lifecycle 3D Model Standard. An industry-standard being developed to improve how 3D models are developed, integrated, handed over, and maintained during the lifecycle of a facility to optimize the return on the investment in a 3D model
IFC	Industry Foundation Classes (described in ISO 16739)
IOGP	International Association of Oil & Gas Producers: The petroleum industry's global forum in which members identify and share best practices to achieve improvements in health, safety, the environment, security, social responsibility, engineering, and operations
IP	Intellectual Property
MoC	Management of Change
MTO	Material Take-Off: Refers to a list of materials with quantities and types that are required to build a designed structure or element
OPEX	Operating expenditure
RDL	Reference Data Library
STEP (STP)	Standard for the Exchange of Product model data (described in ISO 10303)
USPI(-NL)	Uitgebreid Samenwerkingsverband ProcesIndustrie-Nederland. USPI-NL is a non-profit association. The mission of USPI is to enable companies in the process industries to share and/or exchange electronically the information needed to design, build, operate and maintain process and power plants using internationally accepted standards
VR	Virtual Reality – a computer generated environment that appears to be real

3.2 Terms & Definitions

	Description
3D model	A three-dimensional representation of an object or a group of objects
3D modelling software	A class of 3D computer graphics software used to produce 3D models
3D Model Attribute	Data fields within the 3D model application that may be used for additional information relevant to the owning object.
4D Model	A 4D model adds the fourth dimension of time to the 3D model content to enable the sequence of construction to be visualised
5D Model	A 5D model incorporates quantity and cost to the 4D model
As-built tolerance	The deviation between the actual installation/assembly position of an object compared to the object's position in the 3D Model
Clash	A 'clash' is the result of two elements in the design taking up the same space
Company	The legal entity owning the facility
Contractor	The legal entity delivering the ordered 3D Model (s) to Company
Digital Twin	A virtual representation of a real-world entity or system
Element	Object (solid and soft volumes) included and visualized in the 3D Model that forms part of the integrated design
EPC contractors	An EPC contractor is made responsible for all the activities from design, procurement, construction to commissioning and handover of the Project to the End-User or Company
Facility 3D model	3D model at facility level to be delivered by Contractor to Company based on the requirements defined in this specification
Facility	The overall process/energy plant
Field weld	Weld made at a location other than a shop or the place of initial construction
Generic geometry	The level of representation of the object should allow for identification of the object
Non-tagged objects	Objects not tagged following the naming convention in accordance with Project's Engineering Numbering System (ENS)
Project	A Greenfield/Brownfield scope of work to build/modify the facility.
Shop weld	Weld made in the workshop before delivery to the construction site
Soft volumes	Volumes in the 3D Model representing reserved areas such as personnel access, escape- and equipment maintenance requirements. During normal operation, soft volumes will be free of obstructions
Sub-Contractor	A legal entity delivering part of the facility to Contractor. The related scope may include 3D model scope or a complete 3D model

4 Overview of a 3D Model

A 3D model is a digital representation of physical objects that are assembled to build a process/energy facility. The 3D shapes reflect the dimensional details of the physical component to ensure sufficient space is available in the required location.

The model is a multi-discipline environment, including civil structures, mechanical equipment, piping, electrical and instrument devices, cable racks and trenches, etc. The 3D objects have associated data that is used for material procurement, cable routes and lengths, that can be exported in reports and drawings.

The 3D modelling software is configured specifically to suit the facility it will represent. The standard library components used to represent structural steel, piping, cable rack, etc. will be based on real world details and specifications. The modelling software should include the ability to check the model content to ensure the final layout is ‘clash-free’.

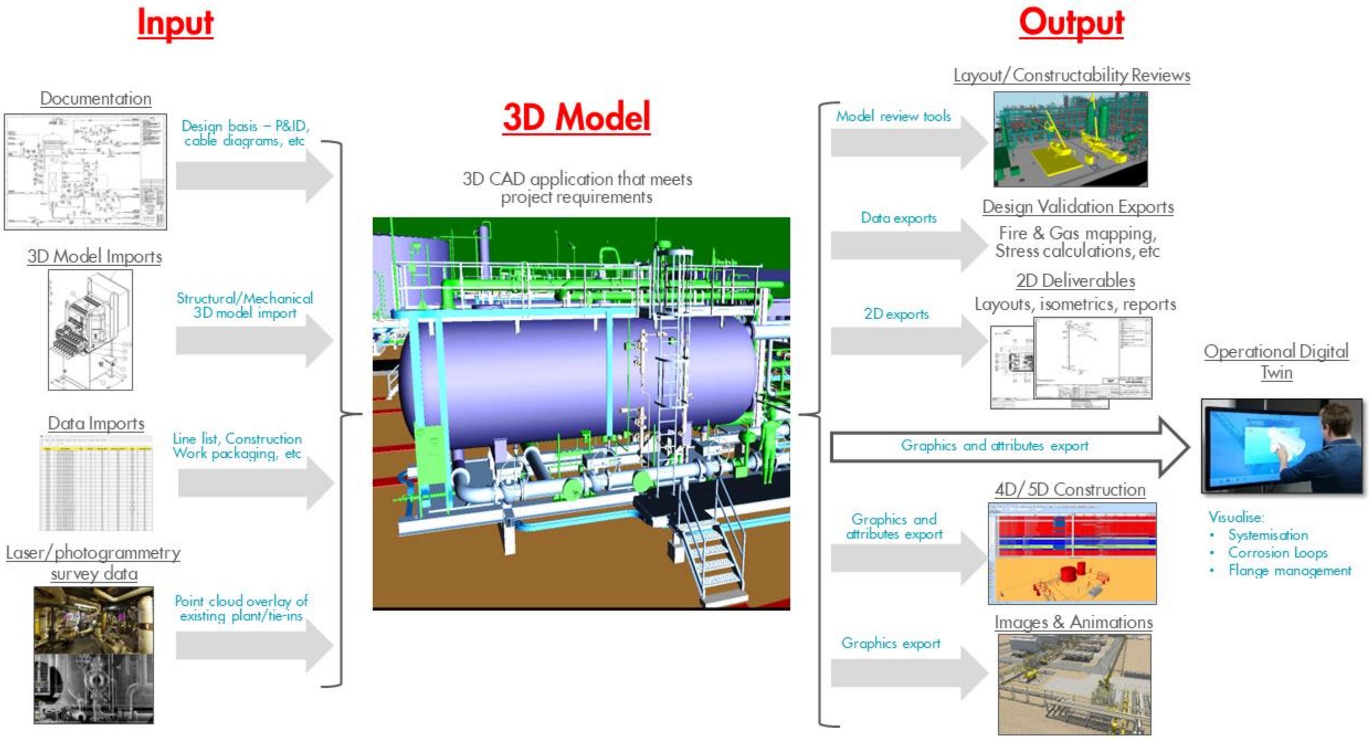
‘Soft volumes’ are built in the 3D model to reserve empty spaces for walkways, escape routes, storage areas, maintenance requirements, etc.

Exports from the model may be used in other engineering tools, such as Fire & Gas detector mapping, lighting levels, 4D planning, escape simulation, etc. It can also be used to generate images and animations for stakeholder engagement and operator training.

The 3D modelling software may be integrated with other design applications such as P&ID schematics, cable routing programs, engineering data warehouse, etc. Laser/photogrammetry surveys can be integrated into the design environment to identify the existing physical layout of the facility for use in modification work.

The model application should have the capability to automatically produce accurate drawings and reports of the model content for procurement, fabrication and construction.

The image below provides an overview of the inputs and outputs to/from the 3D model.



5 Intent of a 3D Model

Everyone involved in the design, construction, operation and maintenance of a facility has a different approach as to what they want from the 3D model. Each stakeholders' intent is the delivery of a 3D model focussed on their requirements.

5.1 The Company/Asset Owner

The asset owner initially wants a 3D model that proves the design and layout meet the project requirements in respect to safety, operability, maintainability, constructability and technical correctness. They require the content to meet local regulatory standards and approvals prior to construction.
They expect the EPC to deliver an accurate model that provides the documents and data to support procurement and construction, with minimum delays to the schedule. Company may also have 4D and 5D expectations to reduce risk and deliver an optimised schedule for efficient construction.
Finally, after handover from the EPC contractor, they may wish to retain an evergreen 3D model to support operations and maintenance, and as the basis for future modification/expansion projects. The Company may have a 'Digital Twin' environment that links together all the asset information, including the visual representation in the 3D model, to improve operations and maintenance access to plant data.

5.2 The Engineering Procurement Construction (EPC) Contractor

The EPC contractor develops the 3D model to represent the physical constructed facility. They will wish to use the 3D modelling application they are familiar with, to build the model swiftly and efficiently.
Initially, during the project FEED phase, their requirement will be to build a simplified model that outlines the layout and provides the basis for a cost estimate to procure and construct the facility.
When the project moves into detail design, the model will be detailed using a library of components that provide an accurate 3D representation of the item, including material, weight, description, etc. The EPC will use the 3D model to generate their procurement, fabrication and construction documentation directly from the application. The EPC will also be expected to include vendor package models into the master facility model, which may be problematic due to the format and complexity of the mechanical model.
At the end of construction and commissioning, based on the contract requirements, the EPC may have to handover an as-built 3D model that represents the physical facility as supplied.

5.3 The Package Vendor

The package vendor who supplies equipment or skid will probably have a 3D model of their assembly, which has been developed in a mechanical modelling application. This is liable to be a different format to the master facility model and will include the detailed content (nuts, bolts, washers) required by the vendor to build their assembly.
Based on their contract requirements and what has been agreed with the EPC, they may be expected to modify their standard model to include project specific naming conventions and deliver the model in an alternative format, suitable for use/import in the master facility model.

5.4 The Consultant

Various consultants are employed during, and/or after the project development to provide specialist services to the EPC/Company. The services may include Fire & Gas detector coverage, lighting coverage, 4D modelling, evacuation simulation, etc.
The consultants will require an export of the master facility model to use in their specialist applications. It is important that the quality of the supplied model is such that the hierarchy and naming conventions are aligned with the project documentation and data in other engineering systems.

6 3D Model Lifecycle Strategy

The lifecycle of a facility is from “cradle to grave”, concept to decommissioning. The Company should have a clear strategy on what phase(s) of the lifecycle they require the 3D model to support.

Understanding the scope and what is required from the 3D model will enable the project to specify the details in contract documentation and ensure the design delivers the correct level of documentation and data.

The use of a facility digital twin impacts the 3D model lifecycle requirements. The content and graphical detail contained in the digital twin should be based on the 3D model. Therefore, the relevant level of detail selected for the facility digital twin, must be represented accurately in the 3D model and be up to date.

****If the Digital Twin of the facility is not accurate, personnel will have no confidence in the application and content and stop using it.****

7 Governance and Ownership

There must be clear ownership and governance of the 3D model to ensure accountability and responsibility for the management, content and accessibility.
Company should identify the party accountable for 3D model management within the facility organisation, e.g. Engineering manager, or Mechanical discipline.
The designated 3D model owner should have specifications that identify the 3D model requirements, data content, interfaces with other applications, as-built scope, MoC procedures, etc. such that all within the Company, or Contractor, understand their input and data requirements to build the model and how it can support their discipline.

When the Company engages a Contractor to deliver a greenfield or brownfield project, the Contractor should identify the relevant person/discipline who is the 3D model owner. This is to ensure one entity is responsible for the 3D model management and development, including configuration, content, quality, review and final handover to Company.

8 Lifecycle Options

The Company has several options available to them when deciding on how the 3D model will be utilised on their facility after the construction is complete. Some typical approaches to this are:

- As designed - layout and construction of the project only
- As Constructed – the model is as-built, incorporating construction changes
- Full Lifecycle – the model reflects the ‘as-is’ facility from cradle to grave

Combinations of the examples shown above are also possible, depending on the Company’s requirements and available budget. The contracting strategy applied to projects should support the Company’s approach to the 3D model lifecycle requirements.

8.1 As Designed

The model may be built to provide a 3D representation of the project for review and construction only. This approach supports the layout review, ensuring the design meets safety, operability and maintenance requirements, including standards and regulations applicable to the plant location. It should deliver a clash-free design and provide procurement and construction deliverables. It may not include 100% of the design, with some of the project being delivered as “site run”. The model will be left ‘as-designed’ and not be as-built to include fabrication and construction modifications.

8.2 As Constructed

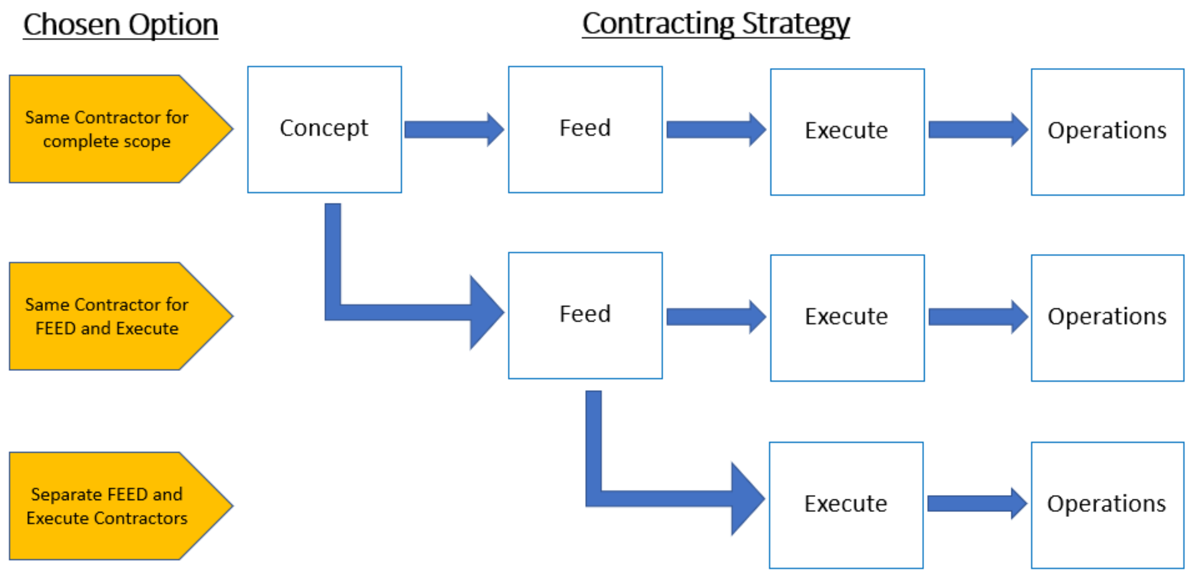
The 3D model is built to the same level applied to the ‘As designed’ approach, but the model is modified at the end of construction to reflect the as-built plant. The scope of as-built must be clear, such that all users of the 3D model understand the accuracy of the content in comparison to the physical object.
This approach is suitable for use as the basis for a basic digital twin and for future Brownfield projects. It may require additional scan data to represent the full physical content of the facility.
The original ‘as constructed’ model may be retained for the lifecycle of the facility, with minimal or no updates incorporated from brownfield modifications, depending on the scale of the changes and the budget and support available for updating the model.

8.3 Full Lifecycle

The model is developed from the initial concept to include all the content required to support procurement and construction, and ultimately the facility digital twin for the complete lifecycle of the project. The construction and all Brownfield modifications are as-built into the model to ensure it reflects the current as-is facility. This model forms the graphical basis of the facility digital twin.

9 Development Options

There are several contracting options available to the Company when developing a new Greenfield or Brownfield project. It may be that one contractor is utilised for the whole project, from concept through to handover or several contractors are engaged for each phase of the development. The chosen option is liable to impact the 3D model application, configuration and content, unless strict controls are put in place by the Company.



A consistent approach from Concept to Handover and Operations support will yield the most benefit to Company in terms of both cost and schedule. Utilising different contractors for each part of the scope will lead to duplication of work (validation of existing design), potential IP and software issues between contractors, and possible delays in project schedule. For instance;

1. Different software or software version used by each contractor.
2. Different software configuration with restricted IP content.
3. Contractor will not continue with previous project phase data until they have validated themselves or data is used for reference only.
4. Different component libraries developed by each Contractor at each phase.

A similar situation exists with Brownfield modifications. The existing 3D model format may not be suitable for the chosen Brownfield contractor and will require conversion prior to start of work.
The contractor may use the same 3D application but the existing model could be in an earlier version and will require updating. Alternatively, the contractor may have a completely different application and the existing model will require conversion to suit their software format. These are all options that must be considered by the Company before making a decision and awarding the project to a particular contractor.

10 Construction Options

The project construction process may influence the 3D model that is as-built and delivered to the Company. The construction contractor may utilise an alternative modelling environment to that used for the engineering model, to support their fabrication process. This could be based on the same software but with a different model breakdown structure or it could be an alternative modelling/fabrication application that requires import/conversion of the master 3D model.

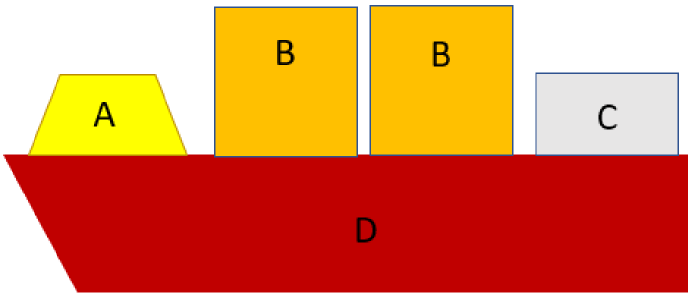
The impact of fabrication/construction being managed in an alternative modelling environment, separate to the master model, is;

1. Control of fabrication/construction changes – which model is updated?
2. Which is the master 3D model that is as-built and delivered at handover to Operations?
3. Site designed items are modelled in the construction contractor's version of the model and do not exist in the master model.

For example, on a major project;

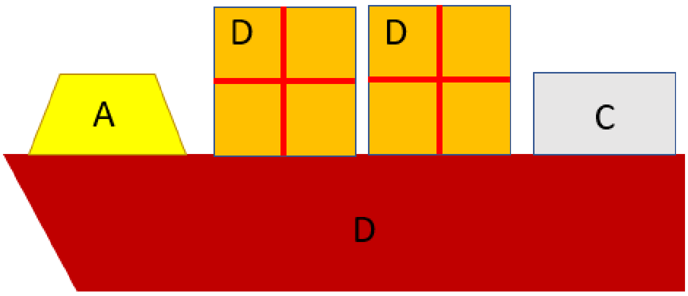
10.1 The Design and Engineering Phase

- Contractors **A, B** and **C** use 3D CAD system **X**
- Contractor **D** uses 3D CAD system **Y**



10.2 The Construction Phase

- Contractor **A** and **C** manage their own construction
- Contractor **D** fabricates and constructs the areas designed by Contractor **B**



Potential issues arise when Contractor D copies Contractor B's design model and modifies the hierarchy and content to suit their fabrication method. Construction change management and as-built process requires considerable effort to ensure the master model reflects the facility at handover.

11 3D Model Environment

11.1 Modelling Application

Company must select their 3D modelling application based on the 3D model lifecycle strategy. If the model is required for layout and construction only and will be discarded at handover, the selected application only needs to meet those requirements. It does not have to align with any other applications that Company may use for operations and future modification support.

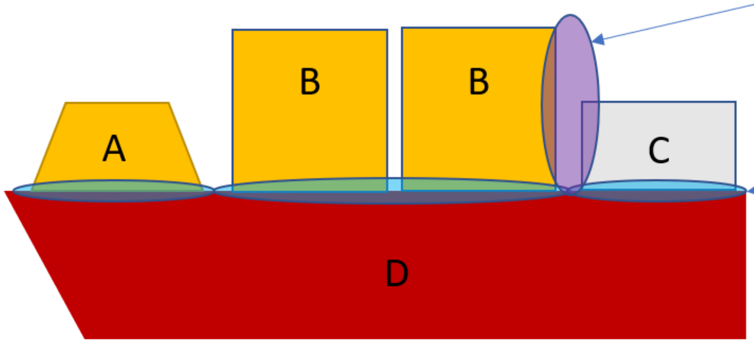
The are several points that should be considered by the Company when deciding on the 3D modelling software to be used for a project;

- Is the proposed modelling software fit for purpose?
- Is the software commercially available and utilised by other engineering contractors globally?
- Are there sufficient skilled resources available to support the project scope using the chosen software?
- Is the proposed software end of life?
- Is the proposed software scalable to suit future expansion of the facility?
- Is it possible to create the required deliverables directly from the software?
- Can the software support the import and export of data to suit other engineering applications used by Company/Contractor?
- Is the software required to be part of an integrated engineering environment?
- Is the software accessed locally or in the cloud? (Country restrictions may restrict cloud hosting)
- Are there any IP restrictions that will stop sharing the model across multiple contractors? (e.g. turret swivel technology)
- Will the software support provide the deliverables format to suit the facility Digital Twin?

Ultimately the selected CAD application depends on the Company's needs and budget.

11.2 Multiple Contractor Development

For major projects, where multiple contractors are involved, the preferred solution would be the same CAD system and version is applied universally across the project. This simplifies interface management, clash checking of the layout and integration of all models into one master model at handover.
However, depending on the project content and the contractors available to deliver the scope, it may be that the native 3D models are built using multiple 3D modelling systems. When this occurs, it is important to identify who is responsible for the interface and how they are managed, to ensure it is possible to have a federated 3D model for the complete project For example, the inclusion of mechanical models representing equipment such as pumps, compressors, etc. may require conversion to STP format for import to the master model. The impact of this process should be reviewed and tested prior to use, as there is a history of poor performance and lack of tag information when imported to the master model.
A typical example is shown below, where the hull of an FPSO is developed in marine/ship-building based software, the topside modules and turret are built in a plant based system, and the accommodation is built in an architectural application.



Major project design and engineering;

- Contractors **A** and **B** utilise a plant 3D CAD system **X**
- Contractor **C** utilise an architectural CAD system **Y**
- Contractor **D** utilise a marine 3D CAD system **Z**

The overall design lies in multiple CAD applications and formats, potentially leading to interface problems that must be managed.
For instance;

- Interface points – position and specification
- Material catalogues and specifications
- Model reviews of separate contractors
- Clash checking of separate models

11.3 3D Model Data Hosting

Generally, all 3D CAD applications now have the ability to be hosted locally, on a network, or in the cloud. Local hosting may be internally by the company or externally with a contractor. It is also possible for the selected contractor(s) to share the 3D model across locations to utilise multiple offices for the project development. This is consistently applied where a contractor has a high-value engineering centre, managed by the project team based elsewhere.
It may be that the Company will not access the master model during a project and not receive the native model files until the project handover. In this instance, it is important to clarify exactly what will be delivered by the contractor during the project development and the data received at handover.
The Company must review the option selected for their project to ensure it meets country requirements and provides the level of access to the model required for design and construction and the continuing lifecycle strategy of the facility.

11.3.1 Local Hosting

In this option, the native model data resides on a local server accessed via the network. The native model may be hosted internally by the Company or externally by a contractor. Access is then controlled via normal network access restrictions.
The Company may designate a contractor to host and support their facility 3D model for all or part of the lifecycle. In this way the Company does not have to employ personnel to manage the 3D model administration.

Benefits:

- Reduced cost
- Direct access via local network

Drawbacks:

- Skilled administrator required (internal or external)

11.3.2 Workshare

Workshare involves configuring an environment where the master model is hosted and managed by one office with an area or discipline shared to another office/location to build the content.
The master model may be stored on a single server accessed by all the contractors offices, with the read/write access assigned to each office/user based on their design area or discipline scope.
Alternatively, the model databases relevant to the design office's scope, may be distributed to the office location. This could be a manual process or automated through the configuration of the 3D modelling application. Updates to the design may be transferred manually between offices or the software can synchronise changes across the environment to ensure all offices have visibility of the latest design.
The master model may reside with the company or one of the contractors but it will require skilled administrators to manage and maintain the architecture. This is to ensure all transfers are successful and all offices are working on the latest information. It is also important that the content, quality and deliverables are checked to be consistent across all offices.

Benefits:

- Improves project delivery by employing a 'global' workforce to build the 3D model.
- All offices have the latest model content (determined by manual/automated synchronisation timing)
- Reliability – 3D modelling applications have utilised automated workshare for many years.

Drawbacks:

- Skilled administrator required at the host office and local office
- Network and firewall configurations between Company/Contractor can complicate the host/local office interface.

11.3.3 Cloud Hosting

With cloud hosting, the 3D model databases are stored in a cloud environment, which is accessed locally by the design application. The cloud storage may be hosted in the Company's cloud, the Contractor's cloud or in the software vendors cloud.
Utilising the cloud hosted model can be limiting for a contractor. They do not have direct control of the cloud and model administration, impacting their ability to share the model across their offices. It may also impact the reference catalogue and procurement systems they already have in place.
The software may be provided and licenced on the 'software as a service' (SaaS) basis, with model management and administration included. The SaaS licence, storage and machine costs, administration and management will be included in the user access costs.

The use of cloud hosting for the 3D model may form part of the Company's overall architecture for their projects and all the associated systems that manage project data.

Benefits:

- Simple access from any location that has a suitable network connection
- Cloud host manages model administration

Drawbacks:

- Country regulations may restrict cloud usage/location
- User access cost is expensive
- Poor performance from slow/inconsistent network connection
- Limited ability to use Contractor's systems

The hosting strategy has cost implications whether it is hosted internally by the Company, externally by a Contractor or in the software provider's cloud.

12 Cost Implications

The 3D model strategy selected for the lifecycle of the facility will affect the total investment required from the Company. There are cost implications to be considered from day one of the 3D model build, through construction and handover to operations, to the decommissioning of the facility.
Historically, after the transition from project phase to operating of a facility, the native 3D model and associated data is rarely maintained and often not used to its full potential.

The business case for developing an industry 3D standard, FL3DMS, identified the potential savings of utilising a common standard and the cost of maintaining the 3D model for the lifecycle of the facility.

The extract below shows the hypothetical savings based on a budget of $500 million.

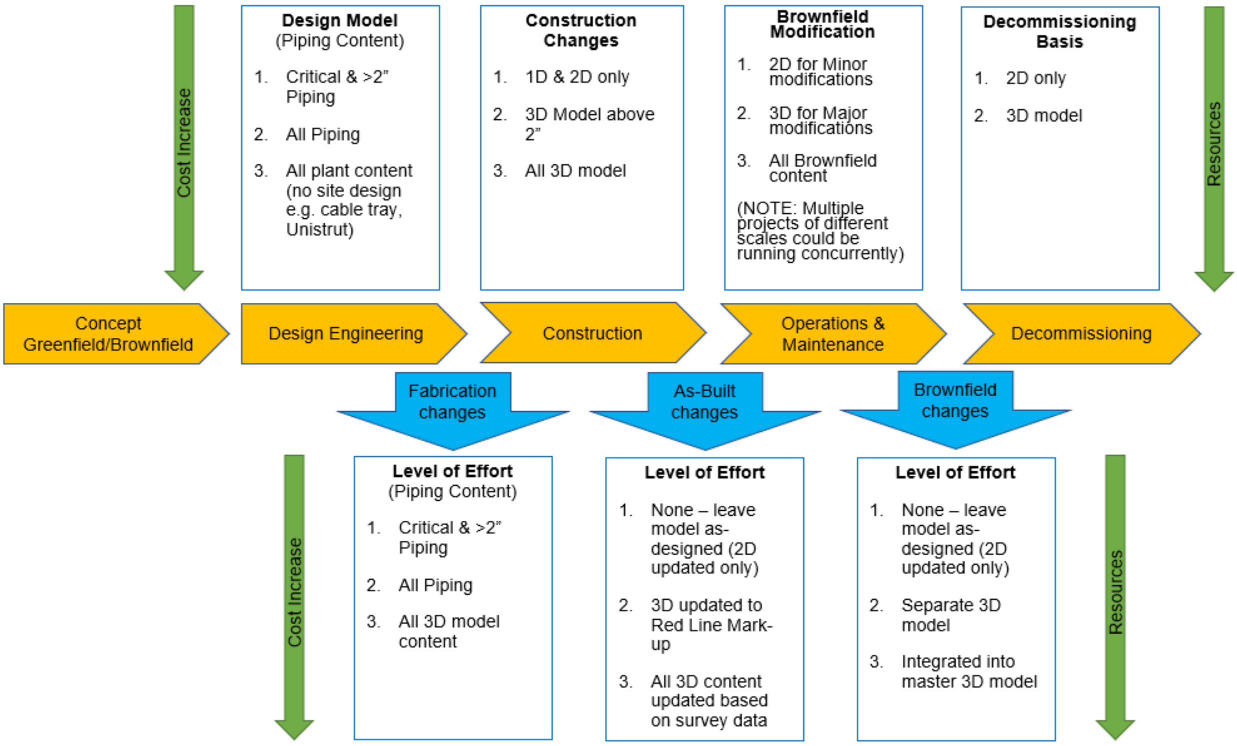
Phase/Activity		Spend Category % of TCO	Saving in activity minimum %	Saving in activity maximum %	% TCO saving minimum	% TCO saving maximum	Notes	Hypothetical average savings of a facility budget of $500 Million
Greenfield	Concept engineering	0.3%	0.0%	0.0%	0.00%	0.00%	Gains already realised, e.g. layout optimisation	$ -
	FEED	0.6%	10.0%	13.0%	0.12%	0.16%	From reuse of FEED 3D model in Detailed Design	$ 350,761
	Detailed design	2.0%	2.1%	3.4%	0.09%	0.17%	From easier integration of 3D models from package vendors*	$ 280,978
	Procurement	5.7%	0.0%	0.0%	0.00%	0.00%	Gains already realised, e.g. generation of bill of material	$ -
	Construction	8.7%	3.0%	6.0%	0.26%	0.52%	From AWP with workpackages identified in 3D model	$ 1,956,522
Brownfield	Repairs and maintenance	17.0%	3.0%	7.0%	0.51%	1.19%	From ability to access virtual asset for planning, training, turnaround AWP	$ 4,239,130
	Brownfield Concept, Feed & Detailed Design	2.8%	3.0%	10.0%	0.08%	0.28%	From avoidance of laser scans and redrawing 3D model	$ 906,750
	Brownfield Procurement	5.3%	0.0%	0.0%	0.00%	0.00%	Gains already realised, e.g. generation of bill of material	$ -
	Brownfield Construction	8.1%	3.0%	6.0%	0.24%	0.49%	From AWP with workpackages identified in 3D model	$ 1,819,565
	Other operational costs	48.3%	0.0%	0.0%	0.00%	0.00%	3D model not used to manage these costs	$ -
	Decommissioning	1.13%	0.5%	3.0%	0.01%	0.03%	From avoidance of laser scans and redrawing 3D model	$ 98,913
Full life	Total unrealised value	100.0%			1.31%	2.84%	* Omits value of replication, as this requires more than 3D model standard.	**$ 9,652,620**

- Value from using a standardised 3D model for the full facility lifecycle 1.3 - 2.8% of TCO
- Cost of maintaining the 3D model for the full facility lifecycle 0.5% of TCO

Therefore, potentially 0.8 - 2.3% of the Total Cost of Ownership (CAPEX and OPEX) is typically lost during the lifecycle of a facility by not standardising the 3D model development and not maintaining the 3D model during operations.

The greater the level of detail specified for the model content, the more effort required to create the model. This is not only direct effort in building the 3D content, it includes the additional data required to be included in the model and the checking process to ensure it is consistent across the project.

It is important that the Company identifies the budget available to build and maintain the 3D model for the lifecycle of the facility. Insufficient budget applied at any point in the 3D model lifecycle will impact the value of the 3D model to the operational facility.
The image below provides a basic overview of the different phases in the 3D model lifecycle, indicating how the level of effort at each phase impacts the resulting value of the 3D model to the facility.



The chosen level of effort, options 1 - 3, applied in updating the model during the initial development and in subsequent modifications, has cost implications to the Company.
A reduced level of effort applied at any stage during the facility lifecycle will also impact the future use of the 3D model;

Option 1

- This was the traditional approach to the development of a 3D model for construction, with a large amount of minor content being designed and run at site.
- The resulting 3D model created for the layout and construction, without any as-built content, being of limited use for the operational facility.

Option 2

- A higher level of detail is included in the model during design to support fabrication, but there is still a degree of site run scope, for example cable and tubing supports, etc.
- The as-built 3D model may be used as basis for future modifications and a simplified digital twin, but will require a survey to obtain details of site run/non-modelled content missing from the model.

Option 3

- A more detailed model created in design, covering the complete scope of the project, will create a more integrated layout, eliminate site design decisions and construction clashes, improving construction efficiency.
- Reliable model that reflects the as-is status of the plant and can be used as the graphical interface in the Digital Twin and an accurate basis for future brownfield modifications and tie-ins.

The Company must ensure multiyear commitment to maintain the 3D model of the facility, based on a firm business case.

12.1 CAPEX v OPEX Budget

Normally a project will have a large CAPEX budget to engineer and construct the facility but limited funds during the OPEX, operational phase. This inevitably means that funds for supporting items such as 3D model maintenance is less, as the priority is maintaining and improving the production of the facility.

12.2 Ownership

The owning Company is liable to change over the lifecycle of a facility, potentially impacting the 3D model requirements and support budget. This could be a positive or negative result, not only based on the available budget, but also on the systems and resources the new Company will use to manage the 3D model.
The change of ownership may also be affected by IP limitations, where the reference data catalogues that the model is based on cannot be shared with the new company.
It is also possible that the new Company will have different software or standards to that on which the model was based, requiring a transition period and update to meet the new requirements.

13 3D Model Standards

It is envisaged that the adoption of USPI's FL3DMS standard across the energy industry will provide a consistent approach to 3D model configuration, build and content. This should improve handover of as-built models from construction to operations, as the requirements are identified in a common standard. It should also enable exchange of models between contractors at each stage of a project, with minimum effort required for review and validation, by providing a benchmark for 3D model content and quality.

The Company should also has a set of standards that applies to the 3D model build, covering required inputs and the deliverables that should be provided by each discipline.
For example;

- 3D Modelling Standard (covering all disciplines)
- User guides, use cases and engineering deliverables to be produced from the 3D model
- Component Reference Catalogues/Specifications
- Templates/seed files, including documentation of template configuration options

This information clarifies the 3D model configuration and development requirements and can be shared with Contractors when developing new projects.

Refer to Appendix A for an outline of the content to be included in the 3D model documentation shown above.

13.1 3D Model Quality Assurance

The handover of a 3D model from the contractor at the end of a project phase cannot be assumed to be accurate by the Company unless some quality assurance is completed on the deliverable.
The Company or Contractor responsible for managing the facility 3D model should have access to skills, either in house or externally, to complete a review of the handover data to ensure it meets the scope of work requirements.
The Company should have detailed audit procedures to confirm the 3D model content is as expected when received from the Contractor.
Strong management is necessary to ensure the contractor delivers an as-built model at the end of the project that represents the physical facility. The Company should consider retaining (part of) the final payment to ensure this scope is completed satisfactorily by the contractor.

13.2 Handover

The 3D model 'Construction to Operations' handover at the end of construction must be accurate and contain sufficient data necessary for Operations to start-up the facility.
For example, 3D item names matched to Company asset/tag names for Operations.
It is important that the Company identifies what information, both data and documentation, is provided by the contractor at the end of the contract. This should either be included directly within the contract text or in the project 3D standard that forms part of the contract.

13.3 As-built Options

The Company must align their as-built strategy with the level of detail they require for operational support systems, such as a digital twin, and future modifications. The facility 3D model is only as good as the level of as-built applied to the content.
As identified in Section 7.3, the more information and detail that is as-built in the model, provides increased benefits to operations and maintenance, but this is at greater cost to

support the required level of effort. Therefore, the level of as-built must be stated in the lifecycle strategy to ensure sufficient budget is allowed to cover the duration of the facility. There are various levels of as-built for the 3D model, from a minimal amount where the as-designed content is sufficient for future use of the facility, to a complete update of all model content to reflect the as-constructed/operating facility.

13.3.1 Red-Line Markup

Historically, the only modifications made to the 3D model was the incorporation of changes that were identified on as-built drawings, 'red-line mark-ups'. The red-line information may be based on deliverable drawings only and not cover all the plant scope. Also, what construction tolerances were applied before a difference between design and construction became a red-line markup?
The FL3DMS standard proposes tolerances (as agreed by FL3DMS team) that are deemed as acceptable construction limits for different types of model content. This may be used when a discrepancy appears in construction, where the difference is more than the proposed tolerance, a query should be raised to record the issue and approve the new location.

The issue for the as-built process, is how to check the 3D model content against the physical installation and ensure it is within the proposed tolerance.

13.3.2 As-built Survey

Building/modifying 3D model content against scan data is a common process when it comes to Brownfield modifications, but less so for the final construction as-built process. This is something that will change in the near future, as technology develops and equipment becomes more accessible, to scan and automatically check the 3D model for discrepancies.

Laser scans consist of multiple overlapping point clouds, requiring storage capabilities for large quantities of data and specialist software to view. The scans may be hosted internally on the local network or externally in a cloud environment.

Laser and photogrammetry scanners are now an affordable option for the Company to purchase to support the evergreening of their 3D model. The level of accuracy is less at the lower end of the scale but the device may be suitable for the Company's requirements. For example:

- Drone/aerial scanner - low accuracy (cm's)
- 360 degree photogrammetry - low accuracy (cm's)
- Hand held/backpack scanner – improved accuracy (cm-mm)
- Tripod laser scanner – best accuracy (mm's)

The scans can be overlaid onto the 3D model to review differences between the model content and the physical object. (Note: This requires a model administrator to link and align the scans with the 3D model content.)

It should be noted that module/equipment vendors are now scanning their packages, prior to shipping, to import into the 3D model to check the overall dimensions and interfaces are aligned with the plant tie-ins and allocated space.

It is also possible to run a weekly scan to collect status and check construction accuracy to identify problems before they affect the construction schedule, e.g. foundations set out prior to pouring and equipment installation

13.4 MOC procedures

The Company person responsible for the facility 3D model should establish a management of change (MOC) procedure, outlining the methodology for incorporating brownfield modifications into the master 3D model.
The procedure should identify how an area of the model is segregated when it is impacted by a change, and how the new content is as-built and merged back into the master model.
It should be possible to visualise work in progress content (including concurrent projects) versus as-built content in the master model or digital twin.

14 3D Model Lifecycle Usage

14.1 Maintenance & Brownfield Modifications

An accurate as-built 3D model provides the basis for turnaround planning, including space assessment for maintenance operations and laydown area usage. It is ideal for locating temporary equipment, such as cranes or containers, ensuring there is no impact on operational safety, for example, blocking escape routes.
It is utilised by company to develop future modification projects, enabling the new content to be clash checked against the existing plant.

14.2 Digital Twin

Digital Twins are technology based digital representations of real-world objects, giving swift access to data associated to the models used for operations, performance and maintenance of the facility.
The 3D model provides the graphical basis for the digital twin environment. The 3D model must be an accurate representation of the ‘as-is’ facility to be a reliable source of truth reflecting the plant layout.
To provide the maximum return on investment in the 3D model, the facility digital twin must be easily accessible for all users and simple to navigate or search for objects.
Some organisations use reality capture, such as laser or photogrammetry surveys, for the digital twin graphics. This requires conversion and an additional layer of intelligence to identify the tagged object location.

14.3 Virtual/Augmented Reality

Design engineering and operations and maintenance personnel are increasingly utilising virtual reality (VR) and augmented reality (AR) environments, based on the 3D model, to visualise the facility layout .

This may be for a variety of reasons during the facility design, construction and operate phases, for example;

- Layout review (complex/restricted areas)
- Stakeholder engagement
- Constructability review (e.g. heavy lift operations)
- Onboarding of new personnel
- Immersive training (Operation and escape)
- Maintenance operations

15 Appendix A – 3D Model Documentation

The sections below provide an outline of the content to be included in the Company 3D model documentation.

15.1 3D Model Standard

The Company should have a 3D Model Standard that identifies their model requirements to be delivered by the contractor for projects, including:

- 3D Model Software – preferred application and version
- 3D Model Configuration – hierarchy, naming conventions
- 3D Model Management – access control, clash checks
- 3D Model Content and Review – level of detail and review process
- 3D Model Deliverables and Exports – reports, drawings, data, etc.
- 3D Model Handover – as-built requirements, quality checks, extent of data exchange

15.2 User guides

The Company should have user guides for all disciplines providing information for the 3D model build procedures, including;

- Discipline specific naming conventions
- Data attribution
- Model libraries (equipment, assemblies)
- Use cases
- Deliverable production

15.3 Component Reference Catalogues/Specifications

The Company should identify the standard reference data/specifications that will be used as the basis for the 3D model. The catalogues may be supplied by the Company or developed by the contractor to suit the project requirements. This will include;

- Piping Specifications
- Structural steel profiles
- Cable rack/tray catalogue

15.4 Templates

The Company may have template or seed files which they supply to the contractor as the basis for creating a new project. The Company should have documentation that provides details of how the contractor should use the template/seed files, including;

- Database details and use
- Reference catalogue/specifications supplied
- Configuration options