OFFSHORE NORGE & NORSK INDUSTRI

GUIDELINE FOR ON-DEMAND MANUFACTURING

APPENDIX

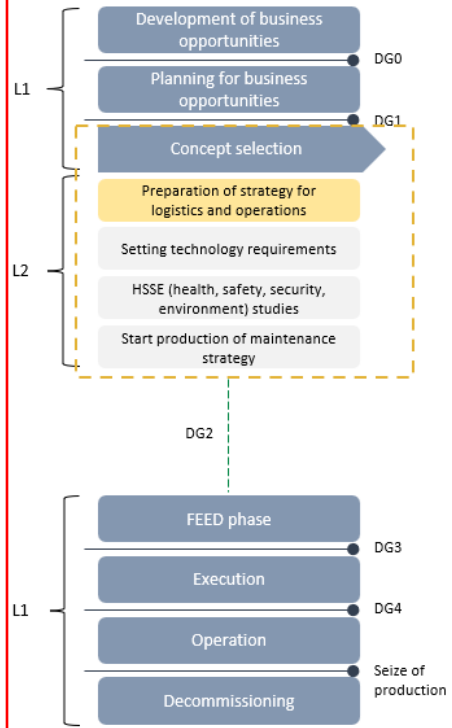
HOW TO READ AND USE THIS DOCUMENT

Navigate back to process taxonomy for respective delivery type

Tracker: Shows the delivery model being explored. Click the icon to return to the delivery type menu.

L1 | CONCEPT SELECTION

L2 | PREPARATION OF STRATEGY FOR LOGISTICS AND OPERATIONS



Process taxonomy tracker: Highlights the current process in focus

Definition	Document subordinate to the Operating Model describing the strategy for logistics and emergency preparedness for the operational phase of the plant
Why is this activity relevant?	The operations organization's ambitions for the use of AM/DI are linked to the logistics function and base warehouse
How can AM / DI impact the activity?	Early focus in relevant parts of the project organization and to manage expectations for suppliers
Output	Plans for AM and DI are initiated at the right time and the project organization is given time to mature for new processes

Description of relevant activity

Action / Recommendations

- Assess whether AM/DI can provide a greater degree of control over the logistics chain?
- Choosing a logistics model and considering proximity to the logistics chain.
- It can be mentioned how AM/DI can influence base structure philosophy, strive for local production and environmental footprint, as well as optimize value creation.

Actions and recommendations for AM/DI implementation

Level of detail

Overall | Concrete | Detailed

Level of action/recommendation specificity

Relevant stakeholders

Project organization
Purchaser
Operations organization
Provider

Key stakeholders involved in recommended action

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AM/DI OFFERS STRATEGIC ADVANTAGES FOR BOTH GREENFIELD (DEVELOPMENT) AND BROWNFIELD (MODIFICATIONS & MAINTENANCE) PROJECTS

GREENFIELD

BROWNFIELD

Development

Development - / Greenfield projects focus on **developing new resources**, following concept studies and sanctioned by an approved PDO/PAD/PUD. These projects are complex, span several years, and involve multiple disciplines across several phases.

Modifications

Modification projects involve **changes or extensions to existing equipment and facilities**, requiring updated technical documentation. Includes change projects and reconstruction outside of maintenance or operational investments.

Maintenance

Maintenance projects cover all **maintenance activities** for offshore **facilities, land plants, and pipelines**, including inspection, preventive and corrective maintenance, and maintenance support.

Guideline

Development Project

For On-demand Manufacturing & Digital Inventories

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DEVELOPMENT PROJECTS FOCUS ON THE DEVELOPMENT OF NEW RESOURCES, AND USUALLY SPAN SEVERAL YEARS

Definition

- After a discovery, the operating company will initiate a "development project" to develop the field and recover value (recover oil and gas)
- Development investments concern the development of new resources. There will always be concept studies before such an investment is made. The budget for the project is sanctioned by an approved PDO/PAD. Some projects are exempt from PDO requirement.
- Development projects usually run over several years, and can be divided in seven different phases with respective activities, characterized by a high degree of complexity and with many different disciplines involved,
- Development projects address and affect all phases related to the field's lifetime, and if you influence these, you can influence the work processes for modification and maintenance in the future

Relevance

- Development projects affect and set guidelines for all phases related to a field's lifetime.
- By establishing a uniform guideline for using AM/DI in greenfield projects, one can manage expectations for the supplier industry and ensure digital content for the implementation of projects in a digital inventories.
- Introduce the use of digital inventories throughout the project lifecycle
- The use of on-demand manufacturing and digital inventories has the potential to prevent delays and cost overruns related to project start-up
- This guideline is based on a process for a typical oil and gas project, but it will be equally relevant to consider how to use AM/DI in other projects within e.g. renewable energy (wind, CCS etc..)

PROJECTS TYPICALLY FOLLOW A STRUCTURED SEQUENCE OF PHASES, WITH KEY ACTIVITIES DRIVING PROGRESS FROM PLANNING TO EXECUTION AND OPERATION

	2 – 3 years	1 – 2 years	1 – 5 years	5 – 30 years	2-3 years
L1 (phase)	Development of business opportunities	Planning for business opportunities	Concept selection	FEED phase	Execution	Operation	Decommissioning
L2 (activity)	Size, scope of fields	Establish a project	Selection of shortlist of concepts	Further develop the chosen concept	Place purchases	Platform operation	Choice of concept for decommissioning
	Drill results	Conducting feasibility studies	Study of shortlist of concepts	All technical choices are made (detailed engineering)	Testing of equipment	Maintenance	Recycling
	Assess whether there is existing infrastructure nearby	Outline of concept options (longlist)	Concept recommendation	Finalization of maintenance strategy/spare parts strategy	Building platform/installation	Modifications	Sale of assets and spare parts
	Setting expectations from the steering group / License partnership	Identify concepts for infrastructure: Subsea, platform, FPSO	Producing Decision Documents	Finalization of logistics strategy	Writing operating procedures	Continuous development and innovation	Consider reuse of assets and spare parts
	Establish a risk matrix for upside and downside risk	Planning of operating philosophy/project philosophy (high level)	Maturation of detailed plan	Finalization of procurement strategy	Finalizing designs	Use of digital capabilities	Setting requirements for recycling
		Assessment of logistics, choice and market	Dimensions of the various concepts are further developed	Completion of operating model	Follow-up of the construction process		
		Outline overall procurement strategy	Preparation of strategy for logistics and operations	Finalization of digitalization strategy /LCI	Preparing for operation		
		Stakeholder mapping	Setting technology requirements	Choice of FEED supplier (e.g., AkerS, Aibel, TechnipFMC..)	Procurement of operational, capital and commissioning is saved		
		Estimate CAPEX / OPEX	HSSE (health, safety, security, environment) studies	Requirements for criteria are communicated to EPCI	Drill wells		
		Assess expected production lifetime/volume/production profile	Start production of maintenance strategy	Starting an IT project	Establish an operating organization		
		Technology studies on which technology to use		Disposal / decommissioning plan	Establish digital tools to be used in the operational phase		
		Project design basis and scope for B and C studies		Economic analysis (CAPEX/OPEX)	Commissioning		

Phase

Activities

DG0 → DG1 → DG2 → DG3 PDO /PDO → DG4 → "SEIZE OF PRODUCTION"

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KEY AM/DI INTEGRATION OPPORTUNITIES ACROSS THE MODIFICATION LIFECYCLE

	2 – 3 years	1 – 2 years	1 – 5 years	5 – 30 years	2-3 years
L1 (phase)	Development of business opportunities	Planning for business opportunities	Concept selection	FEED phase	Execution	Operation	Decommissioning
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Phase
Activities
Areas of opportunity

Click on any L2 process marked as an opportunity for a direct link to the detailed deep-dive or scroll to view all sections

DG0 → DG1 → DG2 → DG3 PDO /PDO → DG4 → "SEIZE OF PRODUCTION"

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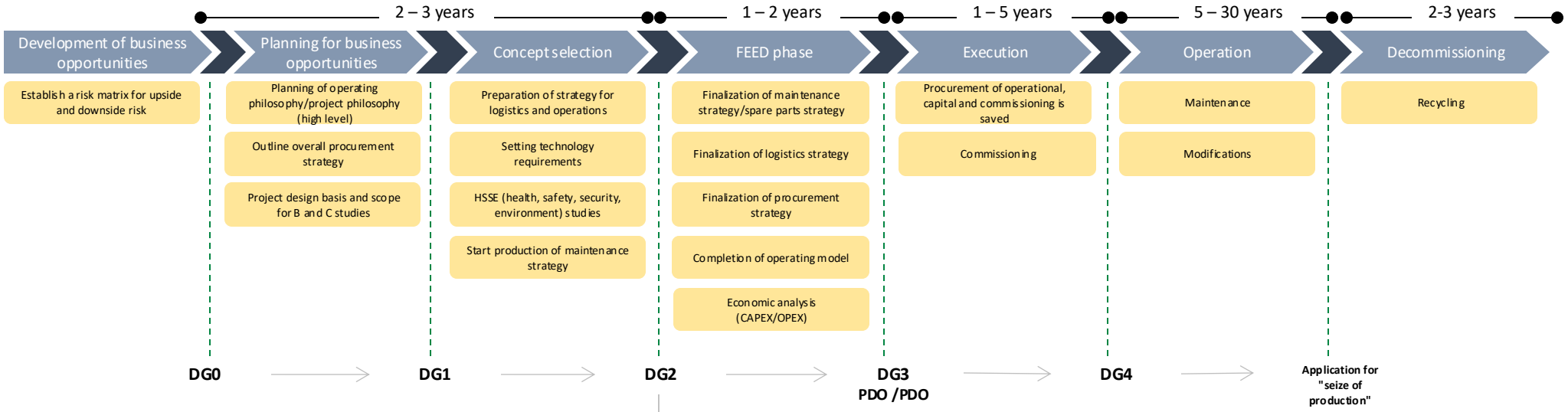
THE LEVEL OF DETAIL IN OUR AM/DI RECOMMENDATIONS INCREASES PROGRESSIVELY FROM PLANNING THROUGH EXECUTION AND OPERATION PHASES



LOW DEGREE OF DETAIL IN RECOMMENDATIONS

- *Overall wording in documents*
- *Philosophy*
- *Dissemination of generic benefits related to AM/DI*
- *Gradual increase in the degree of concretization*

HIGH DEGREE OF DETAIL IN RECOMMENDATIONS

- *Detailed wording in documents*
- *Strategy and practical approach*
- *Specification of benefits related to AM/DI*

Planlegging av forretningsmuligheter | Konseptvalg | FEED fase | Gjennomføring | Drift | Decommissioning

Etablere prosjekt
Valg av shortlist med konsepter
Videreutvikle valgt konsept
Plasser innkjøp
Drift av platform
Valg av konsept for decommissioning

tføre mulighetsstudier
Studie av shortlist med konsepter
Alle tekniske valg tas (detailed engineering)
Test av utstyr
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Recycling

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Anbefaling av konsept
Ferdigstilling av vedlikeholdsstrategi/reservedels strategi
Bygge platform/installasjon
Modifikasjoner
Salg av assets og reservedeler

entifisere konsepter for struktur: Subsea, platform, FPSO
Produsere beslutningsdokumenter
Ferdigstilling av logistikk strategi
Skrive driftsprosedyrer
Kontinuerlig utvikling og innovasjon
Vurdere gjenbruk av assets og reservedeler

Planlegging av losofi/prosjektfilosofi (high level)
Ferdigstilling av anskaffelses strategi
Finalisere design
Bruk av digitale kapabiliteter
Sette krav til recycling

dering av logistikk valg og marked
konse
Ferdigstilling av driftsmodell (hvordan ser driftsorganisasjonen ut?)
Oppfølging av byggeprosess

Skissere overordnet anskaffelsesstrategi
Ferdigstilling av digitaliseringsstrategi /LCI

tlegging av interessenter
av FEED leverandør (f.eks, S, Aibel, TechnipFMC...)
Innkjøp av operational, capital- og commissioning spares

stimere CAPEX / OPEX
m kriterier for EPCI

Vurdere forventet aksjonslevetid/volum/produ ksjonsprofil
Starte IT prosjekt
Etablere driftsorganisasjon

ologistudier rundt hvilken nologi som skal benyttes
Plan for avhending / decommissioning
Etablere digitale verktøy som skal benyttes i driftfase

ct design basis og scope til B og C studier
Commissioning

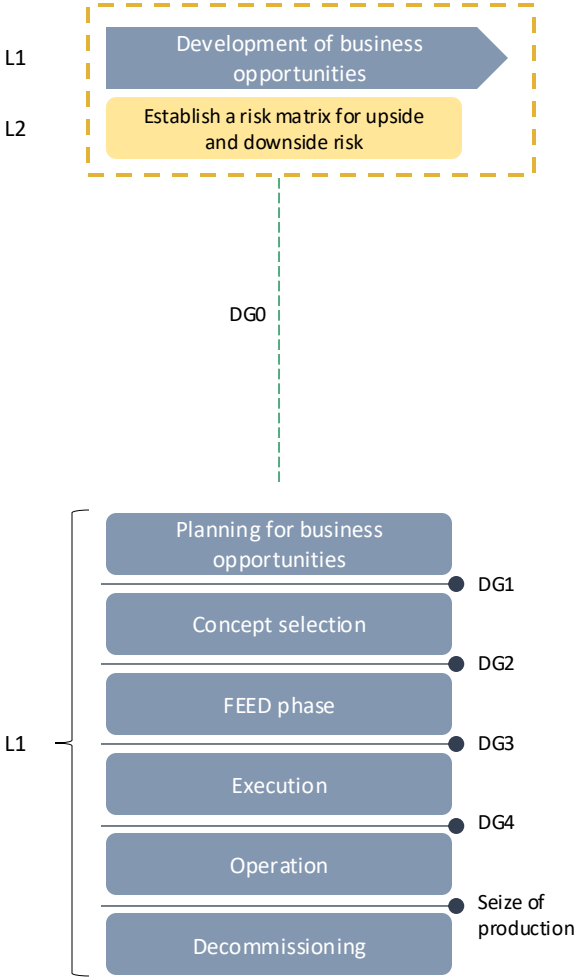
Development Project

DG0

"Development of business opportunities"

DG1 → DG2 → DG3 PUD /PDO → DG4 → Søknad om «seize of production»

L2 | ESTABLISHING RISK MATRIX FOR UPSIDE AND DOWNSIDE RISK



Definition

The establishment of a risk matrix carries out an overall screening of the risk picture for the project(s). Here, the operators look at risk elements and assess upside potentials that can help form positive effects. These factors are included in a "framing document" (a document that shows the framework of the project, which priorities are in place) that is produced and form the basis for the DG0 decision.

Why is this activity relevant?

AM/DI will come in as an upside potential, and local production is considered an obvious/active choice in how parts and components are to be manufactured and procured.

By adding AM/DI as an upside, this can be included in the framing of the project and consider that it is built into contract regimes.

How can AM / DI impact the activity?

Execution time is an important parameter in projects, and this can help improve execution time, local delivery network and production capabilities

Output

Assess whether AM/DI can contribute to improving the implementation time in the project, as well as minimising possible risk elements such as "shortage" of raw materials.

Action / Recommendations

- The operator can formulate requirements in the "framing document" that AM/DI should be something that should be addressed later in the process.
- The requirement can set expectations for suppliers, so that when a shortlist is set, the suppliers must adapt and offer such solutions

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Project organization
- Supply-chain

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Planlegging av forretningsmuligheter | Konseptvalg | FEED fase | Gjennomføring | Drift | Decommissioning

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Sette krav til recycling

dering av logistikk valg og marked
konse
Ferdigstilling av driftsmodell (hvordan ser driftsorganisasjonen ut?)
Oppfølging av byggeprosess

Skissere overordnet anskaffelsesstrategi
Ferdigstilling av digitaliseringsstrategi /LCI

tlegging av interessenter
av FEED leverandør (f.eks, S, Aibel, TechnipFMC...)
Innkjøp av operational, capital- og commissioning spares

stimere CAPEX / OPEX
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Commissioning

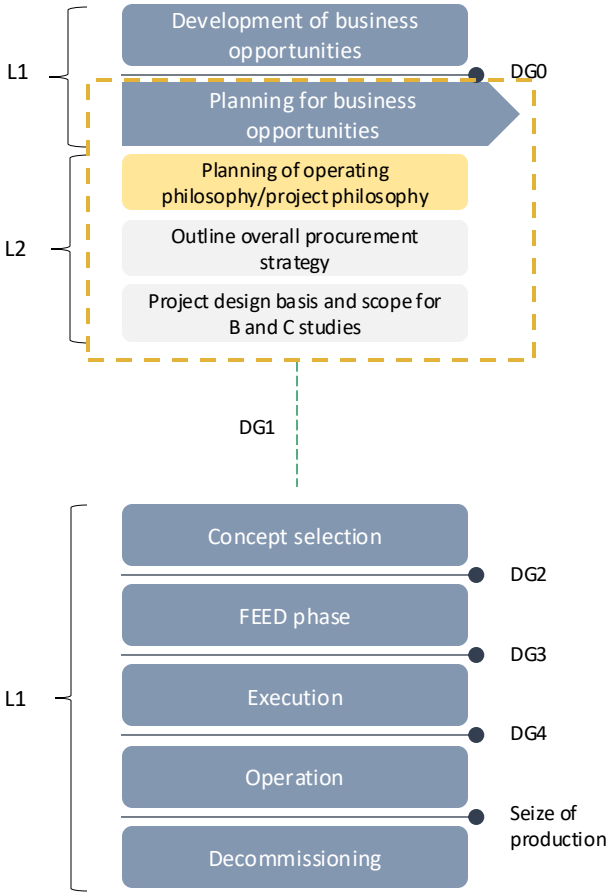
Development Project

DG1

"Planning for business opportunities"

DG1 → DG2 → DG3 PUD /PDO → DG4 → Søknad om «seize of production»

L2 | PLANNING OF OPERATIONS / PROJECT PHILOSOPHY



Definition

Between DG0 – DG1, the documents describing the operating models (describing how the plant will be operated when it is handed over to the operating organization) will be formulated in general terms and based on philosophical considerations. Later in the project's lifecycle, these documents will be concretized and amended

Why is this activity relevant?

It is recommended to mention the use of AM/DI to highlight the expectations from operations to the project organization at an early stage

How can AM / DI impact the activity?

Early focus in relevant parts of the project organization

Output

Plans for AM/DI are initiated at the right time and the project organization is given time to mature for new processes

Action / Recommendations

- Plans for AM and DI are initiated under "preparation of philosophy for operations" so that the project organization has time to mature for new processes related to the use of digital warehouses.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Project organization
- Purchaser
- Operations organization

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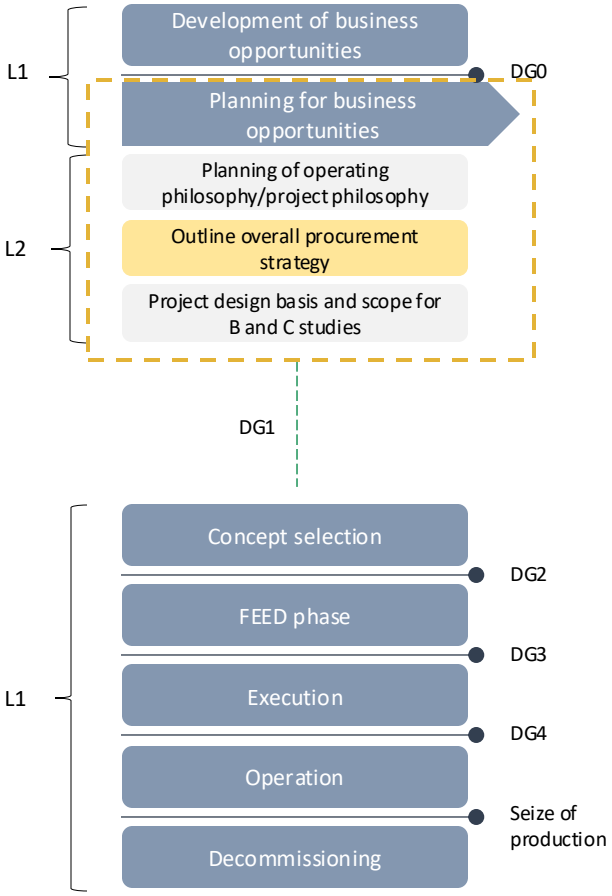
L2 | OUTLINE THE OVERALL PROCUREMENT PHILOSOPHY



Definition

Between DG0 to DG1 in the phase; "Planning of business opportunities" is a mapping of capabilities in the market. Here, an expectation is set for local value creation, emissions and security of supply – life cycle perspectives. Factors such as; location, complexity and local factors (regulatory requirements), will be specified or elucidated in this phase.

Why is this activity relevant?

If AM/DI is facilitated, this will affect the procurement strategy. If there is no provision for AM/DI and local production, this must be considered in the procurement philosophy. The operator must ensure that the supplier has the incentive and capacity to set up a production cluster/service cluster

How can AM / DI impact the activity?

If local conditions make it difficult to obtain spare parts, services, and facilitate local production, it is essential to look at this at an early stage. The procurement strategy must invert/assess methods to ensure the supply of parts, components and spare parts.

Output

Operators can get spare parts when they need them (reduced lead time, cost, and emissions)

Action / Recommendations

- The overall procurement strategy helps to map the opportunities for local production.
- The wording of an overall procurement strategy that can be the following: "Facilitate the use of local supply networks to manufacture and procure parts and components..."

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Project organization
- Purchaser
- Operations organization

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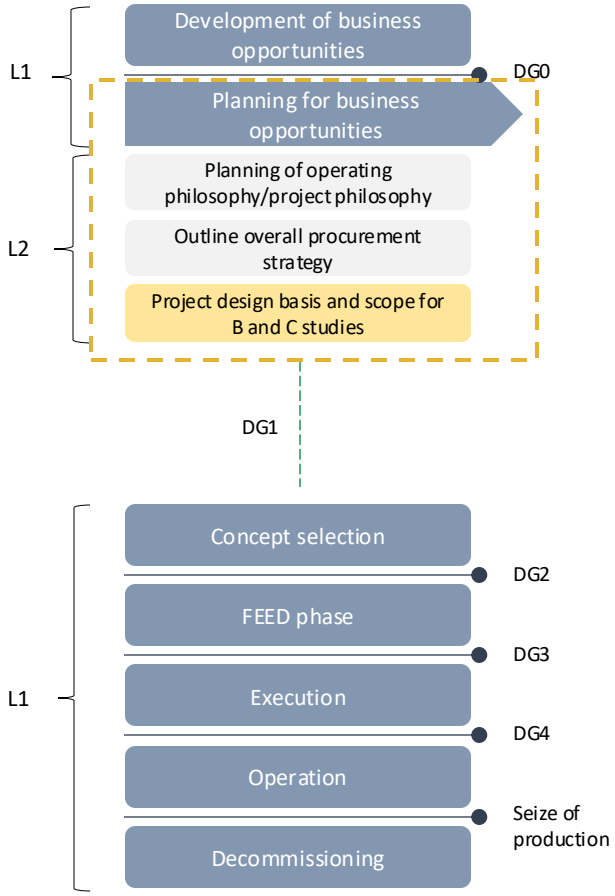
L2 | PROJECT DESIGN BASIS AND SCOPE FOR B AND C STUDIES



Definition

Is an overarching and comprehensive document that describes the field, the project. It is the basis for design to provide an effective anchoring between all the functions in the project for the different development phases. The target group is project participants, internal stakeholders, license partners and external suppliers.

Why is this activity relevant?

AM/DI will never be part of the framework condition in the project design basis but can be described as an ambition. This is also a premise document for future work. The document is updated for each phase and will be a so-called iteration document.

How can AM / DI impact the activity?

Visibility and anchoring for the ambition of using AM/DI in the project – both internally and towards the suppliers who are invited to B and C studies.

Output

Project participants and suppliers can from an early phase mature the use of AM/DI and plan for implementation.

Action / Recommendations

- The operator may consider updating the document templates/design basic document template to include a chapter dealing with AM/DI.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

Project organization

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Planlegging av forretningsmuligheter | Konseptvalg | FEED fase | Gjennomføring | Drift | Decommissioning

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Finalisere design
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Sette krav til recycling

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Ferdigstilling av driftsmodell (hvordan ser driftsorganisasjonen ut?)
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Ferdigstilling av digitaliseringsstrategi /LCI
Klargjøring for drift

tlegging av interessenter
v FEED leverandør (f.eks, S, Aibel, TechnipFMC..)
Innkjøp av operational, capital og commissioning spares

stimere CAPEX / OPEX
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Borre brønner

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Plan for avhending / decommissioning
Etablere digitale verktøy som skal benyttes i driftfase

t design basis og scope til B og C studier
Commissioning

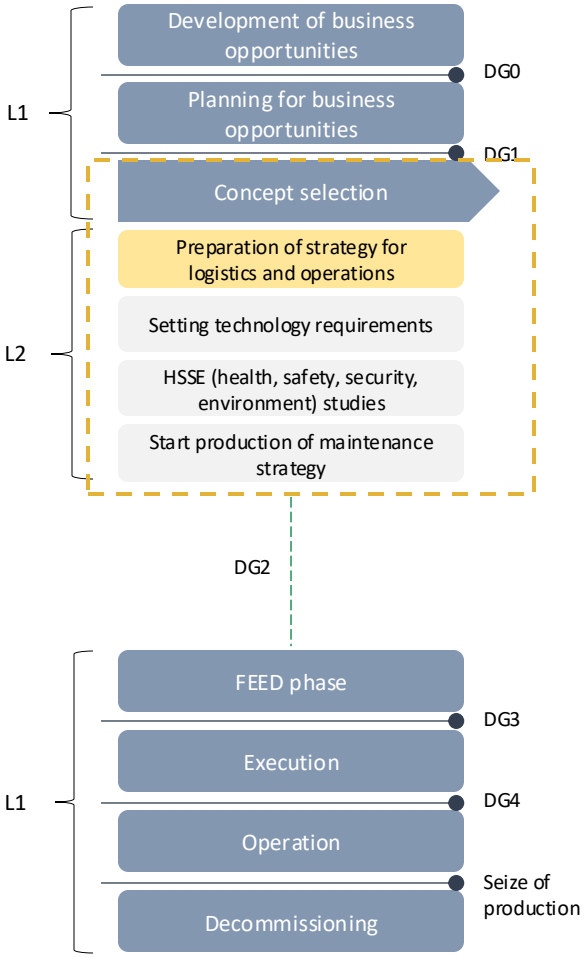
Development Project

DG2

"Concept selection"

DG1 → DG2 → DG3 PUD /PDO → DG4 → Søknad om «seize of production»

L2 | PREPARATION OF STRATEGY FOR LOGISTICS AND OPERATIONS



Definition

Document subordinate to the Operating Model describing the strategy for logistics and emergency preparedness for the operational phase of the plant

Why is this activity relevant?

The operations organization's ambitions for the use of AM/DI are linked to the logistics function and base warehouse

How can AM / DI impact the activity?

Early focus in relevant parts of the project organization and to manage expectations for suppliers

Output

Plans for AM and DI are initiated at the right time and the project organization is given time to mature for new processes

Action / Recommendations

- Assess whether AM/DI can provide a greater degree of control over the logistics chain?
- Choosing a logistics model and considering proximity to the logistics chain.
- It can be mentioned how AM/DI can influence base structure philosophy, strive for local production and environmental footprint, as well as optimize value creation.

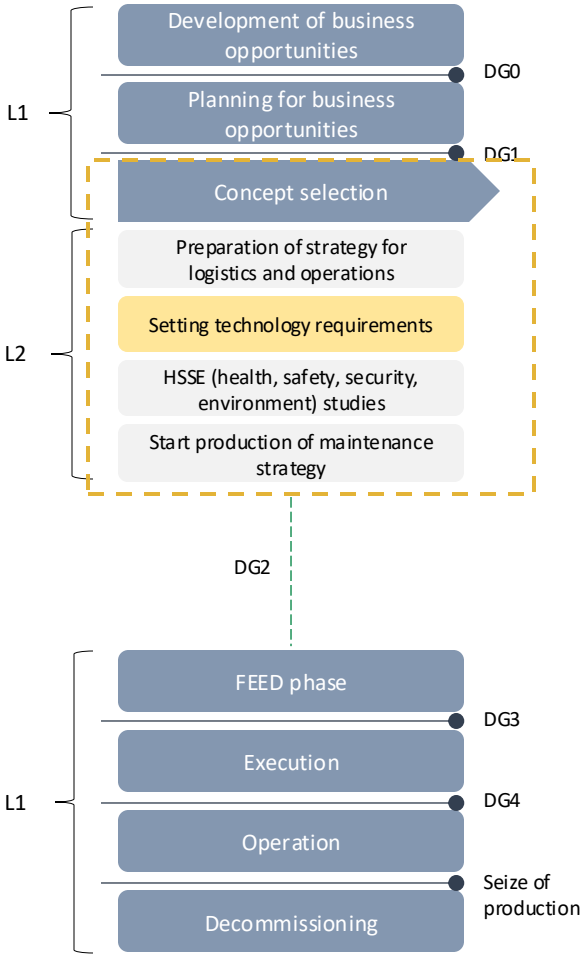
Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Project organization
- Purchaser
- Operations organization
- Provider

L2 | SETTING TECHNOLOGY REQUIREMENTS



Definition

Technology requirements are designed to describe the necessary technical characteristics or functions that must be met to achieve a specific goal or purpose. The requirements may vary depending on the context, but they generally serve to guide developers, engineers, and technology professionals in the design, implementation, and assessment of technological solutions.

Why is this activity relevant?

Determining technology requirements using AM and Digital Inventories is critical to defining functionality, security, performance, and quality.

How can AM / DI impact the activity?

Setting technology requirements ensures that the technology handles security and copyright, is compatible with relevant components, is cost-effective, and provides efficient data management. Quality control requirements ensure that manufactured items meet the necessary standards. Overall, the setting of technology requirements provides a clear direction for the successful implementation and use of AM and DI.

Output

The purpose of setting technology requirements is to achieve several key goals. It provides clear direction and objectives for the project, ensures high performance and quality of technological solutions, addresses safety aspects, promotes compatibility between system components, optimizes efficiency and cost management, facilitates reliable data management, and ensures that products meet strict quality standards. Overall, the determination of technology requirements provides a structured approach that mitigates risk, improves outcomes, and ensures success in a variety of technology-related projects and applications.

Action / Recommendations

- Map different standards for AM
- Describe different production methods (print, welding)
- Assess different equipment families suitable for AM
- Describe technical limitations (size, weight, geometry),
- Describe the regime for testing and verification of the finished product against criticality (DNV, KIWA**), (DNV approved production method (DNV approved AM workshops)

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Project organization
- Purchaser
- Operations organization
- Provider

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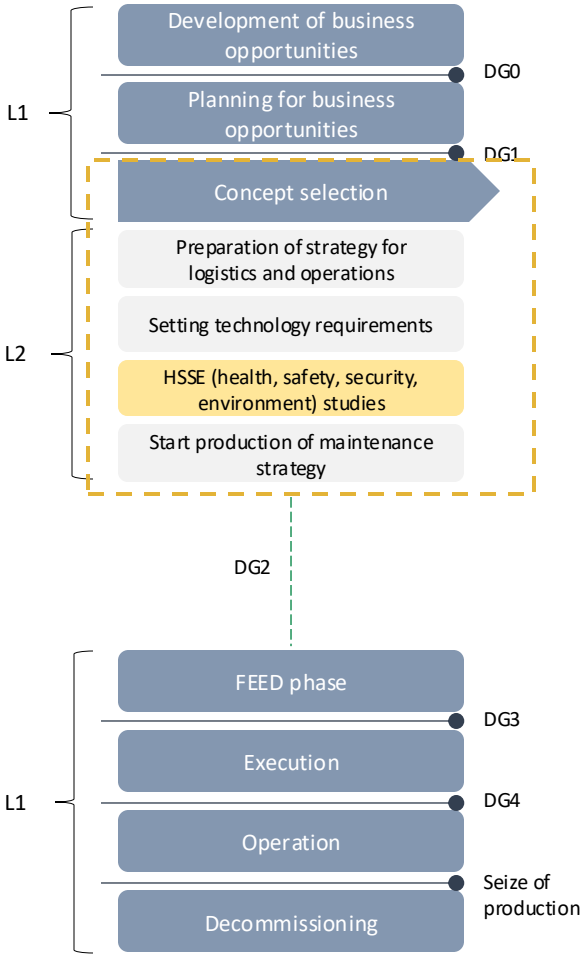
L2 | HSSE (HEALTH, SAFETY, SECURITY, ENVIRONMENT) STUDIES



Definition

Are studies that map HSSE (Health, safety, security & environment) for the concepts and assess dimensions within sustainability, climate, security and the environment.

Why is this activity relevant?

Safety and the environment are two specific parts that can be affected by AM/DI. For example, AM can help reduce emissions by only producing parts when needed, and thus not keeping inventory (C02 linked to inventory). Digital warehouses can contribute to safety by ensuring that parts are always available digitally (and verified) so that they can be produced when needed (based on criticality).

How can AM / DI impact the activity?

Supplier locality (transportation), waste management including recycling of materials, impact on operation efficiency, responsible sourcing of materials, are examples that can be studied

Output

Mature methodology and processes, as well as analysis for the project

Action / Recommendations

- A scenario-based study for environmental impact for local production should be included in an HSSE study. (emissions from the logistics chain, choice of materials, environmental risk, responsible sourcing of materials)
- *Example: xx% is produced through local production, what does this mean for HSSE?*

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

Project organization

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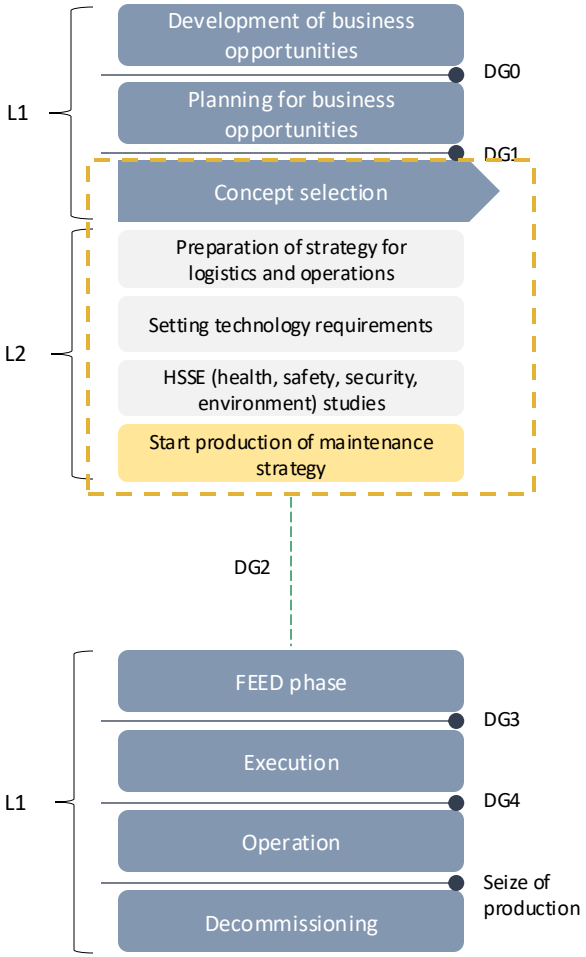
L2 | START PRODUCTION OF MAINTENANCE STRATEGY



Definition

Document for reliability and maintenance in the operational phase. Subject to operating model.

Why is this activity relevant?

Describe the strategy for the use of AM/DI in the maintenance phase of the project. The maintenance programme is a premise for the "spare parts strategy" in the next phase, and it is essential to influence the programme in order to influence the spare parts strategy.

How can AM / DI impact the activity?

Visibility to the project and maintenance organization of the effect of AM/DI on maintenance programs.

Output

Plans for AM and DI are initiated at the right time and the project organization is given time to mature for new processes

Action / Recommendations

- Assess the maintenance program for AM/DI, how are the programs affected (Condition based, run to failure, criticality classification..) and which programs should different components and parts have (Based on criticality)
- Can say something about which component classes should be considered/rules that should apply to different criticality classes

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Project organization
- Operations organization

Norsk Industri

OFFSHORE NORGE

Planlegging av forretningsmuligheter | Konseptvalg | FEED fase | Gjennomføring | Drift | Decommissioning

Etablere prosjekt
Valg av shortlist med konsepter
Videreutvikle valgt konsept
Plasser innkjøp
Drift av platform
Valg av konsept for decommissioning

tføre mulighetsstudier
Studie av shortlist med konsepter
Alle tekniske valg tas (detailed engineering)
Test av utstyr
Vedlikehold
Recycling

ering av konseptalternativer (longlist)
Anbefaling av konsept
Ferdigstilling av vedlikeholdsstrategi/reservedels strategi
Bygge platform/installasjon
Modifikasjoner
Salg av assets og reservedeler

entifisere konsepter for struktur: Subsea, platform, FPSO
Produsere beslutningsdokumenter
Ferdigstilling av logistikk strategi
Skrive driftsprosedyrer
Kontinuerlig utvikling og innovasjon
Vurdere gjenbruk av assets og reservedeler

Planlegging av losofi/prosjektfilosofi (high level)
Ferdigstilling av anskaffelses strategi
Finalisere design
Bruk av digitale kapabiliteter
Sette krav til recycling

dering av logistikk valg og marked
konse
Ferdigstilling av driftsmodell (hvordan ser driftsorganisasjonen ut?)
Oppfølging av byggeprosess

Skissere overordnet anskaffelsesstrategi
Ferdigstilling av digitaliseringsstrategi /LCI

tlegging av interessenter
v FEED leverandør (f.eks, S, Aibel, TechnipFMC..)
Innkjøp av operational, capital- og commissioning spares

stimere CAPEX / OPEX
m kriterier formidles til EPCI
Borre brønner

Vurdere forventet aksjonslevetid/volum/produ ksjonsprofil
Starte IT prosjekt
Etablere driftsorganisasjon

ologistudier rundt hvilken nologi som skal benyttes
Plan for avhending / decommissioning
Etablere digitale verktøy som skal benyttes i driftfase

t design basis og scope til B og C studier
Commissioning

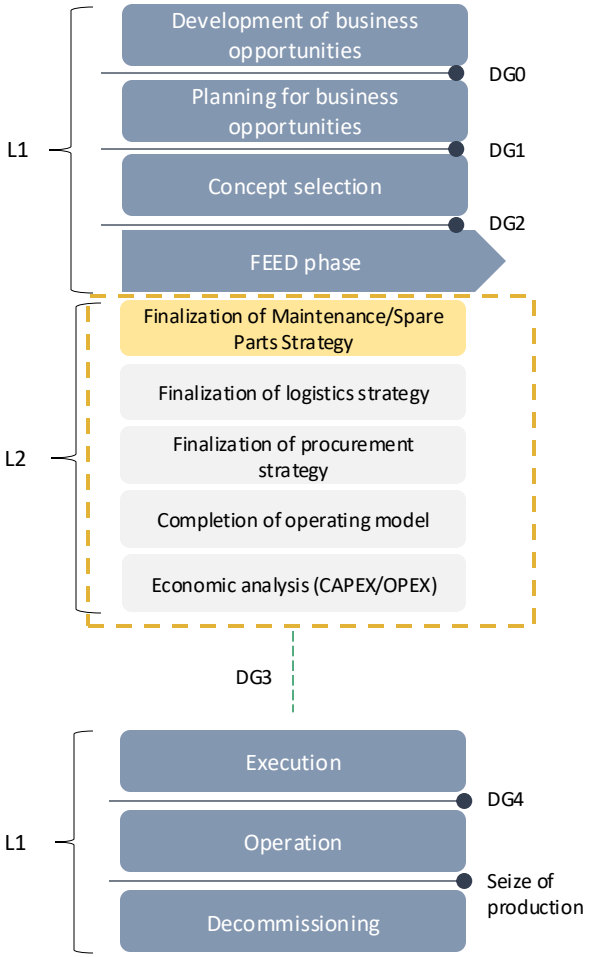
Development Project

DG3

"FEED phase"

DG1 → DG2 → DG3 PUD /PDO → DG4 → Søknad om «seize of production»

L2 | FINALIZATION OF MAINTENANCE / SPARE PART STRATEGY



Definition

Completion of maintenance strategy and spare parts strategy for the selected concept. In this phase, the performance requirements have been set, and the strategy will ensure that the design requirements are met.

Why is this activity relevant?

Here, the specific requirements are made for what is to be delivered on-demand, how large a warehouse you should have (warehouse strategy), screening of maintenance. The operator will provide input to contracts that are to be put out to tender before the implementation phase, and it can be considered whether the parts should be digitally accessible

How can AM / DI impact the activity?

Shall assess suitability for on-demand production, contracts shall facilitate on-demand production of parts.

Output

The most available components that can be delivered through AM, in the project and operational phases to support high PE (production efficiency) (High uptime)

Highest possible uptime/lowest footprint/ low delivery time/ ideally lowest possible cost

Action / Recommendations

- Assess how AM/DI can be included in existing rules for maintenance regimes for the various criticality classifications at tag level.
- Assess AM/DI's influence on spare parts strategy
- Assess the mix of digital and physical inventory.
- Consider AM/DI as an incentive to repair vs replace the part.

Level of detail

Overall | Concrete | **Detailed**

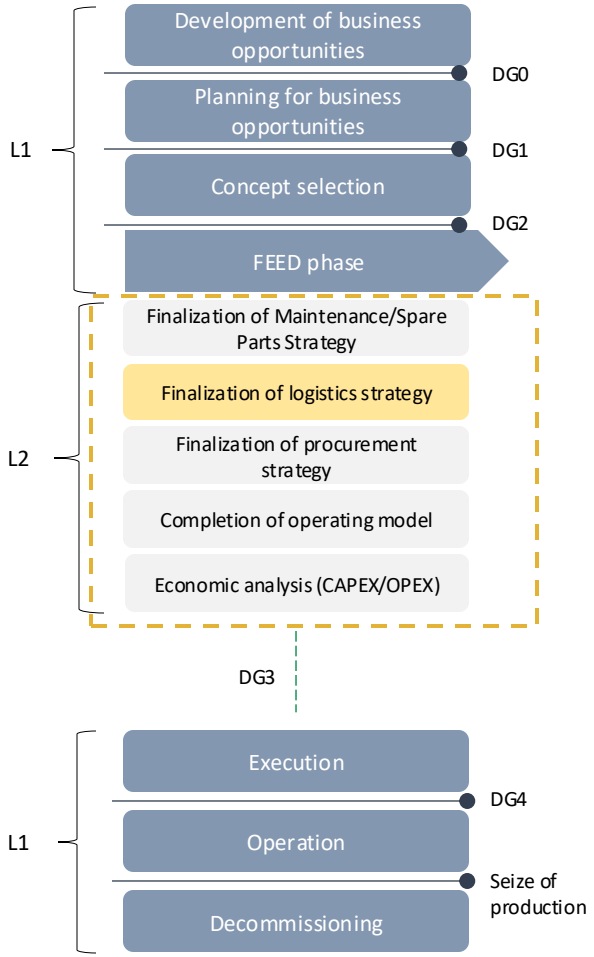
Relevant stakeholders

- Project organization
- Purchaser
- Operations organization
- Supply-chain

Norsk Industri

OFFSHORE NORGE

L2 | FINALIZATION OF LOGISTICS STRATEGY



Definition

Supporting document for operational strategy. Assessment of inventory, base operation, flow of goods from inventory to installations, as well as flow of goods from supplier to operator.

Why is this activity relevant?

Logistics is affected because on-demand production has an intrusive effect on the logistics chain.

How can AM / DI impact the activity?

By having parts digitally, and local production. Change production from mass production in low-cost countries to on-demand production locally. Move inventory from physical to digital, thereby reducing physical inventory.

Output

Reduced inventory (physical), reduced lead time (delivery time), increased availability through digital parts and local production. Reduced tied-up capital in physical inventory. Which in turn reduces risk. Reduce emissions. Move inventory from physical to digital. Reduce costs. Main elements: cost-effectiveness (operator + supplier), sustainability, security of supply, local ripple effects.

Action / Recommendations

- Assess how AM/DI can be included in existing rules for maintenance regimes for the various impact assessments at tag level.
- Assess AM/DI's influence on spare parts strategy
- Assess the mix of digital and physical inventory.
- Consider AM/DI as an incentive to repair vs replace the part.

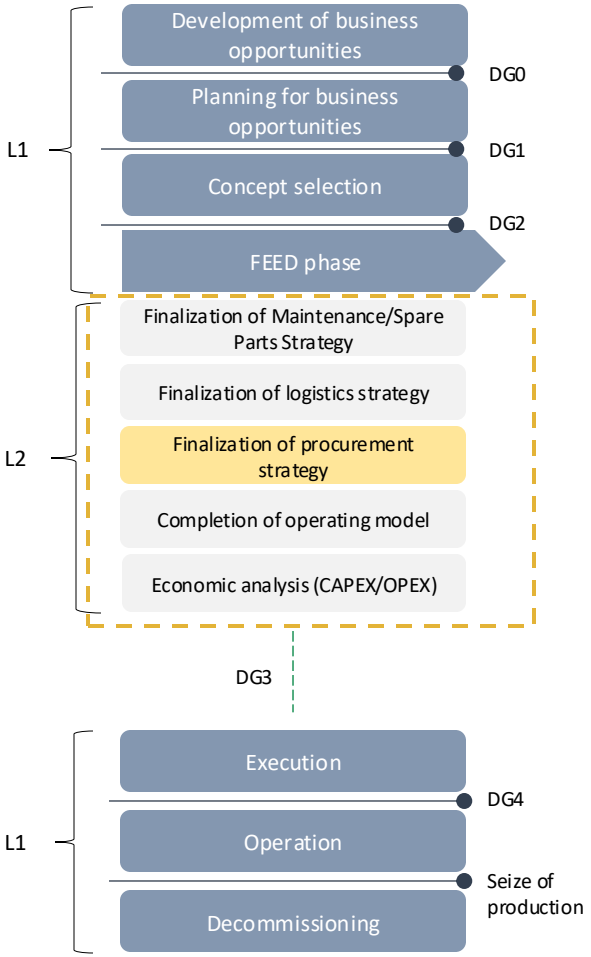
Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Project organization
- Supply-chain

L2 | FINALIZATION OF PROCUREMENT STRATEGY



Definition

Here, the procurement quilt is placed, and the procurement strategy is signed out (which means that it is approved by key stakeholders and steering committees). In this phase, a contract structure is set up, around which contracts are to be used to perform different types of services in the project. These services can be physical deliveries of goods, and services (construction of installation) and parcels (what is to be provided by EPC..)

Why is this activity relevant?

Contract build-up, and interaction with suppliers changes. Setting up strategic partnerships and contract incentives and commercial models. Evaluation plans and criteria that focus on what is emphasized by, for example: sustainability, cost, local production, ESG.

How can AM / DI impact the activity?

"As a service" contracts and other new contract regimes.

Output

Requirements related to AM are set in contract regimes, requirements for uptime of components, minimizing spare parts needs.

Action / Recommendations

- Incentivize suppliers through a standardized quotation text/request text that considers delivery through DI.
- Establish target figures for how much should be made available through AM/DI
- Digital files should exist for critical equipment and promise that the files are maintained by the vendor

Level of detail

Overall | Concrete | Detailed

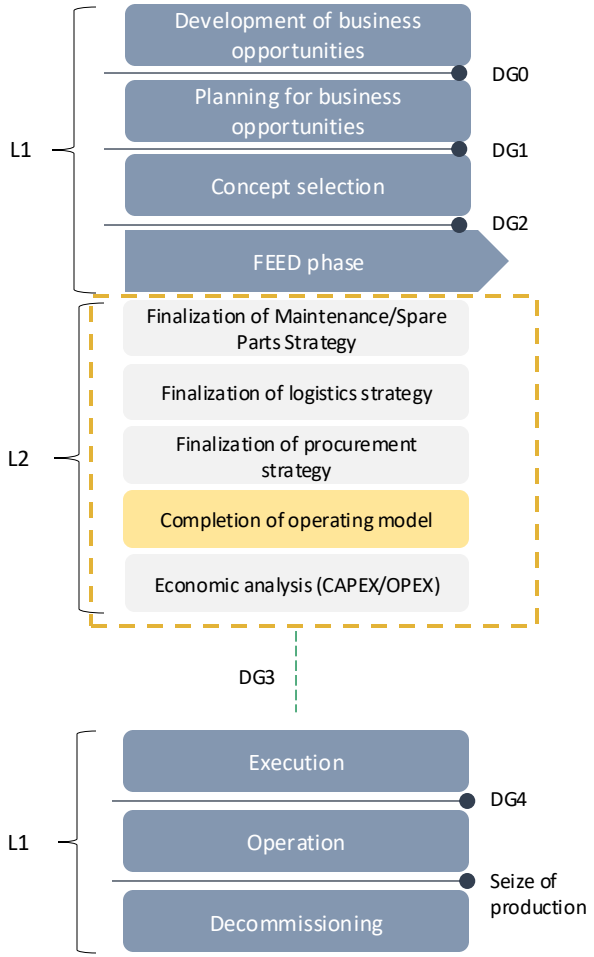
Relevant stakeholders

- Project organization
- Purchaser
- Operations organization

Norsk Industri

OFFSHORE NORGE

L2 | COMPLETION OF OPERATING MODEL



Definition

Determination of what the operating organization should look like. Here it is assessed which activities should be located with the operator, and which should be put on the market.

Why is this activity relevant?

The completion of an operating model is affected because here one will also consider inventory strategy, including min-max (safety stock), the need for capital saves. Which in turn affects the need for warehouse space, and logistics (have key suppliers equipped themselves and are ready to deliver?). Raising awareness of the operating organization about the use of AM/DI will be central in this step.

How can AM / DI impact the activity?

The operating model can be affected because the use of digital warehouses may affect internal and external tasks, and competence requirements in the organization. Should you print/produce the parts yourself, or should these be done by external third parties in the market? (if the operator manufactures the parts themselves, IP rights and qualification must be safeguarded)

Procurement and procurement will also need to be on-boarded to use digital platforms for procurement.

Output

Increase plant uptime with less effort factor.

Action / Recommendations

- Prepare the operations organization to use AM/DI
- Map the necessary competence needs.
- Update management systems and processes to facilitate the use of AM/DI either through an external party or on your own terms.

Level of detail

Overall | Concrete | Detailed

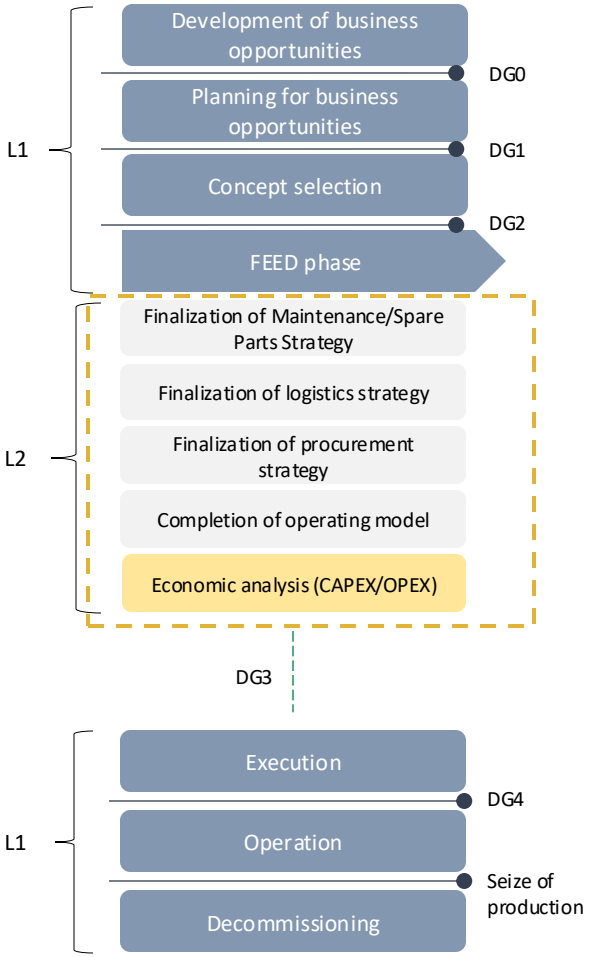
Relevant stakeholders

- Project organization
- Operations organization

Norsk Industri

OFFSHORE NORGE

L2 | ECONOMIC ANALYSIS (CAPEX/OPEX)



Definition

Economic analyses (and present value considerations) are carried out related to different concepts, based on short-list concepts. Economic analyses are carried out throughout the project's life cycle.

Why is this activity relevant?

Assess how the opportunity of using AM/DI can positively affect economic analysis (CAPEX/OPEX).

How can AM / DI impact the activity?

Preliminary analyses of material selection and maintenance principles can be done based on shortlisted concepts

Output

Mature methodology and processes in the project. Frontload work.

Action / Recommendations

- Highlight economic gains and take into account risk elements through AM/DI vs conventional manufacturing.
- Present value analysis (NPV) of AM versus conventional manufacturing.
- Economic considerations related to generic benefits of AM/DI:
  - *Reduced spare parts*
  - *Reduced transport*

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

Project organization

Planlegging av forretningsmuligheter | Konseptvalg | FEED fase | Gjennomføring | Drift | Decommissioning

Etablere prosjekt
tføre mulighetsstudier
ering av konseptalternativer (longlist)
entifisere konsepter for struktur: Subsea, platform, FPSO
Planlegging av losofi/prosjektfilosofi (high level)
dering av logistikk valg og marked
Skissere overordnet anskaffelsesstrategi
tlegging av interessenter
stimere CAPEX / OPEX
Vurdere forventet ksjonslevetid/volum/produ ksjonsprofil
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Studie av shortlist med konsepter
Anbefaling av konsept
Produsere beslutningsdokumenter
konse
v

Videreutvikle valgt konsept
Alle tekniske valg tas (detailed engineering)
Ferdigstilling av vedlikeholdsstrategi/reservedels strategi
Ferdigstilling av logistikk strategi
Ferdigstilling av anskaffelses strategi
Ferdigstilling av driftsmodell (hvordan ser driftsorganisasjonen ut?)
Ferdigstilling av digitaliseringsstrategi /LCI
v FEED leverandør (f.eks, S, Aibel, TechnipFMC..)
m kriterier formidles til EPCI
Starte IT prosjekt
Plan for avhending / decommissioning

Plasser innkjøp
Test av utstyr
Bygge platform/installasjon
Skrive driftsprosedyrer
Finalisere design
Oppfølging av byggeprosess
Klargj
Innkjøp av operational, capital- og commissioning spares
Borre brønner
Etablere driftsorganisasjon
Etablere digitale verktøy som skal benyttes i driftfase
Commissioning

Drift av platform
Vedlikehold
Modifikasjoner
Kontinuerlig utvikling og innovasjon
Bruk av digitale kapabiliteter

Valg av konsept for decommissioning
Recycling
Salg av assets og reservedeler
Vurdere gjenbruk av assets og reservedeler
Sette krav til recycling

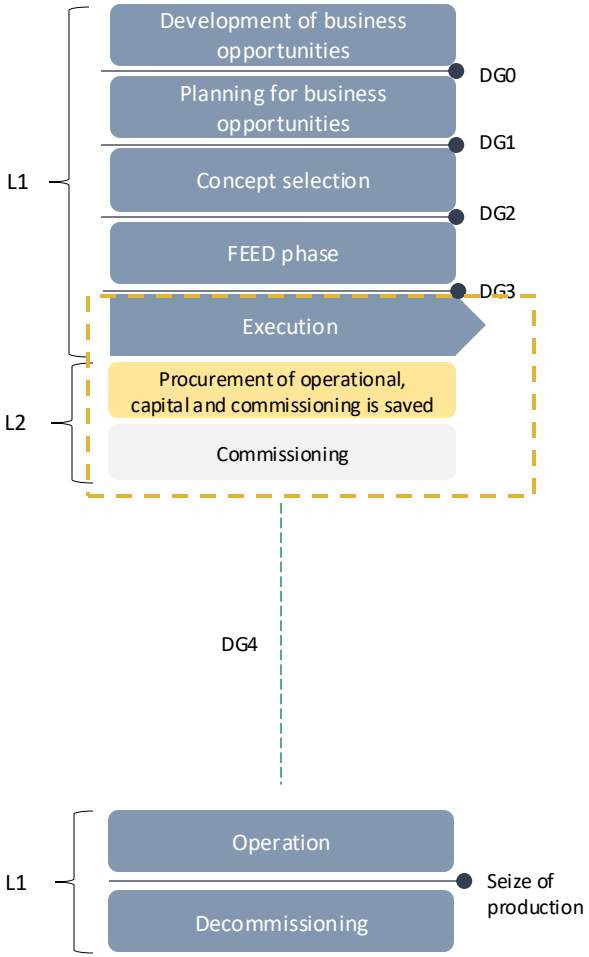
Development Project

DG4

“Execution"

DG1 → DG2 → DG3 PUD /PDO → DG4 → Søknad om «seize of production»

L2 | PROCUREMENT OF OPERATIONAL, CAPITAL AND COMMISSIONING IS SAVED



Definition

Assessments are made about what should and should be purchased of spare parts (capital, operational and commissioning spares). Procurement of the right number of spare parts is central to safe, stable, efficient commissioning, start-up and operation of the facility. The facility must avoid unnecessary risk of lost production due to waiting for parts and avoid unnecessary investment in surplus stock. It is therefore critical to ensure that the right type and quantity of spare parts are maintained at the best possible level.

Why is this activity relevant?

The purchase of spare parts is influenced by, among other things, the criticality and lead time of the various components. DI combined with AM can help the industry rethink its approach to how spare parts are purchased, manufactured and stored.

How can AM / DI impact the activity?

Digital inventory enables the storage of certain parts virtually instead of maintaining large physical inventory. This involves a shift in strategy from "just-in-case" to "just-in-time" (demand-based) procurement and production of spare parts. This can lead to new commercial models for purchasing spare parts, as well as changes in cost structures (production, transport, import duties, etc.) Expected lead times for different components must be assessed against existing strategies.

Output

- ✓ lower warehousing and logistics costs
- ✓ the ability to produce parts when needed.
- ✓ Seamless purchasing process if information and documentation are available in Digital inventories.

Action / Recommendations

- Make relevant spare parts (with associated documentation) available in digital warehouses based on the contracts already set in the FEED phase.
- Assess digital part needs from maintenance strategy.

Level of detail

Overall | Concrete | Detailed

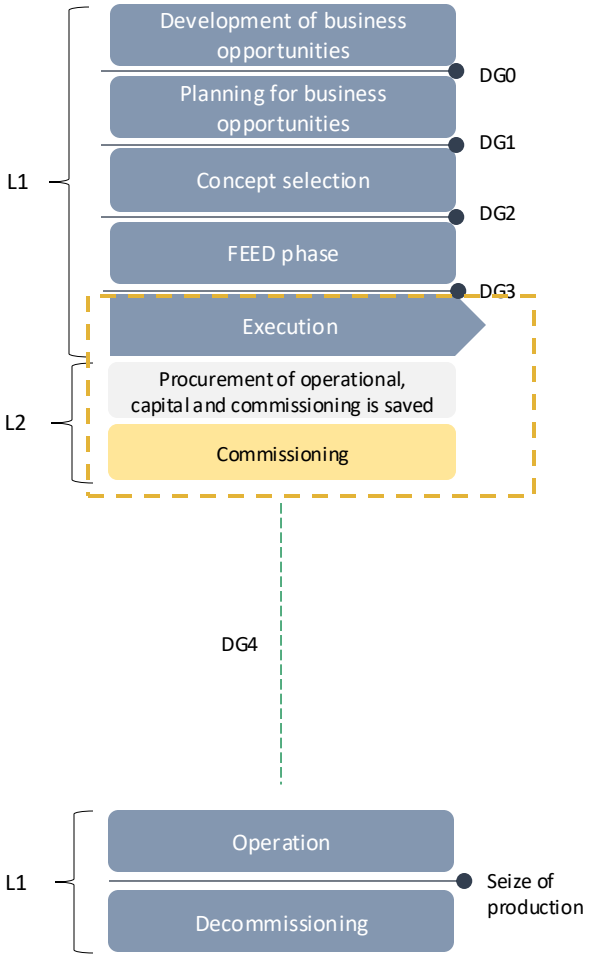
Relevant stakeholders

- Project organization
- Purchaser
- Operations organization

Norsk Industri

OFFSHORE NORGE

L2 | COMMISSIONING



Definition

Commissioning is a process of preparing a plant, system or equipment for start-up and operation. Commissioning involves extensive testing and verification of the equipment, systems, and processes. The goal of commissioning is to ensure that all systems, equipment and associated technology are working properly and that they meet the specifications and standards set for the project. It includes testing and verification of mechanical, electrical, instrumentation and control systems, as well as validation of the function and performance of the processes.

Why is this activity relevant?

Commissioning is central to the start of a project, and it is a phase that sets guidelines for the project's implementation

How can AM / DI impact the activity?

On-demand manufacturing can impact the phase and delivery time of commissioning. Equipment, tools and instruments can be delivered faster and on time through digital inventories.

Output

- ✓ Ends up with less surplus of spare parts and gets a good flow in commissioning because you get access to the parts through AM, and the risk is reduced as you can produce tooling.
- ✓ Reach the target start-up date for first oil.

Action / Recommendations

- Consider AM/DI can reduce the need for commissioning saved.
- Assess the proportion of commissioning saved that is delivered digitally vs physically
- Consider whether the lead-time for commissioning phase can affect the first oil date.
- Establish commissioning saved in Digital Warehouse.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Project organization
- Purchaser
- Operations organization
- Provider

Norsk Industri

OFFSHORE NORGE

Planlegging av forretningsmuligheter | Konseptvalg | FEED fase | Gjennomføring | Drift | Decommissioning

Etablere prosjekt
Valg av shortlist med konsepter
Videreutvikle valgt konsept
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Drift av platform
Valg av konsept for decommissioning

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Bygge platform/installasjon
Modifikasjoner
Salg av assets og reservedeler

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Produsere beslutningsdokumenter
Ferdigstilling av logistikk strategi
Skrive driftsprosedyrer
Kontinuerlig utvikling og innovasjon
Vurdere gjenbruk av assets og reservedeler

Planlegging av losofi/prosjektfilosofi (high level)
Ferdigstilling av anskaffelses strategi
Finalisere design
Bruk av digitale kapabiliteter
Sette krav til recycling

dering av logistikk valg og marked
konse
Ferdigstilling av driftsmodell (hvordan ser driftsorganisasjonen ut?)
Oppfølging av byggeprosess
Kla

Skissere overordnet anskaffelsesstrategi
Ferdigstilling av digitaliseringsstrategi /LCI

tlegging av interessenter
v FEED leverandør (f.eks, S, Aibel, TechnipFMC..)
Innkjøp av operational-, spital- og commissioning spares

stimere CAPEX / OPEX
m kriterier formidles til EPCI
Borre brønner

Vurdere forventet aksjonslevetid/volum/produ ksjonsprofil
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ologistudier rundt hvilken nologi som skal benyttes
ved
Plan for avhending / decommissioning
Etablere digitale verktøy som skal benyttes i driftfase

ct design basis og scope til B og C studier
Commissioning

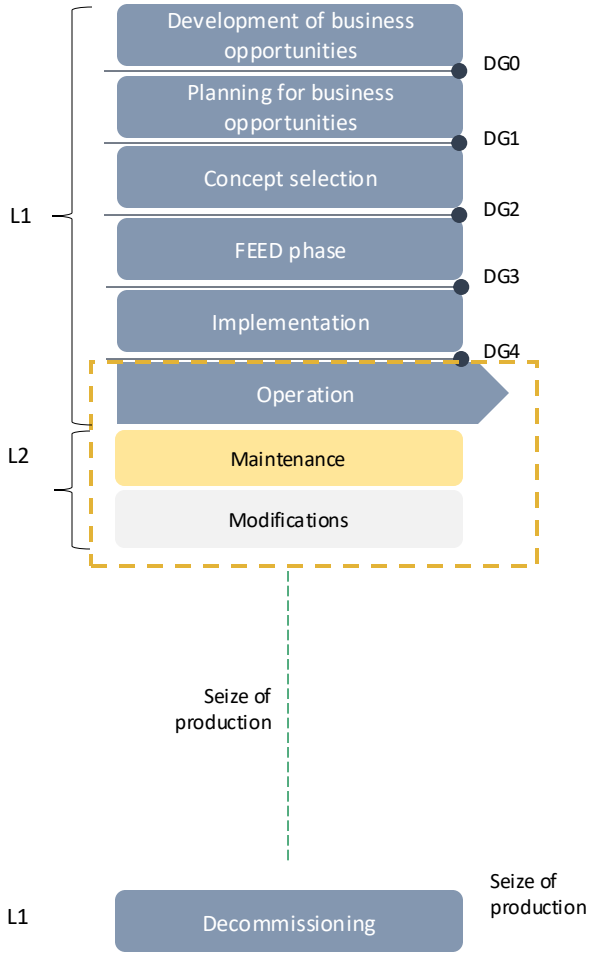
Development Project

DG4

"Operations"

DG1 → DG2 → DG3 PUD /PDO → DG4 → Søknad om «seize of production»

L2 | MAINTENANCE



Definition

Maintenance includes activities performed to maintain and ensure the proper functioning of the equipment or facility and to avoid failures and interruptions. Maintenance tasks can include routine inspection, adjustment, repair, and replacement of parts/components. Maintenance has as its main goal to ensure safe operation, extend the life of the equipment or facility and prevent it from becoming obsolete.

Why is this activity relevant?

AM used in the maintenance process and in the need for maintenance of components manufactured using AM. This equates to a change in both the approach to maintenance and the specific challenges that can arise when handling AM-manufactured parts.

How can AM / DI impact the activity?

AM enables local production of unavailable spare parts, reduces downtime for rapid repairs of equipment parts, and provides the flexibility to produce customized, complex parts for maintenance use. Maintenance personnel must have knowledge of AM technology, as well as guidelines and requirements for documentation. It will be crucial for the successful implementation of AM in maintenance processes.

Output

- ✓ Fast production of spare and end-of-life parts
- ✓ Reduced downtime with quick repairs
- ✓ Cost savings
- ✓ Less inventory
- ✓ Extended life of equipment.

Action / Recommendations

- Refer to the Modification and Maintenance process guidelines.

Level of detail

Overall | Concrete | **Detailed**

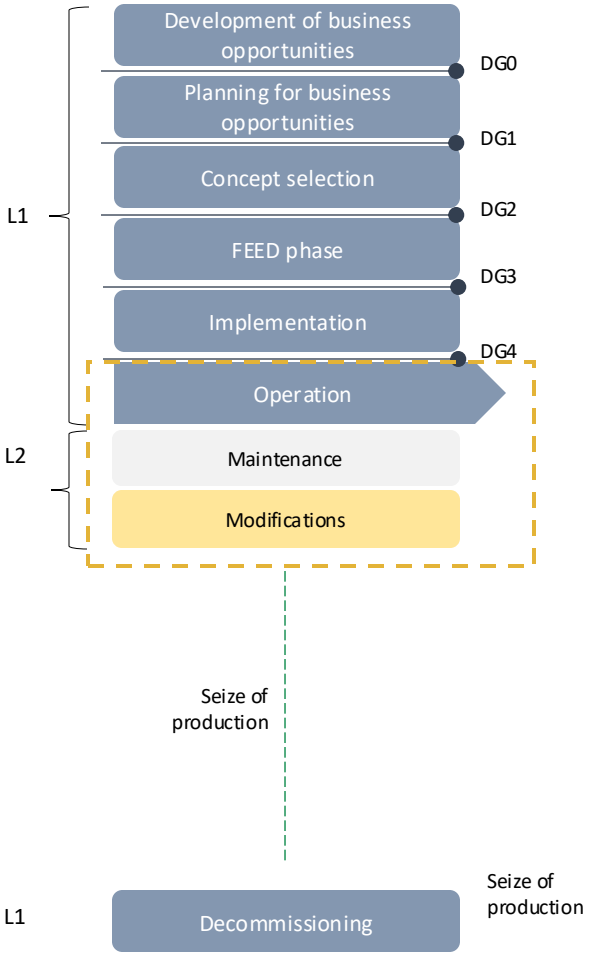
Relevant stakeholders

- Project organization
- Operations organization

Norsk Industri

OFFSHORE NORGE

L2 | MODIFICATIONS



Definition

Modification(s) are activities performed to improve the functionality or performance of the equipment or facility. Modifications may involve the replacement of parts, the installation of new technology, or the development of new features. Modifications are made to adapt the system to new requirements or to increase efficiency or safety.

Why is this activity relevant?

The modification activity is affected by the possibility of using AM in the modification of equipment and facilities.

How can AM / DI impact the activity?

AM technology enables fast and cost-effective prototyping of new parts and components that can be integrated into existing equipment, reducing the time spent compared to traditional methods of prototyping and testing. Furthermore, tailor-made tools and fasteners specific to tasks or installations can be developed and manufactured, thus reducing costs and waiting times associated with external component ordering. AM gives the offshore industry a chance to optimize the design of existing equipment and facilities for improved performance and functionality.

Output

- ✓ Faster prototyping and testing, tailor-made tools and components,
- ✓ Lower costs with unique and customized solutions, optimized design for improved performance.

Action / Recommendations

- Refer to the Modification and Maintenance process guidelines.

Level of detail

Overall | Concrete | **Detailed**

Relevant stakeholders

- Project organization
- Operations organization

Norsk Industri

OFFSHORE NORGE

Planlegging av forretningsmuligheter | Konseptvalg | FEED fase | Gjennomføring | Drift | Decommissioning

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Ferdigstilling av logistikk strategi
Skrive driftsprosedyrer
Kontinuerlig utvikling og innovasjon
Vurdere gjenbruk av assets og reservedeler

Planlegging av losofi/prosjektfilosofi (high level)
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Bruk av digitale kapabiliteter
Sette krav til recycling

dering av logistikk valg og marked
konse
Ferdigstilling av driftsmodell (hvordan ser driftsorganisasjonen ut?)
Oppfølging av byggeprosess

Skissere overordnet anskaffelsesstrategi
Ferdigstilling av digitaliseringsstrategi /LCI
Klargjøring for drift

tlegging av interessenter
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ct design basis og scope til B og C studier
Commissioning

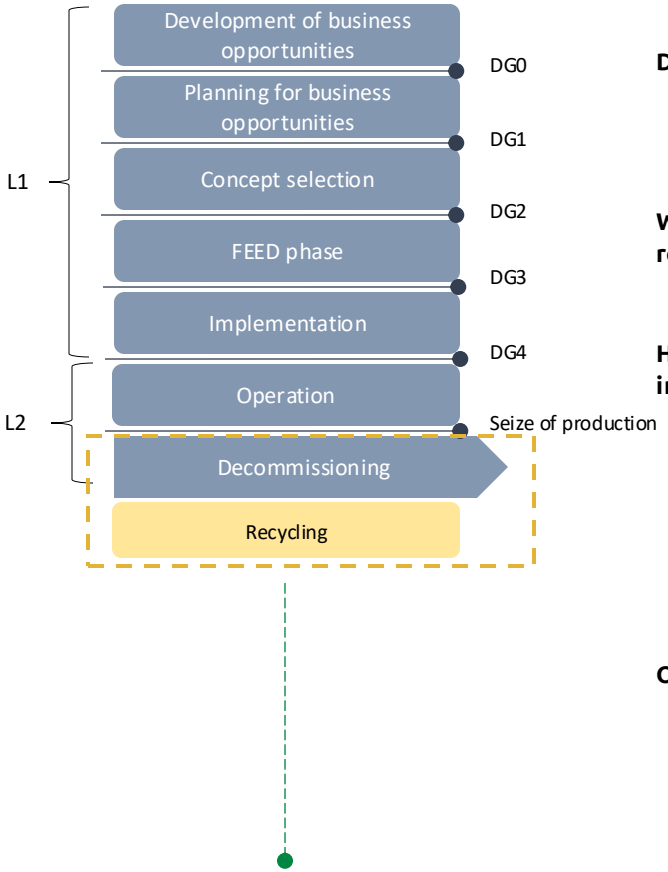
Development Project

Seize of production

"Decommissioning"

DG1 → DG2 → DG3 PUD /PDO → DG4 → Søknad om «seize of production»

L2 | RECYCLING



Definition

Is an activity that considers the reuse of parts and equipment. Requirements for recycling parts are made early, and throughout the life cycle of a project.

Why is this activity relevant?

There are requirements to reduce consumption and CO2, and AM can be a dimension for reducing emissions related to production and material use.

How can AM / DI impact the activity?

Take control of the lifecycle of materials. Design requirements for reuse and recycling. Requirements for data/ storage/ accessibility.

This includes choice of material, performance, functionality and disposal. Provides a market for material recycling/local use. The choice of methods (project period and in the operational phase) that reduce consumption and CO2 emissions improves sustainability.

Output

- ✓ Reuse of parts
- ✓ Reduced emissions.
- ✓ Lifecycle emissions of parts. Requirements for the proportion of recyclable material (will be included in the procurement strategy in DG2)
- ✓ Expectation of %share of recycled material

Action / Recommendations

- Scrap metal can go into the production of powders to improve ESG.
- All scrap metal can be activated in the Collabor8 LOOP as a service to extract powder.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

Project organization

Guideline

Modification Project

For On-demand Manufacturing & Digital Inventories

Norsk Industri

OFFSHORE NORGE

MODIFICATION PROJECTS INVOLVE EXTENSIONS OR MODIFICATIONS OF EXISTING EQUIPMENT OR FACILITIES

Definition

- Activities related to extension or modification of existing equipment and facilities requiring amended technical documentation. Change projects and reconstruction that are neither maintenance nor an operating investment are included.
- There is no standard for differentiating modifications on NCS, but modifications can typically be divided into 2 distinct categories:

Larger modifications

1

- Are complex, with has a lower degree of complexity than development projects. Larger modifications usually follows the same process as development projects, but with smaller timeline.

Smaller modifications

2

- Are modifications on established facilities that are in operations, and is done consistently with internal operation organization
- Operators have fixed V&M contracts for minor modifications, while for large mods the modification goes out to tender. The V&M contract regulates the transaction.

Outcome from modifications

Modifications, are normally investments in operating equipment that have been put to use and that are not classified as maintenance*. These investments seeks to:

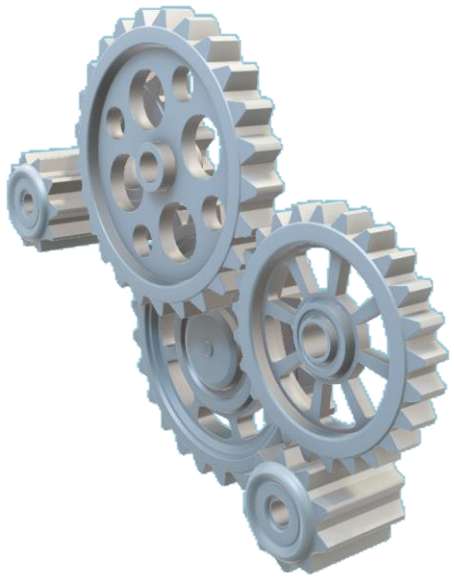
- Increase the production capacity
- Substantially increase the quality and thus the value of the products
- Substantially improve the production process and thereby substantially lower the level of other production costs
- Measures that enhance safety and prevent/reduce future pollution of the environment
- Extensions of the plant and/or new functions

*Agreement concerning petroleum activities - regjeringen.no. https://www.regjeringen.no/globalassets/upload/oed/vedlegg/konsesjonsverk/k-verk-vedlegg-1-2-eng.pdf. (n.d.). Table 5.2

FROM ON-DEMAND MANUFACTURING AND MODIFICATIONS

Outcome from modifications

- *Increase the production capacity*
- *Substantially increase the quality and thus the value of the products*
- *Substantially improve the production process and thereby substantially lower the level of other production costs*
- *Measures that enhance safety and prevent/reduce future pollution of the environment*
- *Extensions of the plant and/or new functions*



Outcome from On-Demand Manufacturing

- ✓ *Reduce Costs related to logistics and transportation*
- ✓ *Enhanced sustainability due to circular material use*
- ✓ *Reduce emissions tied to logistics and transportation*
- ✓ *Improve part design of equipment and components*
- ✓ *Improve functionality of parts with innovative designs in accordance with the supplier of equipment*
- ✓ *Enable on-demand manufacturing of parts and components on-site through digital inventories*

On-demand manufacturing allows harvesting benefits through extended life of the fields and extract more resources from the fields.

Modifications

- The -

MODIFICATION PROCESS

The Modification process, consists of a series of phases, which are separated by decision gates (DG). At each DG, a choice is made on whether to proceed with the project. This review process ensures that there is agreement on expectations for the end-result, that the risk exposure is realistic, and that the requirements from the organization are met.

MODIFICATION PROJECTS RANGE FROM SIX TO SEVEN PHASES, DEPENDING ON THE SIZE OF AND SCOPE OF THE MODIFICATION

L1 (phase)

L2 (activities)

Identify need	Appraisal	Feasibility study	Concept study	Definition study	Execution	Operations
Technical assessment	Establish project proposal	Modification proposal	Specify project organization	FEED engineering	Receive components	Accept modification
Decide on modification or maintenance	Business framing	Design basis	Concept development	Estimate cost	Commissioning	Handover to operations
	Categorize	Functional description	Select concept	Define equipment & resources	Test components	Transfer LCI
	Establish design basis	Evaluate possibilities	Approve funding	Assess suppliers	SPIR	
	Functional requirements	Identify maintenance philosophy, equipment and components	Identify long lead items	Set maintenance program (replace vs repair)	Maintenance procedures	
	Assess schedule and timing	Assess project schedule		Procure long lead items	Prepare for operations	
	Justifications	Perform early estimate		Proceed to execute	Detail engineering	
	Prioritize	Define tech, business case			Procure equipment	
	Risk assessment	Accept and proceed to CTR				
		Document feasability and installation method				
		Preliminary ESG impact				
		Scope of work				

Phase
Phase (Optional)
Activities

DGA Decide on Modification → **DG0** Type of Modification → **DG1** → **DG2** Select Concept → **DG3** → **DG4**

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KEY AM/DI INTEGRATION OPPORTUNITIES ACROSS THE MODIFICATION LIFECYCLE

L1 (phase) / L2 (activities)

Identify need	Appraisal	Feasibility study	Concept study	Definition study	Execution	Operations
Technical assessment	Establish project proposal	Modification proposal	Specify project organization	FEED engineering	Receive components	Accept modification
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	Assess schedule and timing	Assess project schedule		Procure long lead items	Prepare for operations	
	Justifications	Perform early estimate		Proceed to execute	Detail engineering	
	Prioritize	Define tech, business case			Procure equipment	
	Risk assessment	Accept and proceed to CTR				
		Document feasability and installation method				
		Preliminary ESG impact				
		Scope of work				

Phase
Phase (Optional)
Activities
Areas of opportunity

Click on any L2 process marked as an opportunity for a direct link to the detailed deep-dive or scroll to view all sections

DGA Decide on Modification → **DG0** Type of Modification → **DG1** → **DG2** Select Concept → **DG3** → **DG4**

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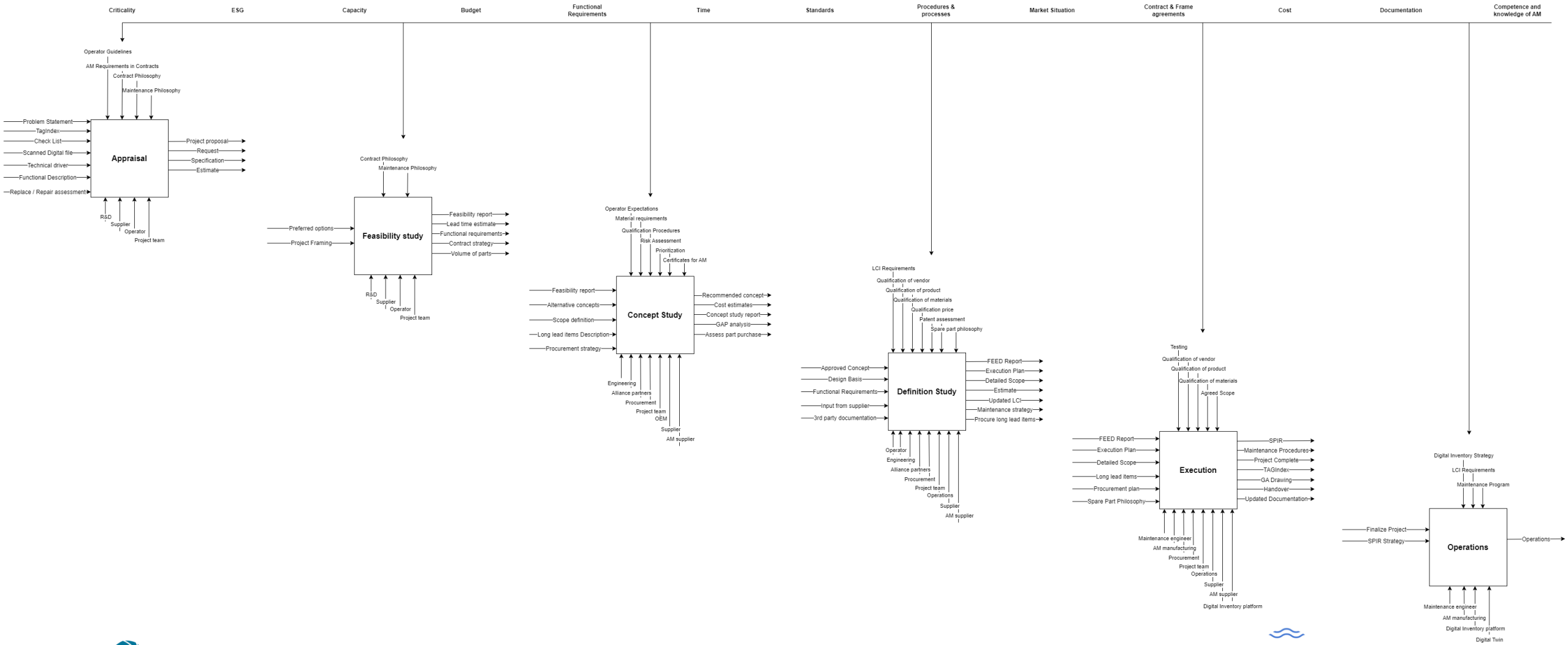
INPUTS, OUTPUTS, CONTROL MECHANISMS AND RESOURCES FOR A TYPICAL MODIFICATION PROJECT



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Modifications

“Identify need”

L2 | TECHNICAL ASSESSMENT

L1 **Identify need**

L2 Technical assessment

L2 Decide on modification or maintenance

Definition

Is based on a notification from Offshore or from internal maintenance plans indicating that a technical assessment will take place. The technical assessment provides the basis for the direction (Whether it is modification or maintenance) and defines the scope to be solved. This may involve a cursory review of design requirements, materials, production processes and other technical factors that may affect the modification. The aim of this assessment is to identify any challenges or limitations early on. With the aim of reducing scope to a minimum scope

Why is this activity relevant?

If the part and component in the technical assessment is of a scope that makes AM appropriate, it could influence the direction of the technical assessment.

This can affect the technical assessment by having to take into account the limitations and possibilities of the AM process when the design is developed.

How can AM / DI impact the activity?

The technical assessment can be influenced by AM because it can make it possible for the modification to be solved through, for example, a repair, or through extensive engineering to improve function and performance. Improvement of functionality- and performance of existing equipment needs to be assessed in accordance with the manufacturer and suppliers.

Output

- ✓ The operator defines the problem
- ✓ The problem is defined through a modification scope
- ✓ Incentivizing contractors towards the “right approach”
- ✓ Influence the budget process, cost phasing, and cost

Action / Recommendations

- "Technical assessment" should consider the possibility of "repair, improved functionality"
- Include a checklist of what is to be assessed in the assessment: repair, replace, improved functionality, do nothing
- Relevant personnel who initiate technical assessment should be trained in the possibilities for AM.
- End-user should include in the scope of work the requirements for assessing AM
- A chapter for AM is included and handled accordingly in later study phases.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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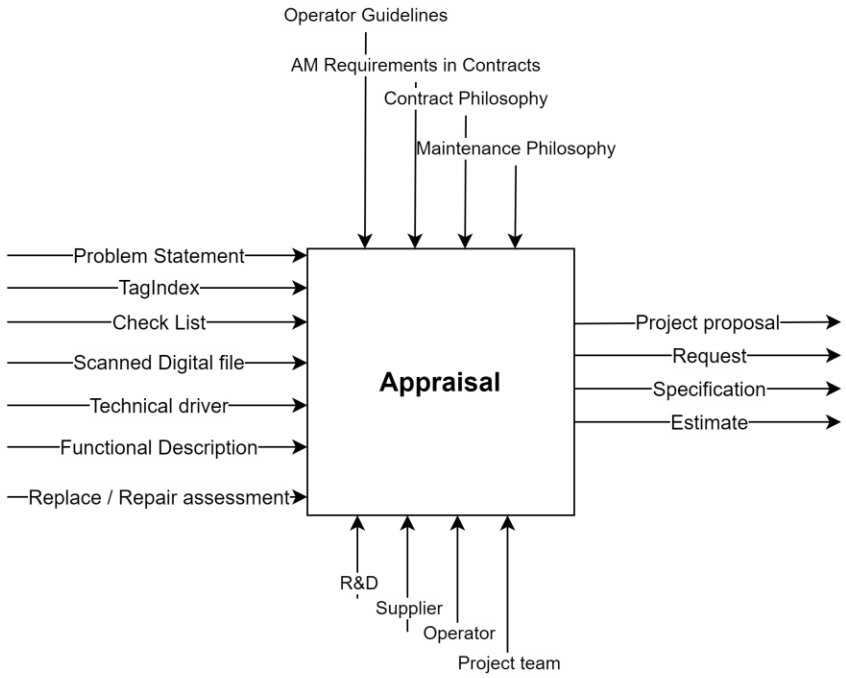
Modifications

“Appraisal”

Identify need | **Appraisal** | Feasibility study | Concept study | Definition study | Execution | Operations



Overall Recommendations

- Operators should specify in the appraisal phase the incentives to assess on-demand manufacturing in the upcoming study phases.
- All technical evaluations, risks, cost, environmental footprint should be included as part of the Appraisal Study Report on a high level.
- Commercial aspects needs to be evaluated and considered, and the incentives should be regulated in the current contracts- and frame agreements.

L2 | BUSINESS FRAMING

L1 **Appraisal**

L2
- Establish project proposal
- **Business framing**
- Categorize
- Establish design basis
- Functional requirements
- Assess schedule and timing
- Justifications
- Prioritize
- Risk assessment

Definition

Through business framing, it is ensured that the modification project is well planned, has clear goals and expectations, and is adapted to the overall strategy and objectives. At the same time, an assessment of risk elements for the delivery is carried out.

Why is this activity relevant?

AM can change the way projects are planned and carried out. It provides new opportunities for design, production and logistics, which can affect traditional business models and strategies. Among other things, it can affect cost structures, production times and the overall supply chain

How can AM / DI impact the activity?

AM can have an impact on lead time and risk assessment in the modification process by enabling faster prototyping and testing of design options (for example: producing a plastic version of components to test fit, before moving on to manufacturing metal components). It can help identify opportunities earlier in the process and produce spare parts and components on site.

Output

- ✓ Improved budget process
- ✓ Cost phasing
- ✓ Improved environmental footprint

Action / Recommendations

- The assignment document should contain a requirement to assess opportunities for AM, in consultation with the supplier.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | ESTABLISH DESIGN BASIS

L1 **Appraisal**

L2
- Establish project proposal
- Business framing
- Categorize
- **Establish design basis**
- Functional requirements
- Assess schedule and timing
- Justifications
- Prioritize
- Risk assessment

Definition

In the early phase of a modification project, it may be appropriate to consider alternative production methods to produce the necessary components. By making this assessment at an early stage, one can identify opportunities to improve the production process and take into account special requirements or limitations that may affect the choice of production method, thereby reducing costs.

Why is this activity relevant?

It may be necessary to establish separate rules for AM that are tailored to the project's unique requirements and challenges. Consideration must also be given to design, where material selection, geometry and production techniques are carefully considered to optimize the performance and lifespan of the finished components.

How can AM / DI impact the activity?

Design basis can assess whether it should be reserved for traditional manufacturing methods or open up to AM. If AM is opened up, one can consider whether extraordinary consideration must be given to design for 3D printing.

Output

- ✓ Improved production
- ✓ Optimized design from "additive thinking"

Action / Recommendations

- The design basis is part of the assignment document, and operators should ask for input on how AM can help optimize the part and production process.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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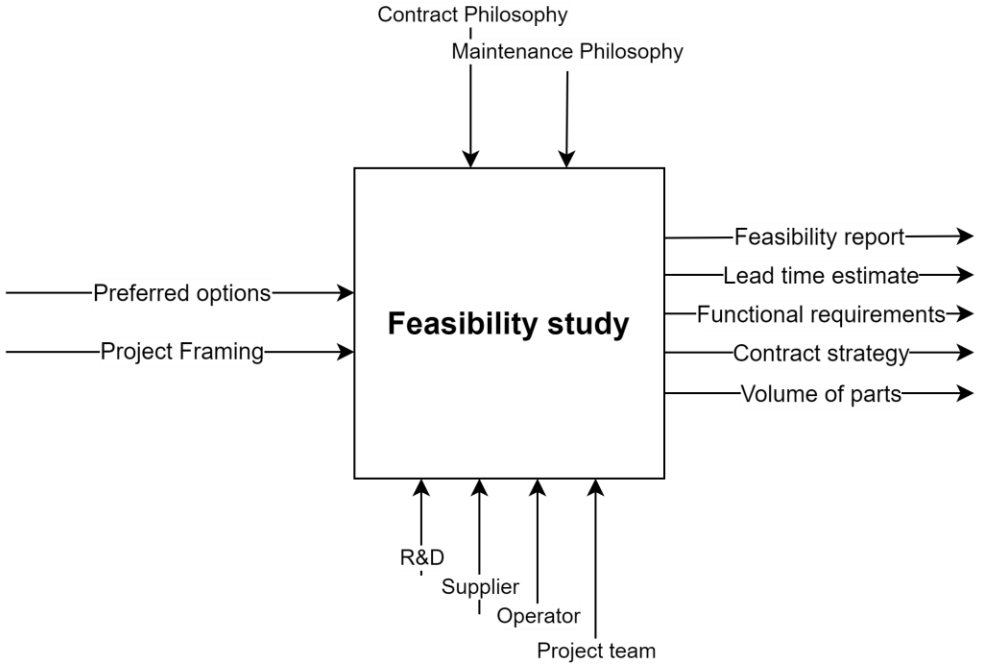
Modifications

“Feasibility study”

Identify need | Appraisal | **Feasibility study** | Concept study | Definition study | Execution | Operations



Overall Recommendations

- In the feasibility study, the Operator will typically state some preferred options for the modification and frame the project.
- The feasibility report should include a chapter about how incorporating AM as an alternative can improve lead time, cost efficiency gains and ESG impact.

L2 | EVALUATE POSSIBILITIES

L1 **Feasibility study**

L2
- Modification proposal
- Design basis
- Functional description
- **Evaluate possibilities**
- Identify maintenance philosophy, equipment and components
- Assess project schedule
- Perform early estimate
- Define tech, business case
- Accept and proceed to CTR
- Document feasibility and installation method
- Preliminary ESG impact
- Scope of work

Definition

The feasibility study builds on the assignment document and here an evaluation of relevant modification alternatives is carried out. This evaluation is often done in accordance with the supplier and contractor. Here, among other things, functional requirements are assessed in line with the maintenance philosophy, and preliminary cost estimates are made for the various alternatives.

Why is this activity relevant?

AM can have an impact on the feasibility study in the modification process by expanding the range of available options. AM offers a wider choice of possibilities than traditional manufacturing methods, this gives engineers and designers the freedom to explore innovative solutions without the limitations that come with conventional manufacturing processes. For example, with AM, a component can often be manufactured with greater design freedom, which can optimize filtration efficiency or reduce manufacturing costs.

How can AM / DI impact the activity?

AM technologies open up more possibilities than conventional manufacturing for carrying out modification, because you can influence and optimize the design according to functional requirements.
E.g., filter, hole square or round

Output

✓ Promote innovative options through AM, which enable better performance, design, reduced cost and lead time.

Action / Recommendations

- Include a chapter in the feasibility study for the possibilities related to AM, and any consequences.
- The contract model should incentivize the supplier to take up AM as a possibility if it is appropriate (advantages for the modification)

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | IDENTIFY MAINTENANCE PHILOSOPHY, EQUIPMENT AND COMPONENTS

L1 **Feasibility study**

L2
- Modification proposal
- Design basis
- Functional description
- Evaluate possibilities
- **Identify maintenance philosophy, equipment and components**
- Assess project schedule
- Perform early estimate
- Define tech, business case
- Accept and proceed to CTR
- Document feasibility and installation method
- Preliminary ESG impact
- Scope of work

Definition

The various alternatives assessed in the feasibility study must be weighed against an OPEX/CAPEX for the maintenance philosophy.

Why is this activity relevant?

AM can have an impact on the maintenance philosophy, equipment and components of the modification process by enabling Digital inventory and "on-demand" production. Digital inventory provides the opportunity to store digital files of spare parts and components, which can reduce the need for physical storage space and transport. On-demand production makes it possible to produce spare parts and components when and where they are needed, which can reduce lead times and costs.

How can AM / DI impact the activity?

Equipment and components can be produced on-demand. This can affect maintenance processes (various types of maintenance regimes)

Output

- ✓ Optimal weighted Capex / Opex assessment.
- ✓ Optimizing the lifetime of equipment and components that are modified.
- ✓ Optimum maintenance regime through Digital inventories

Action / Recommendations

- Feasibility study should include capex/opex assessment, optimization of lead time and effect of AM
- Qualitative assessment of any effect when using AM and look up to the overall philosophy for maintenance

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | DEFINE TECH, BUSINESS CASE

L1 **Feasibility study**

L2
- Modification proposal
- Design basis
- Functional description
- Evaluate possibilities
- Identify maintenance philosophy, equipment and components
- Assess project schedule
- Perform early estimate
- **Define tech, business case**
- Accept and proceed to CTR
- Document feasibility and installation method
- Preliminary ESG impact
- Scope of work

Definition

An evaluation is made of how much should be invested in the project to reduce OPEX later in the equipment's life cycle (CAPEX / OPEX assessment)

These analyzes will also include ESG considerations for the various possibilities for the modification alternatives.

Why is this activity relevant?

Additive manufacturing can have an impact on the choice of technology and capacity assessment in the modification process. When machining, it can be cheaper to make more parts due to a lot of preparatory work that has already been carried out.

How can AM / DI impact the activity?

Choice of technology that can be used to carry out the modification.

Output

- ✓ Business case showing parameters within cost, lead time and emissions
- ✓ Reduced use of material and resources
- ✓ Material reuse 70-80%
- ✓ Production locally

Action / Recommendations

- AM must indicate how this technology can optimize CAPEX/OPEX + ESG considerations
- The business case should give an indication of how Digital inventories can affect the modification.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | SCOPE OF WORK

L1 **Feasibility study**

L2
- Modification proposal
- Design basis
- Functional description
- Evaluate possibilities
- Identify maintenance philosophy, equipment and components
- Assess project schedule
- Perform early estimate
- Define tech, business case
- Accept and proceed to CTR
- Document feasibility and installation method
- Preliminary ESG impact
- **Scope of work**

Definition

"Scope of work" (SoW) in a modification process is a detailed description of all tasks, goals and deliverables involved in a project. This description includes technical specifications, design requirements, and a schedule for implementation. The main purpose is to clearly define what is to be modified, how it is to be done, and what is expected as a result of the modification.

Why is this activity relevant?

AM may require adaptations in the "scope of work" to take account of new design and production methods.

How can AM / DI impact the activity?

AM can impact SOW by offering the ability to produce complex and customized parts that were previously unmanufacturable. This can open up new possibilities and add flexibility to the modification process. By enabling unique and bespoke parts, more advanced modifications previously not possible can be explored and implemented. This require training of employees, implementation of new quality control procedures and adjustment of workflow and logistics. If existing equipment is involved it will require collaboration and involvement with manufacturer and supplier to secure feasible implementation.

Output

- ✓ Reduce the SOW scope by potentially reducing the number of operations and processes required to implement a modification.
- ✓ Efficient and economically beneficial modification process.

Action / Recommendations

- Identify possible components that are relevant to be produced through AM
- Stakeholders who specify the SOW must have sufficient knowledge of AM to identify the scope for profit realization.
- The Master Equipment List (MEL) for the modification, should be updated and include information related to the possibility of AM as part of the modification scope.

Level of detail

Overall | **Concrete** | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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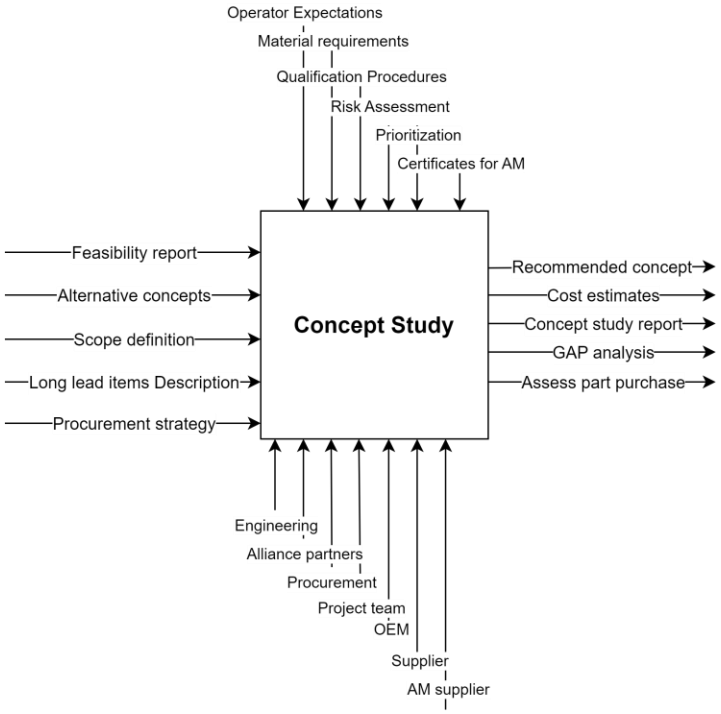
Modifications

“Concept study”

Identify need | Appraisal | Feasibility study | **Concept study** | Definition study | Execution | Operations



Overall Recommendations

- In the concept study, the Operator and Contractor will assess all relevant concepts for the modification.
- If AM is assessed as a relevant concept, necessary certificates for AM should be included in the study

L2 | CONCEPT DEVELOPMENT

L1

Concept study

L2

- Specify project organization
- **Concept development**
- Select concept
- Approve funding
- Identify long lead items

Definition

Development of relevant concept(s) for the modification

Why is this activity relevant?

The concept investigation is directly affected by AM because the technology can open up innovative concept alternatives beyond conventional manufacturing methods. Furthermore, digital stores can influence the delivery model for the concept.

How can AM / DI impact the activity?

AM enables rapid production of prototypes and testing of various concepts and design alternatives for relevant concepts for the modification. This flexibility makes it easier to adapt changes and optimize the concept during the concept study. AM provides great design freedom, as it is not limited by traditional production methods such as casting or machining. This opens up new possibilities and creative solutions in the concept study phase. Complex geometries, cavities, integrated functions and customized designs can be realized more efficiently and cost-effectively.

Through DI, the delivery model for the modification concept will also be affected.

Output

- ✓ Reduction of lifecycle cost for a concept (TCO) through AM.
- ✓ Optimized delivery model for concept through digital warehouses and digital supply networks

Action / Recommendations

- Should have a separate chapter in the concept study that shows the assessment of optimization of functionality vs replace
- Consider whether rapid prototyping through AM/DI can have an impact on concept options.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | IDENTIFY LONG LEAD ITEMS

L1 **Concept study**

L2
- Specify project organization
- Concept development
- Select concept
- Approve funding
- Identify long lead items

Definition

Equipment that takes a long time to acquire or manufacture must be identified early to avoid delays in the project. This involves a thorough review of the modification plan and collaboration with suppliers to understand timeframes and risks associated with these specific parts. Effective resource allocation thus means knowing the availability of equipment and components.

Why is this activity relevant?

AM can help reduce lead times for critical equipment that is usually difficult to obtain.

How can AM / DI impact the activity?

Prototyping and production of critical parts and components can potentially be done faster than through traditional production methods. This aspect of AM is particularly valuable in modification processes, where access to specific, often rare parts can be a challenge.

Output

- ✓ Adaptive supply chain through the digital supply network that can reduce lead time, risk, cost and schedule for modification.
- ✓ Enables the production of Long-lead items through AM / Digital warehouse

Action / Recommendations

- Define critical/long lead items and assess whether it is possible to manufacture parts through AM, as well as make the part available in a digital inventory platform to quickly produce the part.
- The master equipment list (MEL) should contain information relevant information concerning AM and is updated to reflect this change.

Level of detail

Overall | **Concrete** | **Detailed**

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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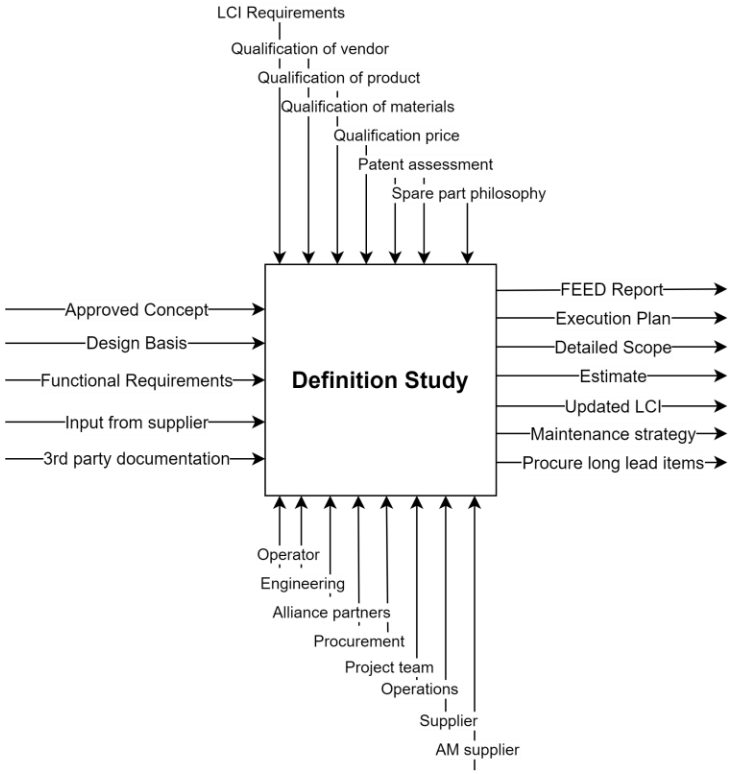
Modifications

“Definition study”

Identify need | Appraisal | Feasibility study | Concept study | **Definition study** | Execution | Operations



Overall Recommendations

- After the concept is approved, the Operator and Contractor can initiate the Definition study (Typically in larger modifications).
- Based on whether AM is feasible, and the overall control mechanisms, the FEED report should highlight the benefits of using On-demand manufacturing and the execution plan should explain how the use of AM and digital inventories will be conducted in the execution phase.

L2 | FEED ENGINEERING

L1 **Definition study**

L2
- FEED engineering
- Estimate cost
- Define equipment & resources
- Assess suppliers
- Set maintenance program (replace vs repair)
- Procure long lead items
- Proceed to execute

Definition

FEED (front end engineering design) Engineering is carried out after the concept has been selected. At this stage, extensive studies are carried out to uncover technical challenges and estimate an approximate investment cost.

By defining the costs, one can plan and budget for the modification in a more accurate way. This includes considering the costs associated with materials, hardware, software, labor and any other resources necessary to complete the modification. FEED is often done in consultation with EPCI.

Why is this activity relevant?

The studies in the FEED phase will typically be affected by the application of AM and DI.
The concept can be optimized and include the possibility of AM.

How can AM / DI impact the activity?

AM can influence activity by offering greater design flexibility and innovation, enabling more complex and customized solutions. Detailed planning and cost estimation are important in this phase, and AM can contribute to faster prototyping and more accurate cost estimates.

The lead time is often shorter with AM, but this must be weighed against the higher costs for raw materials and machine time per unit. In addition, economies of scale and adaptability must be considered, which can be more flexible in AM, but which can also lead to higher costs in the case of small production series.

Output

- ✓ Can improve risk management
- ✓ Can reduce production costs
- ✓ Give engineers the opportunity to explore more efficient and sustainable design options early in the project planning process.

Action / Recommendations

- If there is a FEED study, an economic assessment of AM/DI should be included.
- Include how AM/DI impact TCO (total cost of ownership):
  - Warehouse
  - opportunity cost
  - Material cost
  - input factors

Level of detail

Overall | Concrete | **Detailed**

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | DEFINE EQUIPMENT & RESOURCES

L1 **Definition study**

L2
- FEED engineering
- Estimate cost
- **Define equipment & resources**
- Assess suppliers
- Set maintenance program (replace vs repair)
- Procure long lead items
- Proceed to execute

Definition

Specification of which equipment, components and resource requirements form the basis of the selected concept.

Why is this activity relevant?

In a modification using AM, equipment can be defined as the physical devices and tools used in the process of adding material layer by layer to create or change an object. This can include 3D printers, materials, software, hardware and other accessories necessary to carry out the additive manufacturing process. The equipment must be available and suitable to handle the specific requirements and materials used in the modification.

How can AM / DI impact the activity?

The right expertise ensures that the modification is carried out in a quality-wise manner. AM requires knowledge of materials, hardware, software and processes to achieve the desired result. Without proper expertise, errors or deficiencies may occur in the modification that may affect the performance or durability of the final product.

Output

- ✓ Assess capacity and available equipment
- ✓ Define resource estimates for modification and competence needs.
- ✓ Definition of relevant equipment and components for AM production

Action / Recommendations

- Make available main equipment with associated spare parts in the digital warehouse
- Master equipment list (MEL) is updated and contain relevant information of AM part

Level of detail

Overall | Concrete | **Detailed**

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | ASSESS SUPPLIERS

L1 **Definition study**

- FEED engineering
- Estimate cost
- Define equipment & resources

L2 **Assess suppliers**

- Set maintenance program (replace vs repair)
- Procure long lead items
- Proceed to execute

Definition

Once the concept has been chosen, it will appear which manufacturers and suppliers are relevant to carry out the modification. If there is a call-off on an already existing V&M contract, the relevant suppliers will already have contractual frameworks. If there is a major modification, a tender process is launched.

Why is this activity relevant?

Experience and expertise: Assess the supplier's experience and expertise within both AM and modification. Previous projects, references and customer reviews can be checked to gain a better understanding of their expertise.

Capacity and technology: the supplier must have sufficient capacity and access to the right technology to handle both AM and modification. This includes access to appropriate personnel, equipment, software and materials.

Quality assurance: the supplier's quality assurance processes and certifications must be satisfactory for the need. It is important to ensure that they have strict quality controls in place to ensure that the products meet the required standards.

Adaptability: the supplier's ability to adapt to specific needs and requirements in relation to both additive manufacturing and modification. They should be able to understand specific needs and be able to offer tailored solutions.

Price and delivery time: Compare prices and delivery times between different suppliers.

How can AM / DI impact the activity?

Stakeholders in the modification project should have the necessary expertise within AM to carry out assessments. These assessments should be contractually agreed.

Output

- ✓ Suppliers are connected to digital warehouses, and have capabilities to deliver on-demand manufacturing services for modification

Action / Recommendations

- Making service and product providers available for modification in the digital supply network (Digital Repositories)
- During the tender process, suppliers should be able to offer their services for modification jobs related to AM directly in a digital warehouse. This request should also be included in the PO agreement
- Suppliers must provide standard documentation requirements for competence within AM. This should also be part of the commercial section in the Bid process

Level of detail

Overall | Concrete | **Detailed**

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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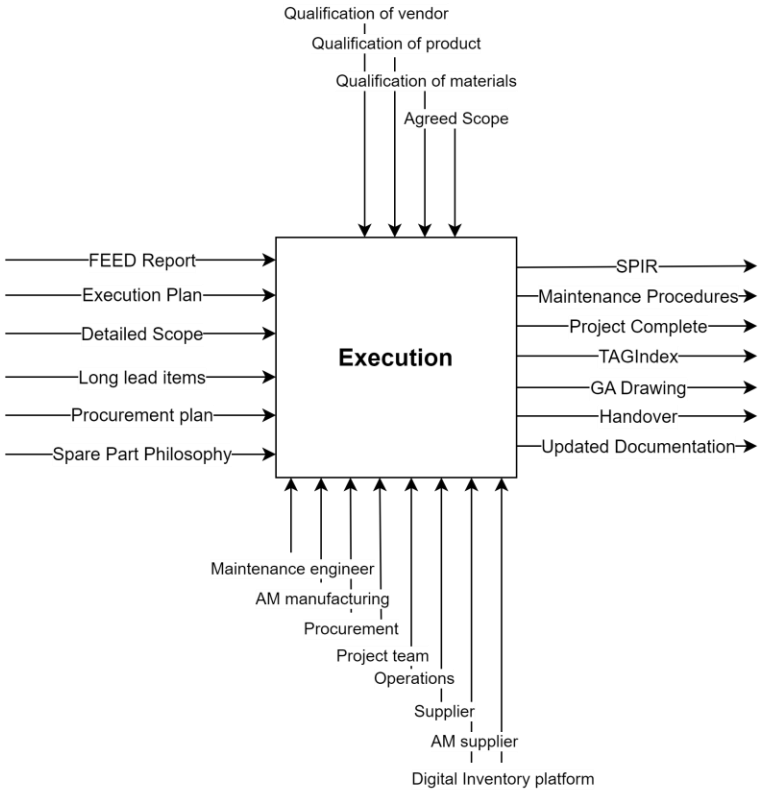
Modifications

“Execution”

Identify need | Appraisal | Feasibility study | Concept study | Definition study | **Execution** | Operations



Overall Recommendations

- In accordance with the execution plan set in the previous phase, the Operator/Contractor will initiate the execution of the modification.
- Relevant spare parts should be made available in the digital inventory with coherent documentations and certificates. And based on the maintenance procedures set in motion in the next phase.

L2 | SPIR

L1 **Execution**

- Receive components
- Commissioning
- Test components
- L2 **SPIR**
- Maintenance procedures
- Prepare for operations
- Detail engineering

Definition

Each purchase package for modification that will have spare parts will have a document called "SPIR" ("Spare Parts and Interchangeability Record"). SPIR is a document showing recommended spare parts for selected TAGs.

The SPIR process is a coordinated process between operator-contractor and supplier.

Why is this activity relevant?

A typical Great Mod. will have many packages and have anywhere from 1 to several SPIRs per package, but the SPIRs within the various packages have roughly the same complexity as a Cat C (Minor Mod. project) with only one package.

By producing parts quickly and efficiently as needed, you eliminate the need to maintain a large inventory of finished products or spare parts. This can be cost-effective and more sustainable, as it reduces the need for storage space and unnecessary production of parts that may not be used.

How can AM / DI impact the activity?

The Digital Inventory should have all relevant documentation for the spare parts that contain the I SPIR document. Recommended spare parts for the relevant tag are made available in a digital inventory. Assess with the EPCI contractor which savings are relevant to make available digitally and which should be physically available.

Output

- ✓ Enable AM for relevant Tags in SPIR
- ✓ Provide incentives to have equipment packages delivered through the AM/DI delivery model
- ✓ Produce parts as needed, thereby maintaining the functionality and extending the life of these devices.

Action / Recommendations

- Optimizing the spare parts strategy for modification and assessing whether the share of Operational, Commissioning and Capital saved in purchasing packages can be purchased on-demand through a digital warehouse
- Parts produced on-demand should be assigned a unique material master number
- Digital inventories should be connected to Eqhub to retrieve standard documentation on main equipment through the API to be able to code the material master number

Level of detail

Overall | Concrete | **Detailed**

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | MAINTENANCE PROCEDURES

L1 **Execution**

L2
- Receive components
- Commissioning
- Test components
- SPIR
- **Maintenance procedures**
- Prepare for operations
- Detail engineering

Definition

Maintenance routines refer to the standardized methods and practices used to maintain, repair and ensure the proper functioning of machinery, equipment, systems or buildings over time. The maintenance routines often include routine inspections, troubleshooting, replacement of worn or defective parts, and general care to extend the life and efficiency of what is being maintained.

Why is this activity relevant?

If AM is used in a modification, this may lead to changes in the maintenance routines.
For example, if there is a change in material choice or functionality/design.

How can AM / DI impact the activity?

Parts manufactured through AM may require customized maintenance to ensure optimal function and lifetime. This may involve more frequent inspections, especially in the initial phase, to monitor their performance under real conditions and adapt maintenance routines accordingly. With AM's ability to quickly produce replacement parts, maintenance teams can quickly respond to the need for repairs or replacements, reducing downtime. At the same time, personnel may require specific training in the handling and maintenance of AM parts

Output

- ✓ Using AM for spare parts can reduce downtime.
- ✓ Recycling or redesign of used parts can be integrated into the new maintenance routines and contribute to sustainable operations.
- ✓ The maintenance procedure can be changed because DI can enable better expectations management of the production of parts.

Action / Recommendations

- Consider whether the maintenance procedure should be changed in line with the use of AM / DI and changes related to design and material selection and on modified equipment.

Level of detail

Overall | Concrete | **Detailed**

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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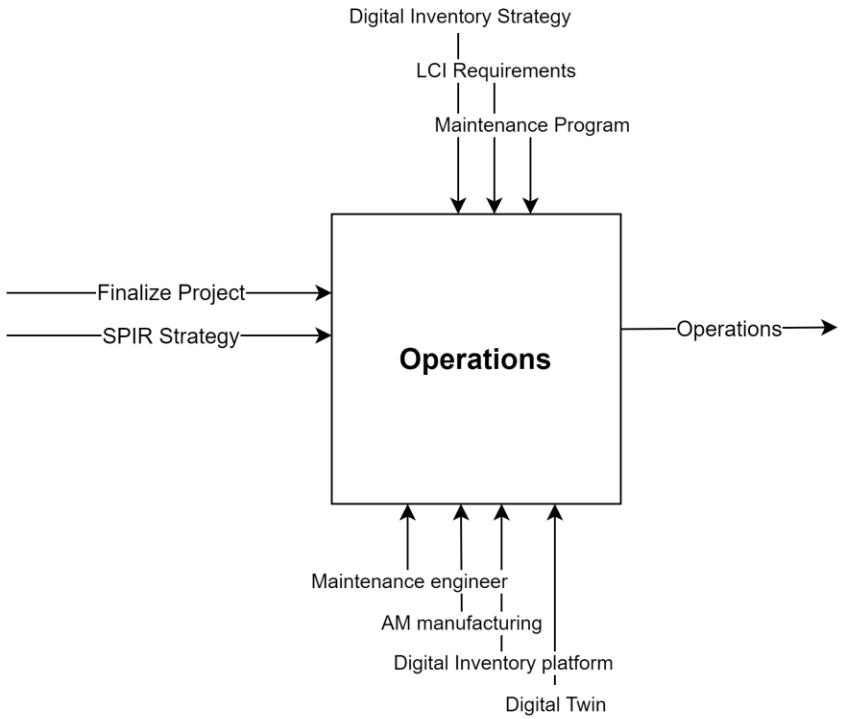
Modifications

“Operations”

Identify need | Appraisal | Feasibility study | Concept study | Definition study | Execution | Operations



Overall Recommendations

- The project will be finalized and the LCI documentation will be updated in accordance.
- The use of digital inventories should align with the maintenance plan.

L2 | TRANSFER LCI

L1 Operations

L2
- Accept modification
- Handover to operations
- Transfer LCI

Definition

Life cycle information (LCI) is the information required by company for design, preparation for operation, start-up, operation, maintenance, repair, modification and dismantling of a facility. LCI includes information submitted to the company and retained by the supplier on behalf of the company (NORSOK)

Delivery of the LCI is done after the modification has been completed, where, among other things, tags and metadata related to equipment and parts are transferred. As-built information, maintenance procedures, Material certificates, documentation, datasheets, loop diagrams, drawings, P&Ids and more.

Why is this activity relevant?

If AM is used in the modification, it will affect the LCI documentation that is transferred and made available.

How can AM / DI impact the activity?

There may be extraordinary documents relating to AM-produced parts because it may include documentation relating to certifications and testing.

Output

- ✓ LCI holds relevant documentation relating to AM if the modification has been carried out with AM technology.
- ✓ The documentation is available in ERP and specific certificates and product lifecycle data are made available in Digital inventory

Action / Recommendations

- Relevant as-built documentation (AM documentation) is made available in a digital inventory that can be linked to ERP (SAP).

Level of detail

Overall | Concrete | **Detailed**

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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CONTRIBUTIONS TO MODIFICATION GUIDELINE

Company	Person	Role
AkerSolutions	Lionel Tarica-Joval	*Transformation Director*
	Øystein Larsen	*VP Life Cycle Services*
aibel	Joffre Jatem	*VP Engineering Technology and Methodology – Modification & Yard*
	Thomas Liaboe	*Welding advisor, robot and mechanized processes Mod & Yard*
	Goncalo Goncalves Martins Ferreira	*Engineering Process Responsible Mechanical Mod & Yard*
	Einar Tvedt	*Concept and Study Team representative*
wood.	Linde Lisberg Bratterud	*Manager procurement*
	Terje Hvaal	*Engineering manager*
	Jørn Sviland	*Procurement manager MMO*
moreld apply	Siri Merete Hansen	*Project Engineer*
	Vigdis Holst Bringedal	*Senior Business manager*
	Jørgen Grønsund	*VP 3D Engineering*
equinor	Brede Lærum	*Head of AM centre of excellence*
	Anders Ranbro	*Project leader*
	Yngvar Klungland	*Manager Modifications*
vår energi	Trine Boyer	*Principal R&D Engineer*
	Dominic John Izzard	*Project engineering manager*
	Perry Olsen	*Modifications*
	Laura Romeo	*Project Manager*
	Jeroen Van den Haak	*Project Engineer*
	Hanne Brynjulfsen	*Project Engineer*
AkerBP	Silje Knatten	*Category & Contract associate SCM*
	Mariann Scotland	*Mechanical Engineer - Crane & Lifting*
	Jan Erik Olvin	*Manager modification alliance*

Guideline

Maintenance Project

For On-demand Manufacturing & Digital Inventories

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MAINTENANCE PROJECTS FOCUS ON PREVENTIVE, CORRECTIVE AND PREDICTIVE MAINTENANCE ACTIVITIES FOR ALL OFFSHORE FACILITIES, LAND PLANTS AND PIPELINES

Definition

Maintenance is defined as (NORSOK, 2001; ISO, 2001):
"A combination of all technical, administrative and management activities, including monitoring activities, which are intended to maintain or regain a condition that enables an entity to perform a required function throughout its lifetime."

Types of Maintenance

Preventive Maintenance

Planned maintenance activities performed on equipment or systems at regular intervals to prevent failures, extend asset life, and maintain optimal performance.

Corrective Maintenance

The process of repairing equipment or systems after a failure or malfunction has occurred

Predictive Maintenance

Maintenance is done using data analysis to identify operational anomalies and potential equipment defects, enabling repairs and maintenance before failures occur.

Outcome of Maintenance

Maintenance activities seeks to:

- Ensure equipment and systems are available when needed and reduce unexpected downtime
- Maintain performance of equipment and expand lifetime to ensure consistent production
- Reduce cost of repairs and optimize resources through maintenance programs
- Prevents accidents and ensure safe operations for employees and environment
- Extend lifepan of equipments by preventing wear and damages

THE MAINTENANCE PROCESS, IS BASED ON A "MAINTENANCE LOOP" AND CONSISTS OF A SERIES OF PHASES WITH CORRESPONDING ACTIVITIES

L1 (phase)

L2 (activities)

Requirements	Maintenance portfolio			Planning	Execution	Reporting	Analysis	Improvement
Set management parameters	Corrective maintenance	Predictive / prescriptive maintenance	Preventive maintenance	Repair or Replace	Work package	Technical feedback	Assessing the Goodness of Maintenance	Change Interval/Program
Regulatory requirements	Notification / Malfunction report	Collect data	Equipment strategy	Technology identification	Work order	Repair report	Maintenance interval assessment	Change of procedures and method
Internal requirements	Prioritization / Risk assessment	Diagnosis of data	Choice of Concept for Maintenance Interval	Cost/benefit assessment	Work permit	Create notification in SAP	Equipment analysis	Assessing spare parts needs
Consequence classification	Choice of Procedure and Method	Choice of Procedure and Method	Consequence classification	Identifying needs	Visual check of equipment	Collect data	Maintenance plan assessment	Update BOM
Maintenance concepts	Repair strategy	Notification	Choice of Procedure & Method	Identifying spare parts	Perform maintenance		Root cause analysis	Keeping time estimates
Prepare the program	Troubleshooting / Information Gathering	Prioritization / Risk assessment	Assess pre-defined spare parts needs	Definition of method	End maintenance		Analysis of time spent	Update operations
Assess discipline and task activities		Repair strategy	Error handling strategy	Plan & Procure			ESG Analysis	Update disciplines
Assessing spare part lists		Connect with DI	Verification Activities	Assess Need for Modification			Analysis of part consumption	Submit suggestions for improvement
				Job description			Inventory Value Analysis	
				Discipline Description			Re-examination of consequence classification	

Phase

Activities

ALERT/FAULT

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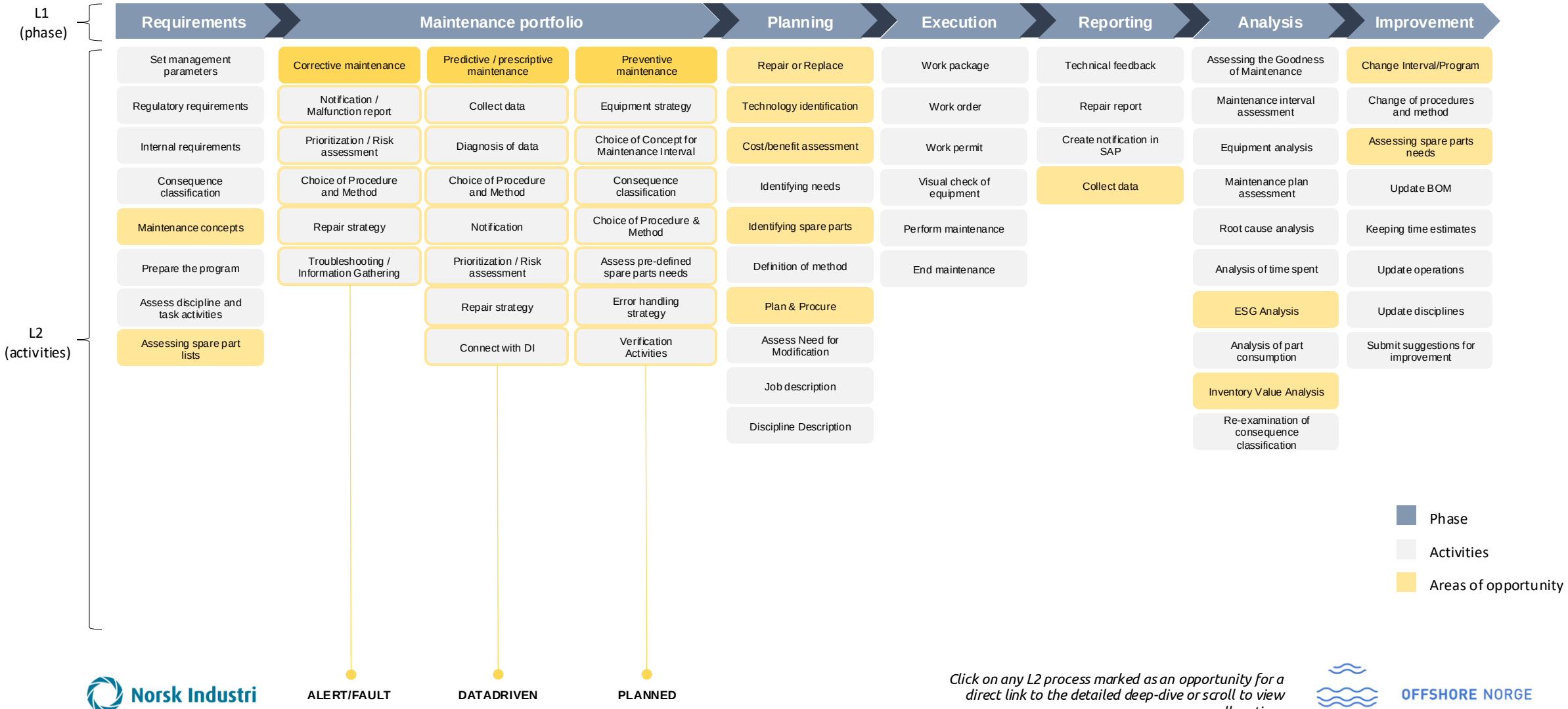
KEY AM/DI INTEGRATION OPPORTUNITIES ACROSS THE MAINTENANCE LIFECYCLE



Click on any L2 process marked as an opportunity for a direct link to the detailed deep-dive or scroll to view all sections

Corrective | Predictive / Prescriptive | Preventive

Notification / Malfunction report | Collect data | Equipment strategy

Prioritization / Risk assessment | Diagnosis of data | Choice of Concept for Maintenance Interval

Choice of Procedure and Method | Choice of Procedure and Method | Consequence classification

Repair strategy | ...ce of Procedure & Method

Troubleshooting / Information Gathering | ...sess pre-defined spare parts needs

... | Error handling strategy

... | ...fication ...vities

Maintenance

Repair or Replace | Work package | Technical feedback | Assessing the Goodness of Maintenance | Change Maintenance Interval/Program

Technology identification | Work order | Repair report | Maintenance interval assessment | Change of procedure and method

Cost/benefit assessment | Work permit | Create notification in SAP | Analyse av equipment | Assessing spare parts needs

Identifying needs | Visual check of equipment | Collect data | Maintenance plan assessment | Update BOM

Identifying spare parts | Perform maintenance | | Root cause analysis at KV | Keeping time estimate

Definition of method | End maintenance | | Analysis of time spent | Update operations

Plan & Procure | | | ESG Analysis | Update disciplines

Assess Need for Modification | | | Analysis of part consumption | Submit suggestions for improvement

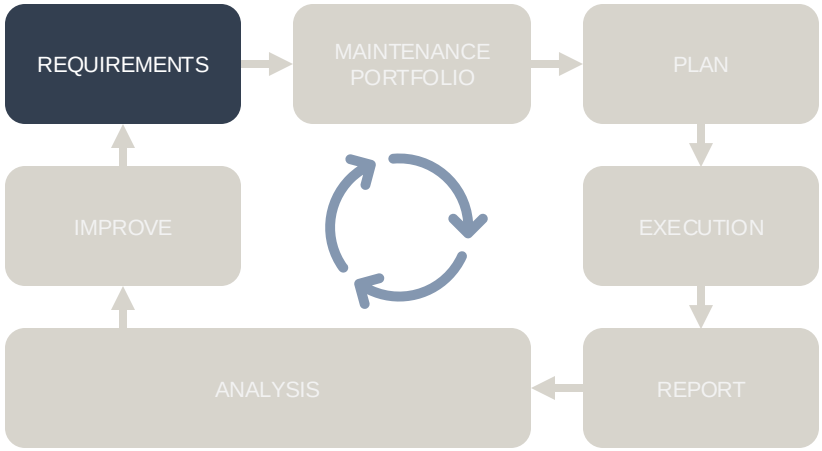
Job description | | | Inventory Value Analysis |

Discipline Description | | | Re-examination of consequence classification |

"Requirements"

ALERT/FAULT | DATADRIVEN | PLANNED

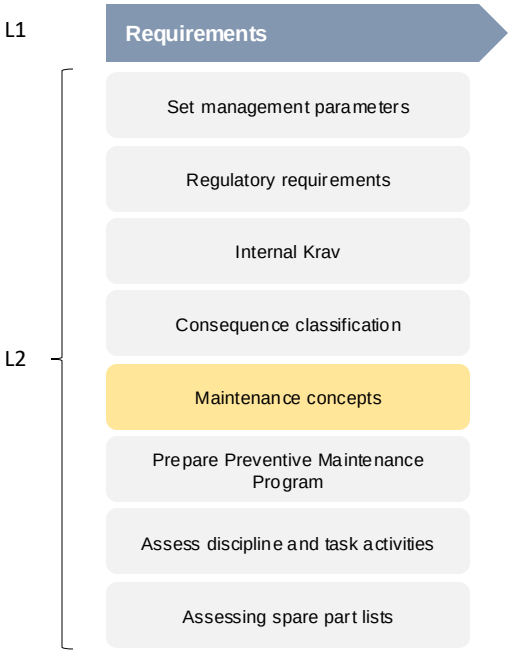
Requirements | Maintenance portfolio | Planning | Execution | Reporting | Analysis | Improvement



Overall Recommendations

- With the requirements for maintenance also comes the need for activities to carry out maintenance. Companies should establish a set of requirements on how AM could be considered as part of the maintenance that is required in relation to accessibility, cost and the environment.
- Include assessment of AM into generic maintenance concepts where this may be relevant.

L2 | MAINTENANCE CONCEPTS



Definition

The operator will set requirements for maintenance with regard to uptime and availability in order to achieve actual production in relation to required production or another reference level during a given period of time. For the safety functions, the requirement for maintenance means that the performance must be taken care of at all times.

The operator will establish a maintenance plan – a structured and documented set of tasks that includes the activities, procedures, resources and time required to perform maintenance on the equipment group.

Why is this activity relevant?

With the requirements for maintenance also comes the need for activities to carry out maintenance. AM should be considered as a tool as part of the maintenance that is required in relation to accessibility, cost and the environment.

How can AM / DI impact the activity?

AM/DI can help reduce lead time in acute unforeseen situations and where it is challenging to obtain spare parts.

AM/DI can reduce the volume of physical spare parts and the subsequent need for preservation, maintenance, and expiration date.

Output

✓ KPIs for company requirements for the use of AM/DI

Action / Recommendations

- Establish company requirements for goal attainment through the use of AM/DI.
- Include assessment of AM into generic maintenance concepts where this may be relevant.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement

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L2 | ASSESSING SPARE PART LISTS

L1
- Requirements

L2
- Set management parameters
- Regulatory requirements
- Internal Krav
- Consequence classification
- Maintenance concepts
- Prepare Preventive Maintenance Program
- Assess discipline and task activities
- Assessing spare part lists

Definition

Norsok z008 categories spare parts as follows:
Capital spare parts: Are vital to the function of the plant, but unlikely to suffer a fault during the lifetime of the Equipment. They are delivered with unacceptably long lead time from the supplier and usually very expensive, although they will likely have lower cost if they are included with the initial order of the system package;
Operational spare parts: Are spare parts required to maintain the operational and safety capabilities of the equipment during its normal operational lifetime.
Consumables: Are items or material that intended for use only once (non-repairable)

Why is this activity relevant?

Maintenance activities will typically involve spare part assessment. AM has the potential to improve the spare part process significantly. Norsok Z-008 Chapter 12 Spare parts evaluation – and 12.06 Additive Manufacturing.

How can AM / DI impact the activity?

AM can reduce the min-max of spare parts by having the spare part residing in a digital inventory instead of physical storage, depending on the demand rate and consequence.
Norsok Z-008 Chapter 12 Spare parts evaluation – and 12.06 Additive Manufacturing.

Output

- ✓ Restored spare parts stock.
- ✓ Reduced lead time.
- ✓ Reduced cost for spare parts' storage.
- ✓ Reduced environmental footprint.

Action / Recommendations

- Operators should assess whether they should change requirements for maintenance with the application of Norsok Z-008 Chapter 12 Spare parts evaluation – and 12.06 Additive Manufacturing.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Contractor

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Corrective | Predictive / Prescriptive | Preventive

Notification / Malfunction report | Collect data | Equipment strategy

Prioritization / Risk assessment | Diagnosis of data | Choice of Concept for Maintenance Interval

Choice of Procedure and Method | Choice of Procedure and Method | Consequence classification

Repair strategy | ce of Procedure & Method

Troubleshooting / Information Gathering | sess pre-defined spare parts needs

Error handling strategy

tification tivities

Repair or Replace | Work package | Technical feedback | Assessing the Goodness of Maintenance | Change Maintenance Interval/Program

Technology identification | Work order | Repair report | Maintenance interval assessment | Change of procedure and method

Cost/benefit assessment | Work permit | Create notification in SAP | Analyse av equipment | Assessing spare parts needs

Identifying needs | Visual check of equipment | Collect data | Maintenance plan assessment | Update BOM

Identifying spare parts | Perform maintenance | Root cause analysis at KV | Keeping time estimate

Definition of method | End maintenance | Analysis of time spent | Update operations

Plan & Procure | ESG Analysis | Update disciplines

Assess Need for Modification | Analysis of part consumption | Submit suggestions for improvement

Job description | Inventory Value Analysis

Discipline Description | Re-examination of consequence classification

Maintenance

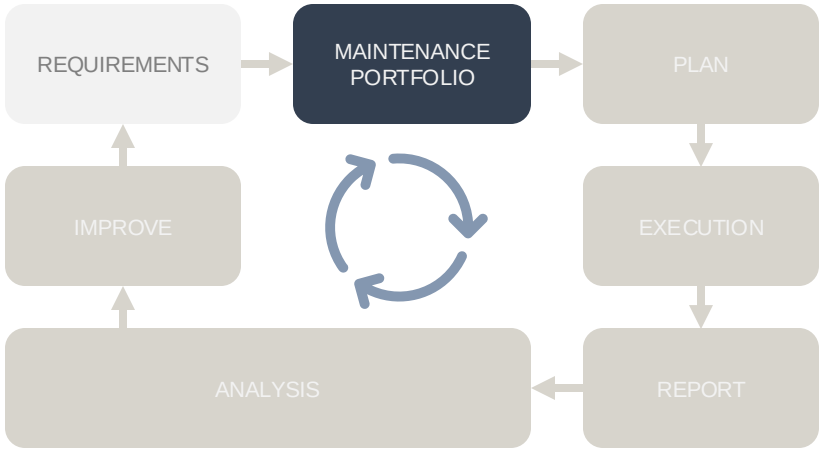
"Maintenance portfolio / Program"

ALERT/FAULT

DATADRIVEN

PLANNED

Requirements | Maintenance portfolio | Planning | Execution | Reporting | Analysis | Improvement



Overall Recommendations

- AM / DI can impact preventive, corrective and predictive maintanence.
- For Preventive programs, parts can be certified and accessible so that it can be produced within planned maintenance intervals
- Depending on the severity of fault, AM / DI can be used in corrective maintenance to resolve the issue and restore the state of equipment.
- For predicitive maintenance, parts can be made ready- and available in a digital inventory before the fault occurs, and based on data, produced before the fault.

L2 | CORRECTIVE MAINTENANCE

L1 Maintenance portfolio

L2 Corrective maintenance

- Notification / Malfunction report
- Prioritization / Risk assessment
- Choice of Procedure and Method
- Repair strategy
- Troubleshooting / Information Gathering

Definition

Corrective maintenance is maintenance that is performed after a fault has been found and aims to restore a device to a state where it can fulfill required function.

The severity of the non-conformity and the final deadline for rectification in accordance with equipment and process safety are assessed. A notification is lifted to a work order, facilitated with hours, parts and possibly assistance from the supplier. The work order goes through the cost-benefit approval meeting and finally execution (NS-EN 13306).

Why is this activity relevant?

From the moment a fault is detected, we have the first interface of AM/DI. In the creation of the deviation, an assessment can be made about different repair methods. Can it be solved with AM offshore
In the facilitation phase, we can assess repair strategy, availability of parts, cost/benefit and criticality.
Corrective maintenance is dynamic and different from time to time. Criticality classification should include both the probability of failure and the consequence if failure occurs. In some cases, it is only the consequence of failure that is decisive, which means that you are at times dependent on fast delivery or the need for new solutions.

How can AM / DI impact the activity?

Rapid rectification of equipment failures is possible with AM.
AM offshore: Remove the need for further proceedings or reduce criticality with a temporary solution.
AM onshore: New solutions versus conventional methods, less delivery time, cost-effective and greater flexibility.
Expand lifetime of equipment and reduce the number replacement projects.

Output

- ✓ Restoring to original quality
- ✓ extending service life
- ✓ maintaining barriers and process safety
- ✓ change design
- ✓ faster reversal of deviations and lower costs.

Action / Recommendations

- Training/availability of design tools, 3D scanner and 3D printer offshore. Across shifts
- Training/awareness of typical 3D/DI cases, good knowledge of what is being done elsewhere. (applies to both offshore/onshore)
- Assess whether AM can be used to extend lifetime of equipment
- Assess whether AM can be used for repair instead of replacing the whole part
- For equipment with higher failure rates, AM can be used to re-design parts to improve performance

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | PREDICTIVE / PRESCRIPTIVE MAINTENANCE

L1 Maintenance portfolio

L2 Predictive / prescriptive maintenance

- Collect data
- Diagnosis of data
- Choice of Procedure and Method
- Notification
- Prioritization / Risk assessment
- Repair strategy
- Connect with DI

Definition

Predictive maintenance is an application of condition-based maintenance that involves using technologies such as AI, sensors, and data analytics to predict when equipment or facilities will require maintenance. The goal is to reduce unplanned downtime, increase efficiency, and extend the lifetime of the equipment by performing maintenance when needed, rather than on a fixed schedule or after a failure has occurred.

Why is this activity relevant?

By predicting when failures occur, predictive maintenance can provide early warnings of the need for new parts. This is relevant because operators can certify the part and make it available in a digital inventory so that it can be produced with AM when needed.

How can AM / DI impact the activity?

Predictive maintenance can identify potential fault patterns ,and AM can be used to prototype solutions for testing and implementation. AM can integrate advanced design features that can improve the performance and durability of spare parts. This helps to extend the life of the equipment and improve efficiency.

Improved repair strategy: AM can be used to manufacture components that may no longer be available from original manufacturers. This makes it possible to maintain older equipment that would otherwise have to be replaced.

DI can impact predictive maintenance, with lead time on parts being reduced, thus increasing the criteria for when maintenance must be started. AM is suitable for predictive maintenance due to the short lead time of producing parts.

Output

- ✓ Minimizes downtime and maintains continuous operation.
- ✓ Reduced costs and time savings.
- ✓ AM can reduce the need to hold large stocks of spare parts by being able to produce parts on demand when predictive maintenance alerts the need.
- ✓ By being able to replace individual components quickly and efficiently, AM helps extend the life of equipment

Action / Recommendations

- Integrate dataflows from Predictive maintenance programs towards digital twins and digital inventories to predict when to engineer new parts/order new parts in a digital inventory ahead of time.
- AM can also be used to create parts that integrate sensors directly into their design, allowing for real-time monitoring of equipment health and performance. This data can be used to predict and prevent failures before they occur.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | PREVENTIVE MAINTENANCE

L1 Maintenance portfolio

L2 Preventive maintenance

- Equipment strategy
- Choice of Concept for Maintenance Interval
- Consequence classification
- Choice of Procedure & Method
- Assess pre-defined spare parts needs
- Error handling strategy
- Verification activities

Definition

Is planned maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item (ISO 14224/EN-13306)
Preventive maintenance helps in identifying and addressing wear and tear before it leads to significant damage.'
Preventive maintenance tasks shall be scheduled in a maintenance management system. In establishing the preventive maintenance programme, the impact on operation should be minimized.

Why is this activity relevant?

By performing scheduled maintenance, operators can minimize unexpected breakdowns, which can disrupt production schedules and result in costly downtime. Operators will need necessary spare parts to carry out preventive maintenance

How can AM / DI impact the activity?

The capability for doing maintenance in due time is improved, due to avoidance of lacking parts.

DI can have an impact on preventive maintenance, with lead time on parts being reduced, thus increasing the criteria for when maintenance needs to start. When spare parts are made available in digital inventories, with significantly reduced lead times, preventive maintenance procedures can be reassessed- and reduce the total duration of maintenance tasks

Output

- ✓ Cost
- ✓ Leadtime
- ✓ Lifetime
- ✓ Maintenance interval

Action / Recommendations

- Replace traditional spare parts with digital inventory files, reduce physical inventory
- Register on demand produced spare parts in CMMS
- Work orders shall contain information about the required **digital** spare parts, as well as resources needed from the digital inventory to perform maintenance.
- For equipment with higher failure rates, AM can be used to re-design parts to improve performance

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

Corrective

Predictive / Prescriptive

Preventive

Notification / Malfunction report

Collect data

Equipment strategy

Prioritization / Risk assessment

Diagnosis of data

Choice of Concept for Maintenance Interval

Choice of Procedure and Method

Choice of Procedure and Method

Consequence classification

Repair strategy

ce of Procedure & Method

Troubleshooting / Information Gathering

sess pre-defined spare parts needs

Error handling strategy

tification vities

Maintenance

ALERT/FAULT

DATADRIVEN

PLANNED

Repair or Replace

Technology identification

Cost/benefit assessment

Identifying needs

Identifying spare parts

Definition of method

Plan & Procure

Assess Need for Modification

Job description

Discipline Description

Work package

Work order

Work permit

Visual check of equipment

Perform maintenance

End maintenance

Technical feedback

Repair report

Create notification in SAP

Collect data

Assessing the Goodness of Maintenance

Maintenance interval assessment

Analyse av equipment

Maintenance plan assessment

Root cause analysis at KV

Analysis of time spent

ESG Analysis

Analysis of part consumption

Inventory Value Analysis

Re-examination of consequence classification

Change Maintenance Interval/Program

Change of procedure and method

Assessing spare parts needs

Update BOM

Keeping time estimate

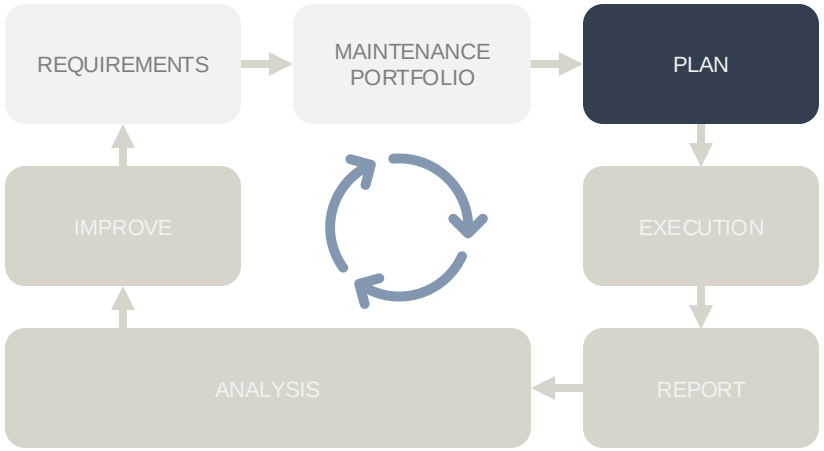
Update operations

Update disciplines

Submit suggestions fo improvement

"Planning"

Requirements → Maintenance portfolio → **Planning** → Execution → Reporting → Analysis → Improvement



Overall Recommendations

- For older equipment where OEM parts may no longer be available, AM can produce custom made parts tailored to specific maintenance needs.
- Facilitate a structure where the operator can use digital inventories for maintenance concepts
- Evaluate if AM parts are competitive against traditional parts for each specific project / corrective maintenance job
- Plan spare part needs- and make digital spare parts accessible through digital inventory platforms based on spare part category (consumable, operational, capital spare)
- Pre-defined Interchangeable parts should reside in digital inventories and be available to produce on-demand based on the maintenance programme.

L2 | REPAIR OR REPLACE

L1

Planning

L2

- Repair or Replace
- Technology identification
- Cost/benefit assessment
- Identifying needs
- Identifying spare parts
- Definition of method
- Plan & Procure
- Assess Need for Modification
- Job description
- Discipline Description

Definition

The operator will perform technical assessment and determine whether equipment should be repaired or replaced, based on failure mechanisms, repair methods, operation envelope, route cause analysis.
Repair – refers to the process of fixing or mending a part that is broken or not functioning as intended. It involves restoring the part to its original condition or functionality, this can include (but not limited to) replacing faulty parts or fixing structural damage.
Replace – involves substituting and old, damaged or ineffective item with a new one. The replacement item typically performs the same function as the old one. Replacement is often necessary when repair is not feasible or cost effective.
Interchangeability: Predefined substitution of an original part

Why is this activity relevant?

Avoid replacing parts that can be reused if spare parts can be sourced, and this does not compromise with the intention of the original design / part. To make the best decision for the equipment as possible related to time (repair/replace time), equipment lifecycle, equipment criticality and total cost.

How can AM / DI impact the activity?

AM can help reduce inventory for long lead items and AM can create custom made parts that can be used for repair.
AM can reduce time and cost of the maintenance for long lead items, and avoid a big replacement scope by printing repair parts

Output

- ✓ Evaluate work scope and parts compatibility in early phase maintenance planning
- ✓ Improve lifetime of equipment
- ✓ Interchangeable part in a digital inventory
- ✓ Updated documentation

Action / Recommendations

- Evaluate if the AM parts are as suitable as the traditional parts when planning maintenance and installing new equipment
- For older equipment where OEM parts may no longer be available, AM can produce custom made parts tailored to specific maintenance needs.
- Part need to be defined as interchangeable in CMMS / Maintenance software.
- incentivize repair instead of replacement in contracts in existing contracts
- Interchangeable parts should be accessible through digital inventories.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | TECHNOLOGY IDENTIFICATION

L1

Planning

L2

- Repair or Replace
- **Technology identification**
- Cost/benefit assessment
- Identifying needs
- Identifying spare parts
- Definition of method
- Plan & Procure
- Assess Need for Modification
- Job description
- Discipline Description

Definition

Refers to the process of recognizing and understanding various technological tools, systems or methods. This involves understanding how the technology operates, its purpose, its impact on society or the environment and how it can be utilized or improved.

Why is this activity relevant?

Implementing new technology where the AM is considered already for the design phase simplifies the maintenance (repair / replace) process as the inventory / equipment parts are already identified and digitally uploaded

How can AM / DI impact the activity?

Digital inventories can be used in accordance with the maintenance programme,

AM spares identified when the technology is implemented – inclusion in maintenance programmes for simplification and robustness

Output

✓ Possibility to use Digital inventory from a pre-planning phase

Action / Recommendations

- Facilitate a structure where the operator can use digital inventories for maintenance concepts
- Setting up process structure for associated maintenance regimes
- Launch a large-scale campaign to shed light on how digital inventories can be exploited in maintenance

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | COST/BENEFIT ASSESSMENT

L1 **Planning**

L2
- Repair or Replace
- Technology identification
- **Cost/benefit assessment**
- Identifying needs
- Identifying spare parts
- Definition of method
- Plan & Procure
- Assess Need for Modification
- Job description
- Discipline Description

Definition

Cost/benefit assessment refers to a systematic process to analyze what decisions to make, and which to forgo. This takes into account the potential gains, the total cost associated with the task and finding measurable cost metrics to evaluate the result of the decision.

Why is this activity relevant?

An AM part might be more expensive to pursue (first time, certification, measurements offshore etc.), however can be cheaper in the long run as the total downtime of the equipment could be shorter. Logistics through AM provide possibilities of local production of parts, shorter logistic changes

How can AM / DI impact the activity?

Save time (thus cost) for the operation by having a shorter downtime on equipment / operation. The cost benefit analysis should assess the delivery time of parts, price of parts, downtime on equipment, as well as investigate the overall impact of using AM versus conventional method on a broad level- not just component by component.

Output

- ✓ Minimize downtime
- ✓ Reduced maintenance time
- ✓ Reduce spare part inventory
- ✓ Increased equipment lifetime?

Action / Recommendations

- Evaluate if AM parts are competitive against traditional parts for each specific project / corrective maintenance job
- Conduct inventory cost/benefit analysis for the application of conventional inventory vs digital inventory,

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | IDENTIFYING SPARE PARTS

L1 **Planning**

L2
- Repair or Replace
- Technology identification
- Cost/benefit assessment
- Identifying needs
- **Identifying spare parts**
- Definition of method
- Plan & Procure
- Assess Need for Modification
- Job description
- Discipline Description

Definition

The operator will use documentation from the Bill of materials (BOM) and previously performed Maintenance, to identify and plan spare parts needs.
Based on the overall requirement (from measurements and requirements) for spare parts, and chosen by program, spare parts need is set up for specific equipment.

Why is this activity relevant?

In case of discontinued material, very expensive or long delivery time. It may be appropriate to use AM for repair method on already existing material or copy and printing of discontinued material.

How can AM / DI impact the activity?

AM can reduce cost, delivery time and environmental footprint. In the case of discontinued materials, AM can enable the implementation of Maintenance that would otherwise require equipment replacement or rebuilding.

Output

✓ Obtain materials for maintenance activities.

Action / Recommendations

- Raise awareness of the possibility of AM as a repair method
- Raise awareness of the possibility of AM copy and 3D printing new parts
- Qualification of multiple providers for AM rep
- Plan spare part needs- and make digital spare parts accessible through digital inventory platforms based on spare part category (consumable, operational, capital spare)

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | PLAN & PROCURE

L1 **Planning**

L2
- Repair or Replace
- Technology identification
- Cost/benefit assessment
- Identifying needs
- Identifying spare parts
- Definition of method
- **Plan & Procure**
- Assess Need for Modification
- Job description
- Discipline Description

Definition

Planned procurement refers to a strategic process in which an organization or individual plans and prepares to procure goods or services in the future. This involves identifying needs, analyzing the market, setting a budget, assessing suppliers, and preparing a procurement plan based on the organization's goals and requirements. Dialogue with suppliers refers to a mutual communication process between an organization and its suppliers. The aim of the dialogue is to establish a cooperative relationship based on mutual trust, respect and understanding. Through the dialogue, the organization and suppliers can discuss and solve any challenges, share information, set common goals and expectations, as well as identify opportunities for improvement and innovation

Why is this activity relevant?

New value chain, new way of procuring goods and reduction of stock retention of spare parts and components.
The suppliers may have specialized knowledge and expertise in AM that can be useful in ensuring successful projects. Through dialogue, you can take advantage of the supplier's insight and experience to optimize design, material selection and production processes.

How can AM / DI impact the activity?

Reduce dependency on external suppliers for specific components.
The supplier's competence in AM/DI, in terms of technical competence, choice of materials, production capacity, etc.

Output

- ✓ Faster delivery time – optimize the purchasing process
- ✓ More adapted parts if needed
- ✓ Reduced CO2 emissions
- ✓ Opportunities for local production
- ✓ Ensure efficiency
- ✓ Delivery of AM/DI
- ✓ Securing production capacity

Action / Recommendations

- Assess whether the supplier can deliver through digital warehouses and has been certified in the area.
- Assess whether infrastructure and logistics
- Assess the need for digital file that allows for rapid prototyping and production
- Ensure files are available for AM/DI and invest in the right equipment to achieve optimal production performance and efficiency.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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Corrective

Predictive / Prescriptive

Preventive

Notification / Malfunction report

Collect data

Equipment strategy

Prioritization / Risk assessment

Diagnosis of data

Choice of Concept for Maintenance Interval

Choice of Procedure and Method

Choice of Procedure and Method

Consequence classification

Repair strategy

ce of Procedure & Method

Troubleshooting / Information Gathering

sess pre-defined spare parts needs

Error handling strategy

tification vities

Maintenance

ALERT/FAULT

DATADRIVEN

PLANNED

Repair or Replace

Technology identification

Cost/benefit assessment

Identifying needs

Identifying spare parts

Definition of method

Plan & Procure

Assess Need for Modification

Job description

Discipline Description

Work package

Work order

Work permit

Visual check of equipment

Perform maintenance

End maintenance

Technical feedback

Repair report

Create notification in SAP

Collect data

Assessing the Goodness of Maintenance

Maintenance interval assessment

Analyse av equipment

Maintenance plan assessment

Root cause analysis at KV

Analysis of time spent

ESG Analysis

Analysis of part consumption

Inventory Value Analysis

Re-examination of consequence classification

Change Maintenance Interval/Program

Change of procedure and method

Assessing spare parts needs

Update BOM

Keeping time estimate

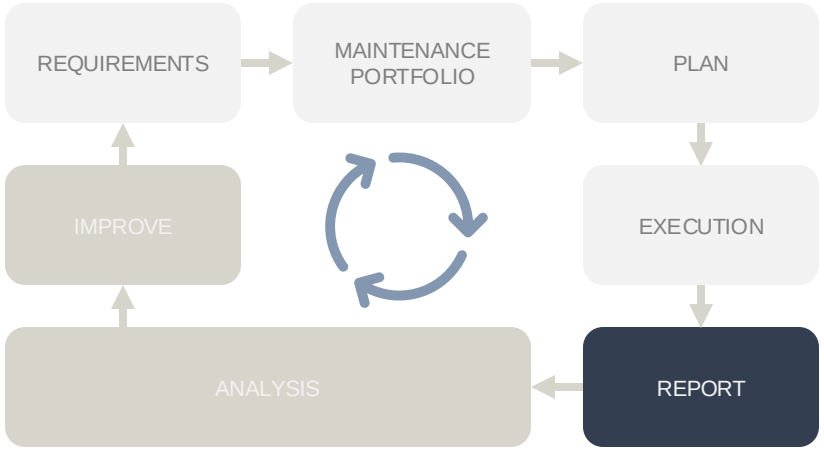
Update operations

Update disciplines

Submit suggestions fo improvement

"Reporting"

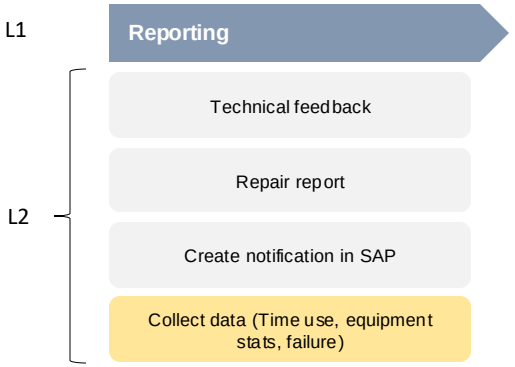
Requirements → Maintenance portfolio → Planning → Execution → **Reporting** → Analysis → Improvement



Overall Recommendations

- Data can be collected- and analyzed to verify the goodness of maintenance process, and improve overall maintenance through the use of digital inventories and manufactured through AM.
- Implement predictive maintenance with dataflow support structures to extract synergies between digital inventories and maintenance software.

L2 | COLLECT DATA (TIME USE, EQUIPMENT, STATS, FAILURE)



Definition

Collect data refers to the process of systematically recording and storing information (Time use, equipment stats, failure) related to maintenance activities in order to monitor, analyze and improve. In predictive maintenance, data collection is done continuously based on sensors.

Why is this activity relevant?

Collecting data after offshore maintenance is relevant because the collected data can be used to improve the maintenance process and report goodness when using digital warehouses and AM.

How can AM / DI impact the activity?

By including information about the use of AM in the repair report, traceability is ensured in documentation of which methods and materials have been used to rectify faults. This is important for future maintenance and audits.

Logging the use of AM makes it possible to evaluate how effective AM is compared to traditional methods and identify which types of errors and components can be solved most effectively with AM. When AM is used, associated 3D models can be saved and referenced in the repair report. This enables the reproduction of parts in future needs and simplifies the ordering process.

Output

- ✓ Ensure clear and traceable documentation of maintenance methods and materials used.
- ✓ Enable evaluation of AM's effectiveness compared to traditional methods.
- ✓ Quickly respond to similar failures in the future by using proven AM solutions.
- ✓ Optimize maintenance processes and increase equipment uptime.
- ✓ Lower the cost of maintenance and spare parts procurement by producing parts on-demand.
- ✓ Creating custom-made parts that meet specific requirements and improve equipment reliability.

Action / Recommendations

- Assess whether data should be mirrored to Digital Warehouses or internal software – traceability

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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OFFSHORE NORGE

Corrective

Predictive / Prescriptive

Preventive

Notification / Malfunction report

Collect data

Equipment strategy

Prioritization / Risk assessment

Diagnosis of data

Choice of Concept for Maintenance Interval

Choice of Procedure and Method

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Consequence classification

Repair strategy

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sess pre-defined spare parts needs

Error handling strategy

tification vities

Maintenance

ALERT/FAULT

DATADRIVEN

PLANNED

Repair or Replace

Technology identification

Cost/benefit assessment

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Identifying spare parts

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Job description

Discipline Description

Work package

Work order

Work permit

Visual check of equipment

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End maintenance

Technical feedback

Repair report

Create notification in SAP

Collect data

"Analysis"

Assessing the Goodness of Maintenance

Maintenance interval assessment

Analyse av equipment

Maintenance plan assessment

Root cause analysis at KV

Analysis of time spent

ESG Analysis

Analysis of part consumption

Inventory Value Analysis

Re-examination of consequence classification

Change Maintenance Interval/Program

Change of procedure and method

Assessing spare parts needs

Update BOM

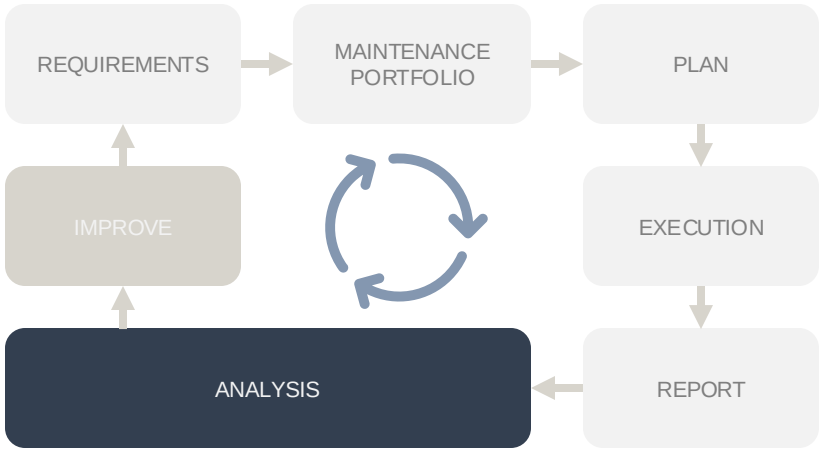
Keeping time estimate

Update operations

Update disciplines

Submit suggestions fo improvement

Requirements → Maintenance portfolio → Planning → Execution → Reporting → **Analysis** → Improvement



Overall Recommendations

- Operators should perform inventory analyses- based on maintenance data- and conclude on which parts that should be accessible in digital inventories, and which parts that should reside in physical inventories.
- Analyses should look assess future need in terms of replace/repair

L2 | ESG ANALYSIS

L1 **Analysis**

L2
- Assessing the Goodness of Maintenance
- Maintenance interval assessment
- Analyse av equipment
- Maintenance plan assessment
- Root cause analysis at KV
- Analysis of time spent
- **ESG Analysis**
- Analysis of part consumption
- Inventory Value Analysis
- Re-examination of consequence classification

Definition

ESG stands for; Environment, Sustainability and Governance. It refers to the fact that investments should consider other aspects than costs and profit. In the Oil- and gas industry ESG often refers to a comprehensive approach of managing environmental risk and reducing carbon footprint.

Why is this activity relevant?

Due to stricter regulations, oil-and gas companies must comply with ESG measures for new investments. On-demand manufacturing and usage of digital inventory platforms can potentially lower carbon footprint and enhance sustainability

How can AM / DI impact the activity?

- Local production
- Lower emissions and footprint
- Improved design and lifetime
- Reduced raw material

Output

- ✓ Higher ESG rating
- ✓ Possibilities for reduction in energy use
- ✓ Less energy in logistic chain
- ✓ More efficient parts (ex impellers redesigned)

Action / Recommendations

- Include ESG considerations in tenders and contracts
- Standardize on demand impact production on ESG
- Use AM / on demand where energy is high to get a lower footprint

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | INVENTORY VALUE ANALYSIS

L1

Analysis

L2

- Assessing the Goodness of Maintenance
- Maintenance interval assessment
- Analyse av equipment
- Maintenance plan assessment
- Root cause analysis at KV
- Analysis of time spent
- ESG Analysis
- Analysis of part consumption
- **Inventory Value Analysis**
- Re-examination of consequence classification

Definition

Analyzing inventory value in the maintenance process involves evaluating and optimizing the quantity and value of spare parts in inventory. This implies how often parts needs replacing and how large stock is needed. This includes identifying critical parts, balancing inventory to ensure availability, controlling costs, and using data, to predict future needs and define the stock level of spare parts. The goal is to minimize downtime and maintenance costs, while avoiding unnecessary capital tied up in the warehouse.

Why is this activity relevant?

An analysis of the inventory values may be relevant for the application of digital warehouses and AM. By identifying which parts can be produced on-demand with AM, the need to keep large quantities of spare parts in stock is reduced, thus helping to optimize inventory

How can AM / DI impact the activity?

AM can produce required parts quickly and cost-effectively based on stock analysis. Inventory analyses can also give an indication of which parts are relevant to have in a digital inventory and which parts are relevant to keep in physical inventories. In the event of a reduction in delivery times, we can reduce/remove stock levels on spare parts.

Output

- ✓ Reduce tied-up capital in the warehouse.
- ✓ Ensure availability of critical parts.
- ✓ Minimize downtime.
- ✓ Improve cost efficiency in maintenance.

Action / Recommendations

- Operators should perform inventory analyses- based on maintenance data- and conclude on which parts that should be accessible in digital inventories, and which parts that should reside in physical inventories.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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Corrective | Predictive / Prescriptive | Preventive

Notification / Malfunction report | Collect data | Equipment strategy

Prioritization / Risk assessment | Diagnosis of data | Choice of Concept for Maintenance Interval

Choice of Procedure and Method | Choice of Procedure and Method | Consequence classification

Repair strategy | ...ce of Procedure & Method

Troubleshooting / Information Gathering | ...sess pre-defined spare parts needs

... | Error handling strategy

... | ...fication ...vities

Maintenance

Repair or Replace | Work package | Technical feedback | Assessing the Goodness of Maintenance | Change Maintenance Interval/Program

Technology identification | Work order | Repair report | Maintenance interval assessment | Change of procedure and method

Cost/benefit assessment | Work permit | Create notification in SAP | Analyse av equipment | Assessing spare parts needs

Identifying needs | Visual check of equipment | Collect data | Maintenance plan assessment | Update BOM

Identifying spare parts | Perform maintenance | | Root cause analysis at KV | Keeping time estimate

Definition of method | End maintenance | | Analysis of time spent | Update operations

Plan & Procure | | | ESG Analysis | Update disciplines

Assess Need for Modification | | | Analysis of part consumption | Submit suggestions for improvement

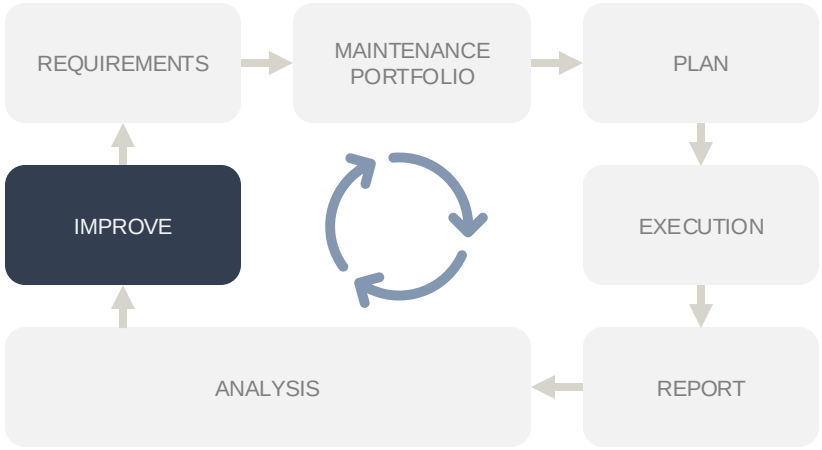
Job description | | | Inventory Value Analysis |

Discipline Description | | | Re-examination of consequence classification |

"Improvement"

ALERT/FAULT | DATADRIVEN | PLANNED

Requirements → Maintenance portfolio → Planning → Execution → Reporting → Analysis → **Improvement**



Overall Recommendations

- Based on finding from analyses, 3D models, and digital files of spare parts should reside in a digital inventory so that parts and components can be ordered automatically when needed – in the context of intervals, and equipment data (failure / anomalies)
- Include continuous improvement in processes and work procedures

L2 | CHANGE INTERVAL/PROGRAM

L1 **Improvement**

L2
- Change Interval/Program
- Change of procedures and method
- Assessing spare parts needs
- Update BOM
- Keeping time estimates
- Update operations
- Update disciplines
- Submit suggestions for improvement

Definition

A process in which maintenance strategies and methods are regularly evaluated and updated to increase efficiency, reduce downtime, and improve the reliability and longevity of your equipment. The operator can change the stipulated interval for maintenance based on analyses of the effect of performed maintenance.

Why is this activity relevant?

Continuous improvement of the maintenance program is relevant for AM because it allows customization and optimization of maintenance processes. The use of AM can streamline the production of special tools and parts, which are necessary for maintenance.

How can AM / DI impact the activity?

DI allow the storage of 3D models of tools and parts and enable automatic ordering when generating new work orders. This improves the availability and efficiency of the maintenance process, and can cause interval changes

Output

- ✓ Improve customization and efficiency in your maintenance program. Reduce downtime by ensuring quick access to necessary tools and parts.
- ✓ Increase cost efficiency by using AM to produce parts on-demand.
- ✓ Ensure continuous improvement through optimized maintenance strategies.
- ✓ Improve the quality of maintenance by using specially adapted tools and parts.
- ✓ Increase flexibility in maintenance operations by being able to produce parts on demand.

Action / Recommendations

- Add 3D models for components in a digital inventories so that parts and components can be ordered automatically when needed – in the context of intervals, and equipment data (failure / anomalies)
- Include continuous improvement in processes and work procedures
- Assess whether AM can be used to improve the quality of a unit's physical condition in order for it to have a longer duration, given the environment to which it is exposed.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

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L2 | ASSESSING SPARE PARTS NEEDS

L1 **Improvement**

L2
- Change Interval/Program
- Change of procedures and method
- **Assessing spare parts needs**
- Update BOM
- Keeping time estimates
- Update operations
- Update disciplines
- Submit suggestions for improvement

Definition

Use of maintenance history, equipment criticality and lead times to define the stock level of spare parts.

Why is this activity relevant?

AM and DI can affect delivery times for spare parts and access to spare parts

How can AM / DI impact the activity?

In the event of a reduction in delivery times, we can reduce/remove stock levels on spare parts.
Increases access to spare parts when using AM/DI

Output

- ✓ Secure spare parts for the right maintenance at the right time. Reduce tied up capital in spare parts in stock.
- ✓ Reduce environmental footprint by reducing inventory.

Action / Recommendations

- Qualification of suppliers
- Define which spare parts can be produced by using AM
- Clarify IP rights and legality
- Clarify the possibility of using DI and warehouses across operators.

Level of detail

Overall | Concrete | Detailed

Relevant stakeholders

- Facilities Engineering
- Operations
- Logistics
- Procurement
- Supplier
- Contractor

DEFINITIONS

Word	Definition
Process	*Series of actions or operations performed in order to do, make, or achieve something*
Additive manufacturing / AM	*Additive manufacturing (often used synonymously with 3D printing) is an on-demand manufacturing method where materials are added layer by layer to build an object from nothing*
Digital Inventory / DI	*Digital inventories are software platforms that enables entities in the network access to offer their services, as well as transact- and interact with eachother*
Modification	*a modification of the original equipment unit where the original design has been altered or the item in question replaced with one of a different type/make. If the modification is of significant character, it is not considered as a maintenance action.*
OPEX	*Operating expenditure – costs that incurs through operations*
CAPEX	*Capital expenditure – investment costs*
ESG	*Environmental, Social and Governance – often used to describe sustainability impact*
FEED	*Front End Engineering Design*
EPCI	*Engineering, Procurement, Construction and Installation*
Scope of work / SOW	*The scope of which the work is to be performed and conducted*
LCI	*The information required by company for engineering, preparation for operation, start-up, operation, maintenance, repair, modification and dismantling of a facility. LCI includes information submitted to the company and retained by the supplier on behalf of the company*
TCO	*Total cost of ownership*
As-built	*Documentation where mark-up information has been formally incorporated into a new revision of the original document according to individual requirements for each project. (NORSOK Z-001 Rev.4)*

CONTRIBUTIONS TO MAINTENANCE GUIDELINE

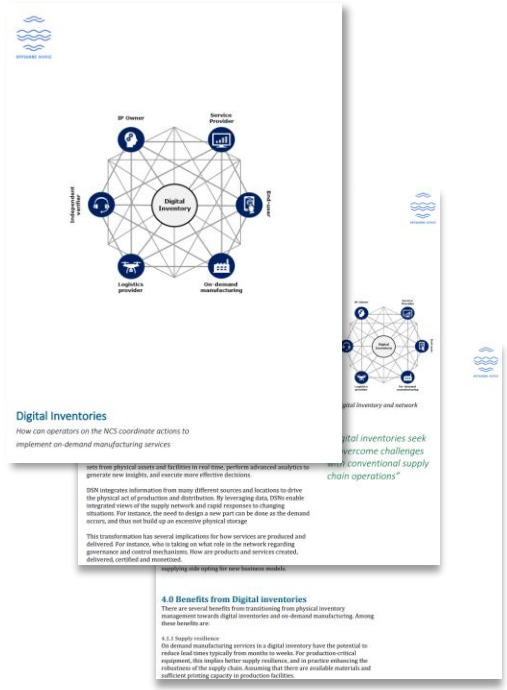
Company	Person	Role
AkerSolutions	Lionel Tarica-Joval	*Transformation Director*
	Øystein Larsen	*VP Life Cycle Services*
aibel	Joffre Jatem	*VP Engineering Technology and Methodology – Modification & Yard*
	Thomas Liaboe	*Welding advisor, robot and mechanized processes Mod & Yard*
	Goncalo Goncalves Martins Ferreira	*Engineering Process Responsible Mechanical Mod & Yard*
	Einar Tvedt	*Concept and Study Team representative*
wood.	Linde Lisberg Bratterud	*Manager procurement*
	Terje Hvaal	*Engineering manager*
	Jørn Sviland	*Procurement manager MMO*
moreld apply	Siri Merete Hansen	*Project Engineer*
	Vigdis Holst Bringedal	*Senior Business manager*
	Jørgen Grønsund	*VP 3D Engineering*
equinor	Brede Lærum	*Head of AM centre of excellence*
	Anders Ranbro	*Project leader*
	Yngvar Klungland	*Manager Modifications*
vår energi	Trine Boyer	*Principal R&D Engineer*
	Dominic John Izzard	*Project engineering manager*
	Perry Olsen	*Modifications*
	Laura Romeo	*Project Manager*
	Jeroen Van den Haak	*Project Engineer*
	Hanne Brynjulfsen	*Project Engineer*
AkerBP	Silje Knatten	*Category & Contract associate SCM*
	Mariann Scotland	*Mechanical Engineer - Crane & Lifting*
	Jan Erik Olvin	*Manager modification alliance*

FOR MORE INFORMATION

PLEASE SEE THE EXTENSIVE REPORT ABOUT DIGITAL INVENTORIES AND ON-DEMAND MANUFACTURING

For extensive report about On-demand manufacturing and Digital inventories, please visit

www.OffshoreNorge.no



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