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Ship Lifecycle Software Solutions (SHIPLYS)

Project Deliverable Report

3.2 SHIPLYS model and data requirements

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EXECUTIVE SUMMARY

Introduction

The SHIPLYS project is mainly focused in the development and integration of rapid virtual prototyping tools with life cycle tools. It aims to empower European SME designers and production yards to make their own decisions on how to arrive at early stage via a life-cycle approach, at both: optimum ship design configurations and optimal retrofitting/Conversion.

A crucial part of the SHIPLYS approach will be the definition and modelling of a set of three case study scenarios, representing different needs across the European SME shipbuilding community. The scenarios will serve one important purpose on this task, as they will promote a high level of discussion around the important issues and information requirements across different workforces, which we will be used to gain strong insights into developing the optimal data structure and user interfaces for the models.

Aims and Objectives

In this deliverable, we will define algorithms for model and data required for initial product design and the corresponding production processes involved in the context of the SHIPLYS case study scenarios. In parallel, the requirement (algorithms and type of data) for the implementation of life cycle approaches will be determined.

Methodology

Special technical meetings were organised among relevant project partners to determine the functionality required from the models to meet SHIPLYS objectives. Technology providers within the Consortium provided potential solutions (algorithms) to satisfy the functionality required. The three SHIPLYS Scenarios were used to direct the development of solutions. Where applicable, shipyards present in the SHIPLYS Consortium provided feedback as to the practicality of the solutions proposed.

Cognisance has been taken of existing models and approaches such as the ISO10303 Application Activity Model of ship life cycle to determine data requirements.

Summary of the results

This document describes the requirements for models and data necessary for product design, production process, and life cycle approaches. The algorithms/ solutions developed will be presented as a series of papers at the IMAM 2017 conference.

Conclusions

This report presents algorithms for models and types of data required for SHIPLYS prototyping and life cycle approach. The requirements will be reviewed from time to time in light of developments in the project.

CONTENTS

FIGURES:

SHIPLYS

Abbreviations used

AAM Application Activity Model

AP Application Protocol (as defined by ISO 10303, ISO 13584,…)

API American Petroleum Institute

BEP BIM-enabled practice

BIM Building information modelling

CoF Consequence of Failure;

Consequences of a Failure or an adverse event, as used in some Risk Assessments (RA).

CML 2010 CML-2010 – is an impact assessment tool developed by the Center of Environmental Science of Leiden University (CML). The CML methodology groups the LCI results into midpoint categories, according to themes. These themes are common mechanisms (e.g. climate change) or groupings.

DSS Design support system

EC: European Commission

EI Environmental impact;

Possible adverse effects caused by a development, industrial, or infrastructural project or by the release of a substance in the environment.

FEM Finite element method.

HSLA High Strength Low Alloy

ISO International Standardisation Organisation

LCCA Life Cycle Cost Analysis;

Alternative terminology for Life Cycle Costs (LCC).

DSS Design support system

MCDA Multi-Criteria Decision Analysis;

A sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision-making.

O&M Operation and Maintenance

PoF Probability of Failure; The likelihood or probability of failure or an adverse event occurring

RA Risk Assessment;

Systematic use of information to identify sources and to estimate the risk. Risk Assessment provides a basis for risk evaluation, risk mitigation and risk acceptance. Information can include historical data, theoretical analysis, informed opinions and concerns of stakeholders.

RBI/ RBM	Risk Based Inspection/ Risk Based Maintenance; RBI/RBM typically involve an evaluation of risks and prioritization of actions (inspection/maintenance) based on such evaluation
RiskWISE®	The RBI / RBM software developed by TWI Ltd to support the implementation of certain American Petroleum Industry (API) standards.
SHIPLYS design workflow	The term used to include all activities pertaining to rapid virtual design prototyping, production simulation, life cycle cost analysis (LCCA), Environment Impact and risk assessment that will be considered during the early ship design stage.
SHIPLYS LCT	SHIPLYS Life Cycle Tools; The suite of tools providing life cycle cost analysis, environmental assessment, risk assessment, and decision support functionalities
SME	Small and Medium Enterprises
VC	Value Chain
VP	Virtual prototyping
VR	Virtual Reality
WD	Working Draft (of a Standard under preparation)
WP	Work Package

Definitions

Product Model: A digital representation of a real or abstract object described by a collection of graphical and non-graphical attributes as well as relationships with other objects, such that together the collection spans the full lifecycle of the product and conceptually, appears to reside in a single repository. *(Polini & Meland 1997)*

Smart product model: A product model developed following an object-oriented approach such that it addresses not only an object's attributes and relationships, but encapsulates behaviours with the object that control how the product data is accessed and used. *(Polini & Meland 1997)*

1 Introduction

"*In this task we will define algorithms for models and data required for the initial product design and the corresponding production processes involved. In parallel, the requirements (algorithms and type of data) for the implementation of life cycle approaches will be determined.*

In this task, we will consider what sort of information is readily available or can be generated in SHIPLYS." MG4.3-2015 RIA Final Proposal, p.13

Work done in this task shall provide key specifications/constraints for the development of the tools in WP4, WP5 and WP6, in order to facilitate their integration in WP7.

The development work in the project applies to two main areas: Virtual Prototyping and Simulation modelling, and the SHIPLYS life cycle suite of tools (called SHIPLYS LCTs) that include LCCA, environmental assessments, risk assessments and multi-criteria decision support modules.

Regarding to **Virtual prototyping** is a method in the process of product development. It involves using computer-aided design (CAD), computer-automated design (CAutoD) and computer-aided engineering (CAE) software to validate a design before committing to making a physical prototype.

On the other hand**, Simulation based design** focuses on computational simulation tools and techniques to evaluate the performance of a Ship design or design alternatives, starting at earliest conceptual design phases to help naval architects make informed design decisions.

3D Models

The value of intelligent 3D models of the as-built asset, combined with advanced information management technologies, is being increasingly recognised in the marine industry.

3D models commonly differ in the detail of their content and are highly optimised to suit the process they are used to support.

Model complexity causes problems to many applications that utilise 3D models. Model simplification has been reported to increase physical simulation performance by several magnitudes with negligible impact on the results.

Recently, by adding innovative new capabilities it has become possible to allow easier generation of more simplified, universal 3D models:

1. The use of a topological model instead of a geometrical model facilitates model definition, allows the quick study of design alternatives and simplifies modifications.

2. The use of a ship model created in 3D CAD for FEM analysis would optimise design performance in the early stages. For this, there must be an efficient link that allows exporting a simplified ship model, leveraging its topological characteristics.

Practical difficulties in integrated modelling

There are many general purpose CAD tools available that can largely contribute to ship concept design, such as CATIA. Furthermore, there are software tools such as CADMATIC, SMARTMARINE, NAPA and SHIPCONSTRUCTOR, which are specialised in ship design. Most of these specialised tools are able to perform the concept and detailed ship design with a strong emphasis on excellent solutions that enhance the speed of the detailed design. However, to our knowledge, there are no standard data models that are powerful enough to both use analytical models and its results and additionally the ability to include the different relationships between CAD models and its results regarding engineering. This surely impacts the interaction between CAD modelling, simulation and LCCA systems. PLM products often claim to address this, but in reality they just store and document all the data. Relationships must be established manually or by using "business rules", which require costly development and often are not flexible enough (e.g. when changing the product - so you are back to the original problems).

Existing tools such as general digital content creation packages Autodesk Maya, Blender and Autodesk 3dsMax, and more specialised tools **Simplygon** and **Meshlab**, are capable of producing simplified meshes for 3D work such as we require for the Product Model.

The BIM concept will be used to contribute here, by formalising the heuristics that we currently use on an individual manual basis when transferring information between model types. A related problem is the merging of overlapping standards, such as general CAD standards and ship specific standards.

Production

SHIPLYS will provide solutions according to two aspects with the target of obtain a Rapid Virtual Prototyping tool with life cycle tools that will be compatible with existing early design software. These aspects are Design and Production. In the last case, it is proposed to enable existing production simulation tools by means of extended product data generators: Expedite the generation of an early design CAD model that provides a sufficient number of main definition parameters. Use these parameters as input to a data generator, that establishes a data set suitable to determining work load, processes, resource needs etc.

Taking a selection of use cases, a tool for stochastic analysis of existing designs will be implemented to derive to an appropriate set of templates for product generation. This could be used with our existing Virtual Product Generator platform (which is currently used to manually define product data parameter sets using such templates).

2 Objectives

- To develop a Comprehensive and detailed approach to system integration and optimisation, based on virtual product / VR capabilities model to include all systems, and include all operational conditions.

- To transfer tools and analysis techniques to simplify virtual prototyping and develop specific multi-criteria decision support techniques, allowing more intensive and comprehensive detailed Life cycle modelling and decision making at the early design stages, providing a modelling methodology to fully understand the operational options available over the full lifetime of marine assets.

- To introduce a new industry wide paradigm for information standardisation and transfer based on our experience with successful approaches in the construction, aerospace and oil & gas industries (for example BIM – Building Information Modelling, coupled with Risk Based assessments in the power generation and the O&G sector), will provide the **first systems information framework for the maritime industry supply chain** (designers, builders, OEMs and lower-tier materials and subsystems suppliers and the owner-operators) to be able to work collaboratively to define and improve lifecycle costs from the early design stages.

- Simplify the 3D models for efficiency, using a level of detail (LOD) approach such as is frequently used in real-time rendering applications to save rendering time, coupled with the Design Building Block approach and the Library based approach, as pioneered by University College London (UCL)'s Marine Research Group among others.

- The development of a standardised product model data representation is an important target, since, SHIPLYS, should be able to obtain inputs of different software like are CAD/CAM/CIM and production data models, therefore, SHIPLYS should be compatible with other software. The requirement is to obtain a better communication between different databases, software modules and company ERP systems.

- To define SHIPLYS model and data requirements according to rule ISO 10303, analyzing the relationship with the shipbuilding.

3 Approach (to meeting the Deliverable objectives)

- *"The concept of lifecycle management as applied to ship design is composed of a number of key elements: the modelling and simulation tool, the value chain processes and their weightings for specific stakeholders, the product hierarchy, and the underlying equipment database. By utilising our existing models (developed by SU and TWI particularly) for shipbuilding, we shall be able to produce accurate life cycle estimates. We shall also use our expertise gained from previous work to include the crucially important aspects of knowledge about the uncertainty of the estimates, and the multi-stakeholder viewpoints*." (Source - SHIPLYS PROPOSAL)

- The alternative design options explored in previous projects will feed their results into the modelling aspects of SHIPLYS. Additionally, relevant lessons from the specific operational aspects developed to improve safety and efficiency of ships will be incorporated in SHIPLYS.

The goal of the SHIPLYS project is to produce new techniques for quick, reliable multi-disciplinary modelling capability for the marine industry. The software/tool developed within SHIPLYS will integrate early ship design tool with life cycle, environmental and risk assessment tools. Therefore, it is important to establish the communication between different modules:

- Extensive database
- Life cycle cost assessment
- Life cycle environmental assessment
- Life cycle risk assessment
- Multi-criteria decision support
- Ship operation profile
- Ship configuration
- Rapid prototyping
- Production analysis and planning

Existing software, that are suited for the early ship design and LCA, have already been investigated within D3.1 and it remains an open question to determine the most relevant tools/software that can be used within SHIPLYS. Many of the existing tools are complex with the functionalities that are beyond the scope of the SHIPLYS definition and therefore, the suitable tools for SHIPLYS will be determined considering the price, appropriate functionalities and simplicity of the integration. The requirements of the integration process will be presented in D3.3. Here, the focus will be on the design process and data requirements.

3.1 The idea of the integrated design system

In order to gain competitive advantage and productivity, shipyards and design offices have a need for the software that will reduce the time and resources needed for basic and detailed design, but also for the early ship design, which is the aim of SHIPLYS. The idea of the integrated design system has been present for quite some time. The meaning of the integrated design system is a set of different software tools provided by different vendors but used at the same time to complete the ship design. Basic ship design typically consists of many phases, which demands collaboration of multiple experts that combine knowledge of mathematics, physics, fluid mechanics etc. The designers involved in different phases are usually dislocated from one another in different departments and possibly in different companies. In the early ship design (focus of the SHIPLYS), the number of designers is reduced to only a few or even only one. However, there is another challenge that is common for Early and Basic design phases and it is the fact that the ship design process deals with large amounts of parameters (main dimensions, scantlings, etc.) and characteristics (stresses, strength, weight, production costs, risk and reliability, etc.) that need to be tracked during the process. Another challenge is that different design tools are used and multiple geometrical and mathematical models are generated during the design work. Also, the design is subject to constant changes and modifications. In order to overcome these challenges, it is important to enable transfer of the design parameters between these multiple models or preferably if possible, to have only one object-oriented ship model. Meaning, a single database instead of having copies of the ship model for every different software tool used in the design process.

3.2 Concurrent group design system

One of the prototypes for integrated design system is ng.zine, which is based on the concurrent group design concept [1], [2]. It is worth noting that apart from the idea of integrated design system, ng.zine was made to enable simultaneous design of multiple mutually dependant design parts, in comparison to the traditional sequential design. While sequential design process possesses strict hierarchy between design phases, commonly scheduled to start after the previous nears completion, concurrent design encourages the use of all available resources roughly at the same time and overlapping of phases, thus decreasing the design time and increasing its efficiency (**Error! Reference source not found.**).

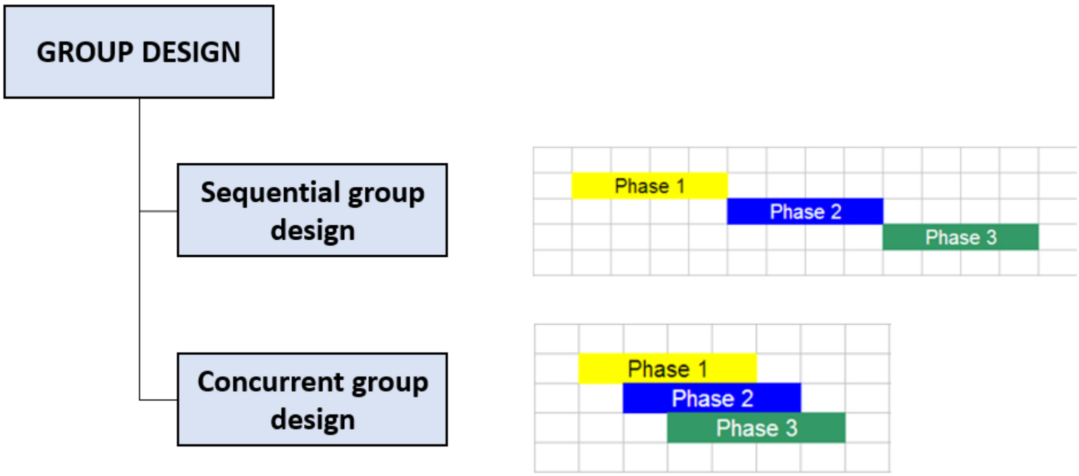


Figure 1: Group design

However, the concept of ng.zine is a design system for conceptual and basic ship design, aiming to make simple and easy-to-use integration of the design tools. It is developed as a joint platform that enables a creation of a virtual model of a ship which encompasses different functionalities. It acts as a flexible XML database, storing and on-demand supplying current and previous values of significant ship parameters, allowing designers to concurrently accommodate the variations created by their colleagues. The idea behind the ng.zine concept is to integrate the work of a multiple designers, combine models into one project and to share models and data between different tools. The concept applies the theories of group decision-making to enhance the handling of parameters and to interpret for designer the quality of the decisions made. In principle, designers are supported in filtering good from bad decisions and aided in reaching satisfactory – efficient designs by indicating consequences when changing parameter values. The parametrically based integration enables also the integration of design applications, which do not share the common platform. Unfortunately, the ng.zine system is insufficiently tested, especially the decision support system. Therefore, one should consider ng.zine concept as the design system intended to enable interaction of design tools and translation between their models in the basic design stage. Although SHIPLYS doesn't aim for the basic design stage, the concept similar to ng.zine could be implemented for the early ship design (concept phase).

ng.zine consists of one central application located on server and a number of local applications located on each and every designer's work station which are task-specific, i.e. they are customized to the design tool they are meant to integrate.

Central application's task is to:

- Gather XML converted design data from the local applications
- Store gathered data to the server
- Supply on-demand gathered data to the local applications
- Local application's task is to:
    - Convert relevant design parameter values to the XML data structure
    - Supply or gather XML data to or from the central application
- Local applications are further split into these basic modules:
    - Group design module evaluating the quality of decisions, i.e. the satisfaction of all designers with every change made
    - Graphical user interface (GUI)
    - Data conversion module(s)

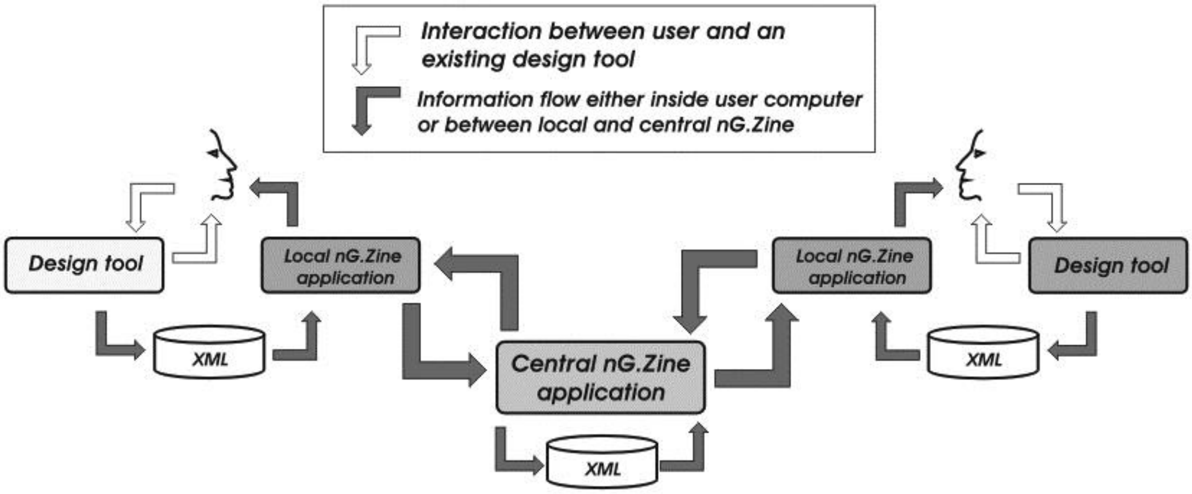


Figure 2: ng.zine Communication Flow Chart

Communication between the central and local applications is established using standard networking protocols, Figure 2.

Design process advances with designers changing the ship parameters through and with the assistance of their design tools. This leads to change of ship attributes, also computed in the very same tools. Whenever any change occurs and is stored to the hard disk, central application triggers the data converter which assembles XML data structure of the current parameter values. Each change in attribute impacts the change in the level of designer's satisfaction with the respective design alternatives, expressed through the utility value.

Group design module reassesses the changes in utilities and displays them in local application.

Group design module also identifies and ranks design alternatives based on their concurrent satisfaction of designers, i.e. on the design quality. If the newly created alternatives are improving the design quality, and they dominate the previous, then the design process advances properly.

Central application combines XML data from all the other applications as the current design parameters state and stores them into history data folder on server. After that, central application provides local applications with the new design parameters.

Local application either converts the XML data file to the standard application file format or it notifies the system user to perform import of the newly arrived data set to the design application by means of application interface.

For example, Figure 3 shows the parameter flow with only a few of significant representatives.

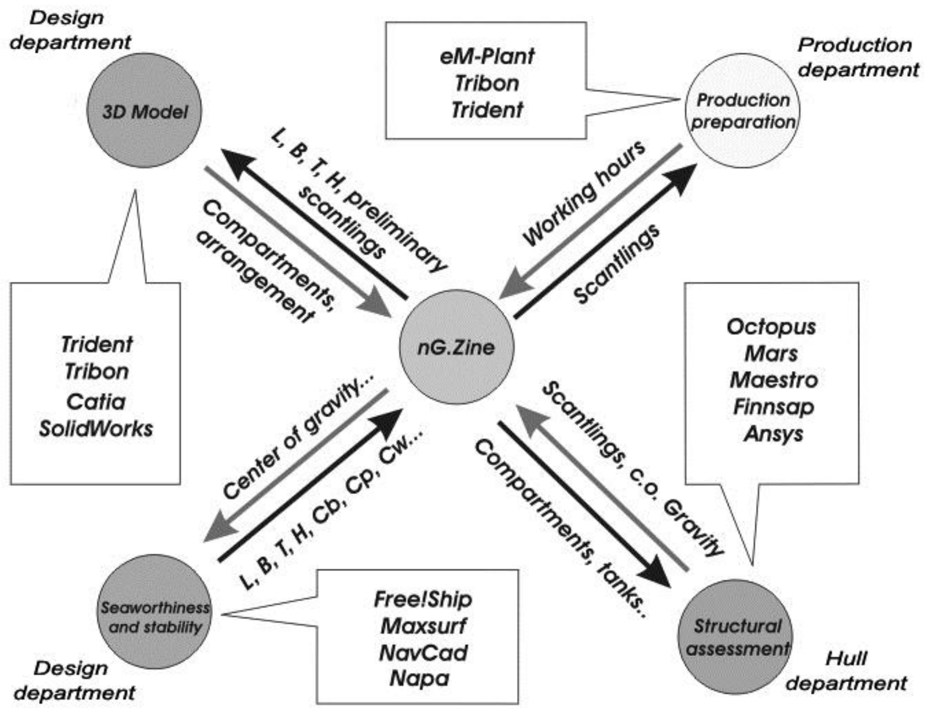


Figure 3: ng.ZINE flow and sharing of the design parameters

nG.ZINE system uses simple communication protocols. In that way, its usage is flexible and provides communication through LAN or WLAN within the local network, and VPN (Virtual Private Network) for creating a secure connection to another network over the Internet. Besides the communication in and between design offices, other system users such as classification society and ship-owner can be involved in the design process.

Requirements for Concurrent Group Design are:

- Server with sufficient resources for storing the large amount of data.
- LAN, WLAN and Internet VPN connection.
- Users' own work station / computer.

3.3 Object-oriented design support system

Another approach that can be considered is Web-based object-oriented design support system presented in [3]. The approach is based on Web collaboration meaning that it provides coordination and communication between cooperating partners via the Internet. For example in ship design, users can share and update 3D models through a standard communication protocol. This way, it is possible to construct the 3D model at an earlier design stage.

The approach provides a central storage of neutrally formatted data that are collected from the design tools. It allows to access the data, add their own establishment when required, and perform design and analysis, while translating and maintaining consistency with all of the software tools. The communication between different software tools is carried out through a middleware which standardize the data content. Several middleware solutions for shipbuilding have already been developed, such as Topgallant (by AES), Integrated Shipbuilding Environment (by Intergraph Solution Group) etc.

One of the commonly used data format standard is XML which become a standard in shipbuilding industry. It is a way to describe and structure data.

The design support system (DSS) has three physical systems:

- Knowledge Server – containing the domain knowledge useful for problem solving and allowing to edit knowledge database
- Draft Server – including main user interface to design structural elements of ship
- User Interface Application – connecting via the Web browser

The example of DSS architecture is shown in Figure 4.

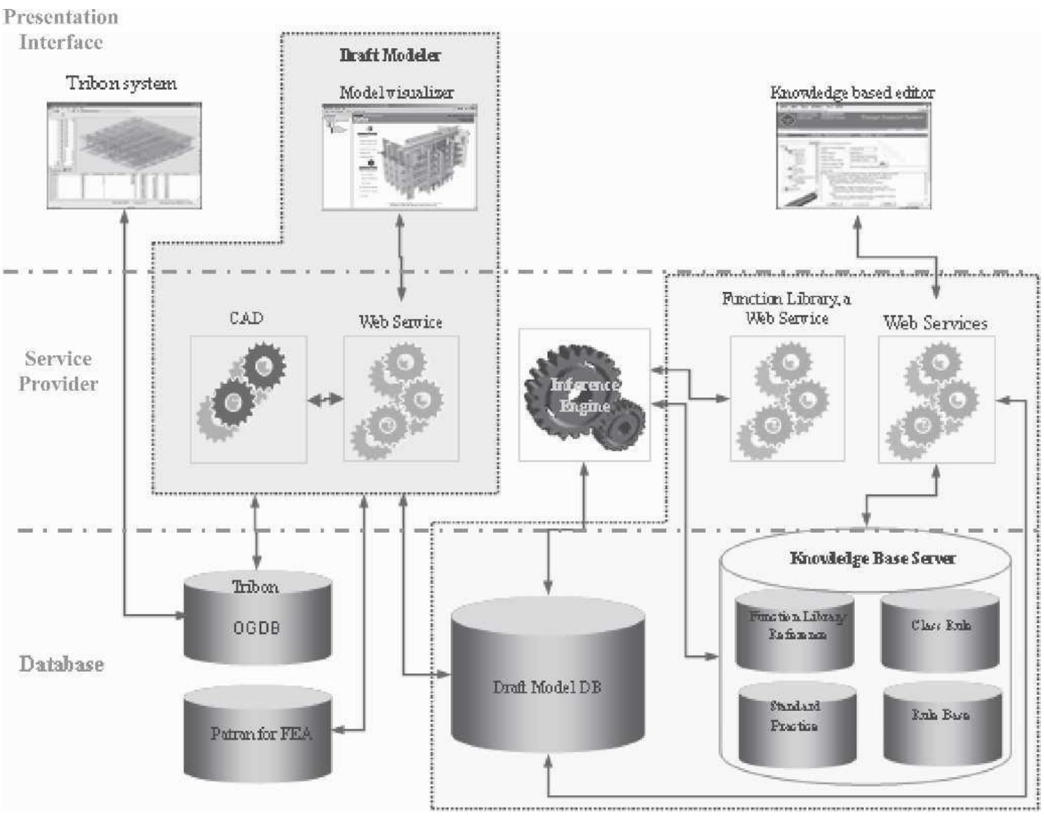


Figure 4: Overall architecture of DSS [3]

Basically, this approach is very similar to previous mentioned Concurrent and Group design approach but the overall architecture of the DSS is more sophisticated. They both allow a communication between design tools by translating the data in a standard form which makes easy to share, modify and connect close related parts of the model. Moreover, they allow communication between designers working on a same project but from different locations.

In comparison with ng.zine, the approach presented in [3] provides a Web-based visualization and 3D representations which makes it more advanced. The users can not only exchange data but also view and manipulate 3D design objects. As the objects from CAD programs are usually very large and complex, they are converted to a 3XD (XML for 3D objects) format which reduces the resources and time needed to upload them on the Web. In this way, the users can quickly control the 3D model and the work which is distributed among several designers.

3.4 Relation to SHIPLYS

Regarding the SHIPLYS project, the object-oriented approach can be applied to resolve the communication between necessary modules/tools that will be integrated.

Prior to connecting the data and integrating the ship design tools, it is necessary to organise design data and parameters in order to enable object-oriented approach. Therefore, the ISO activity model has been introduced within D3.1 with the aim to organise the large collection of parts that are useful for the early ship design.

Within SHIPLYS, the ISO10303 Application Activity Model of a ship's life cycle will be considered. It is the International Standard for the computer-interpretable representation of product information and for the exchange of the product data and its purpose is to describe the work flow of the ship design process. The model is presented as a set of figures that contain the activity diagrams and a set of definitions of the activities and their data. Every activity will represent one functionality of the SHIPLYS software and the activity model will show the connections between various functionalities. For more detailed explanation see Deliverable D3.1.

Following step will be to translate all the data from different parts into a common format such as XML which allows interaction between different tools, whether they are already existing commercial software or tools developed within SHIPLYS.

4 General SHIPLYS MODEL

A product model is a set of objects and relationships between the objects. While the objects describe the assemblies and components of the products, the relationships describe the architecture of the product. As the base for different activities, from idea to final product, the product model is the key to successful product realisation. As a knowledge base it contains geometric and technical data but can also refer to company specific information, product background, history, synthesis and analysis results, reasons for decisions etc. The ship product differs from many other products by:

- it's complexity - a variety of different production branches and organisations have to collaborate in a co-ordinated way
- it's uniqueness - ships are usually built in very small series of one to a few which positions it closer to a power plant than to a car while being a means of transport.

This creates specific requirements on the handling of the product data. The complexity of the ship causes the fact that not all information about this product is possible to be handled by one specific software but a variety of systems in the different organisations involved and even within one organisation (e.g. the ship yard) is necessary to create process and maintain the data. This creates the problem that this data needs to be shared or even exchanged between the systems which either requires a lot of time consuming and error prone conversions or an underlying data structure that is commonly available to the different systems. The complexity also creates the need for co-ordination between the numerous different organisations and between the departments within these organisations which requires configuration management information to be available and maintained by the systems. Different versions of a design for instance can exist in parallel at the same time and are used by different organisations (e.g. the yard's design office and design subcontractors) due to concurrent engineering.

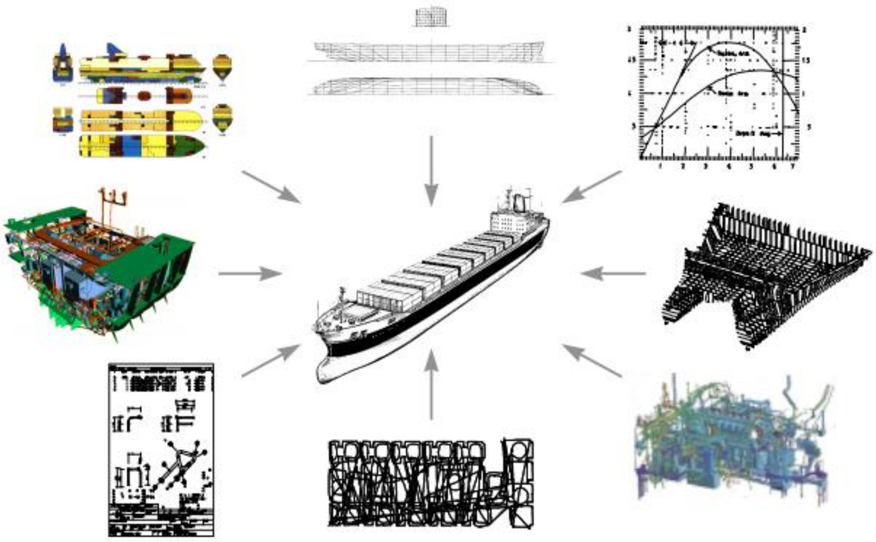


Figure 5: Ship Product Model

The small series that are usually built in the shipbuilding industry require this complex and interlinked information to be maintained in a very efficient and open way and describes as complete as possible all information related to a ship.

The current approach to integrate the ISO 10303 shipbuilding application protocols is driven by the above mentioned requirements.

ISO 10303 Standard for the Exchange of Product model data (STEP)

Organizations and industries all over the world have problems exchanging product model data. These exchanges can be between design, analysis, or manufacturing systems. Industry collaborators have developed a suite of standards in the Organization for International Standardization (ISO) to exchange neutral product model data. It is the Standard for the Exchange of Product model data (STEP).

ISO 10303 for Ship Product Model Data Exchange:

The STEP development community is working to ensure these standards support international product model exchange requirements. The ship community is participating to ensure that their product model data can be exchanged to support real business processes. Integrated Resource parts in STEP address geometry, materials, tolerances, configuration management, and other general requirements. Application Protocol (APs) parts have been developed to address specific products and processes.

SHIPLYS aims to connect a wide variety of ship design tools into one framework. Therefore, it is necessary to know the exact purpose of a single tool, its required inputs and generated outputs. Furthermore, the required and generated data must be put in context. An activity model is necessary to describe the typical work flow of the design process of ships. WP3 Task1 asks for the identification of transferable know how from existing models/approaches. One option chosen is to take into account the ISO10303 Application Activity Model of a ship's life cycle.

ISO 10303, also informally known as the Standard for the Exchange of Product model data (STEP), is a family of standards defining a robust and time-tested methodology for describing product data throughout the lifecycle of a product. STEP is widely used in computer-aided design (CAD) and product data/lifecycle management (PDM/PLM) systems. This mechanism is suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases, and as basis for archiving [4].

The list below shows the STEP Application Protocols (APs), which are all built on the same set of Integrate Resources (IRs) so they all use the same definitions for the same information. For example, AP203, AP214, AP238, and AP242 use the same definitions for three dimensional geometry, assembly data and basic product information.

- AP 201: Explicit Draughting[1]
- AP 202: Associative Draughting
- AP 203: Configuration Controlled Design
- AP 203e2: Configuration Controlled Design (second edition)
- AP 209: Composite and Metallic Structural Analysis and Related Design
- AP 210: Elecrconneackaging Design[2]
- AP 214: Automotive Design

[1] This part of ISO 10303 is applicable to the inter-organization Exchange of computer-interpretable drawings information and product definition data.

[2] Electronic assembly , interconnection and exchange design

- AP 215: Ship Arrangement
- AP 216: Ship Moulded Form
- AP 218: Ship Structures
- AP 219: Dimensional Inspection Information Exchange
- AP 221: Functional Data and Schematics for Process Plant
- AP 223: Cast Parts
- AP 224: Feature-Based Process Planning
- AP 225: Building Elements
- AP 227: Plant Spatial Configuration
- AP 232: Technical Data Packaging
- AP 235: Engineering Properties
- AP 236: Furniture Catalog and Interior Design
- AP 238: STEP-NC Integrated CNC
- AP 239: Product Life Cycle Support
- AP 240: Macro Process Planning
- AP 242: Managed Model Based 3D Engineering

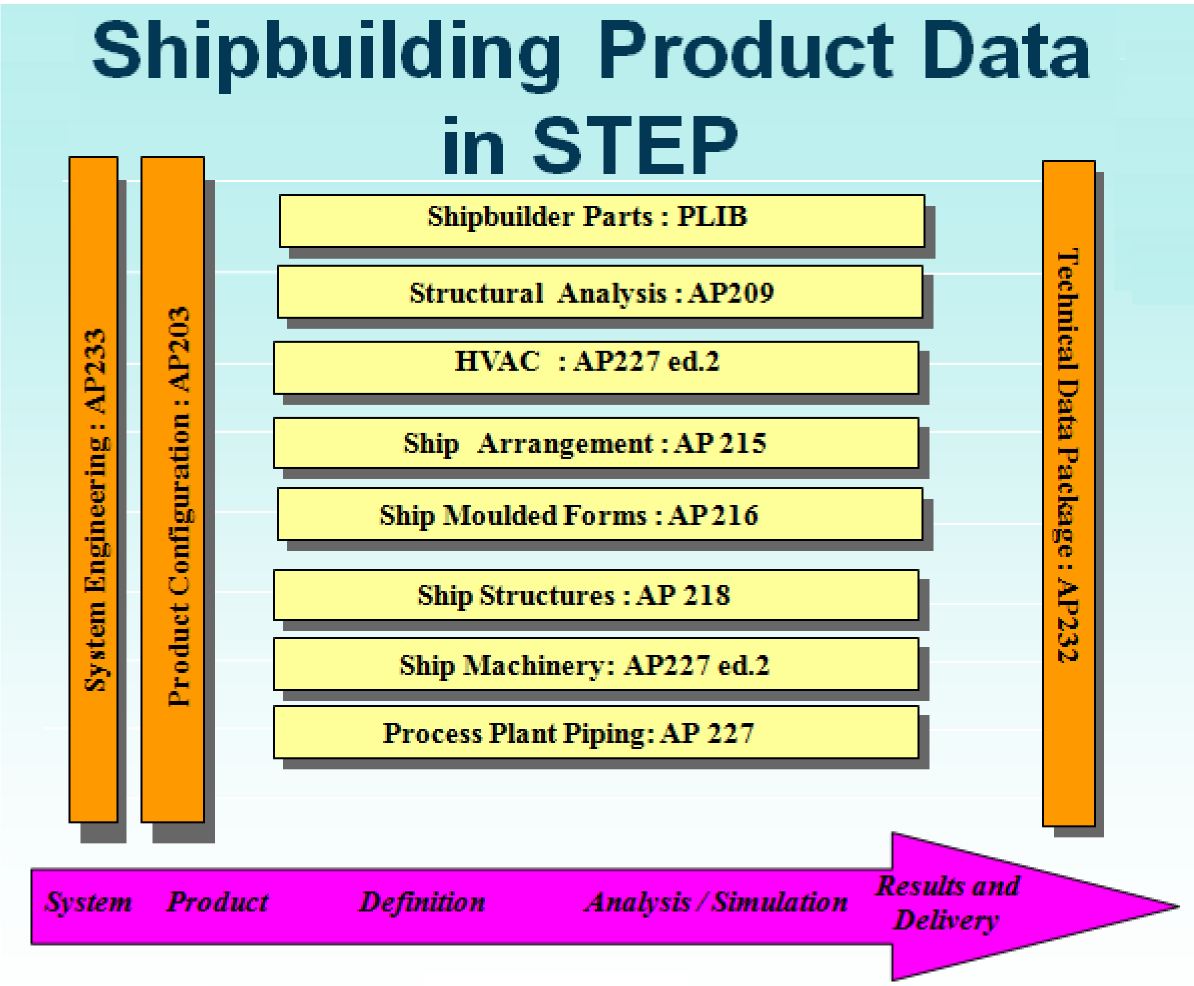


Figure 6: Shipbuilding product Data in STEP (I)

In the case of SHIPLYS, a set of application models (AM) of ISO10303 (215,216,218 plus the abandoned part 226 and 227) together aim to provide an integrated computer interpretable product model for ships.

Annex F of each of these AMs, which are of interest for SHIPLYS, contains the Application Activity Model (AAM). In the following, the Applications models (AM) related to SHIPLYS can be seen in more detail:

SHIP STRUCTURAL ENVELOPE APPLICATION PROTOCOLS (APs)

- AP 215: *Industry Standard – Ship Arrangement:*

This application protocol has been developed to support the downstream design stages (and not the early stage) in the product (ship) life cycle: detail design, production engineering, etc., for both commercial and navy ships. It provides a detailed definition (property, function, geometric representation, etc.) of the internal subdivision of the ship into compartments, zones in addition to the relationships between these spaces. Furthermore, it offers a detailed description of many aspects associated with the ship arrangements like the definition of cargo, damage stability analysis, loading conditions, etc.

For thus, AP 215 addresses the transfer of product definition necessary to support necessary to support the following activities:

  - Subdivision of ships into compartments and zones.
  - Volumetric capacity calculations.
  - Compartment connectivity/adjacency checking.
  - Stability calculation and spatial accessibility.
  - Area/volume reporting.
  - Tank capacities.

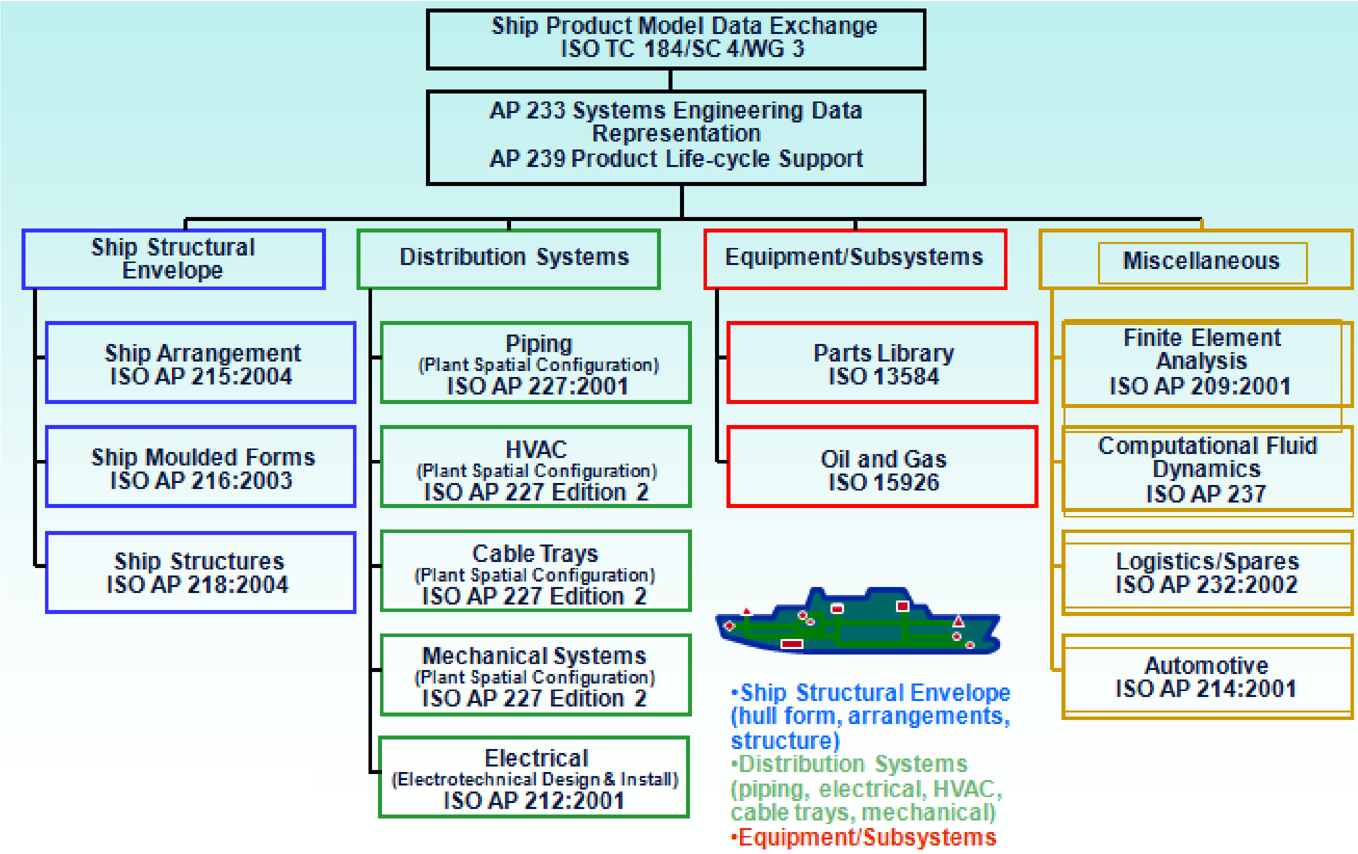


Figure 7: Shipbuilding product Data in STEP (II)

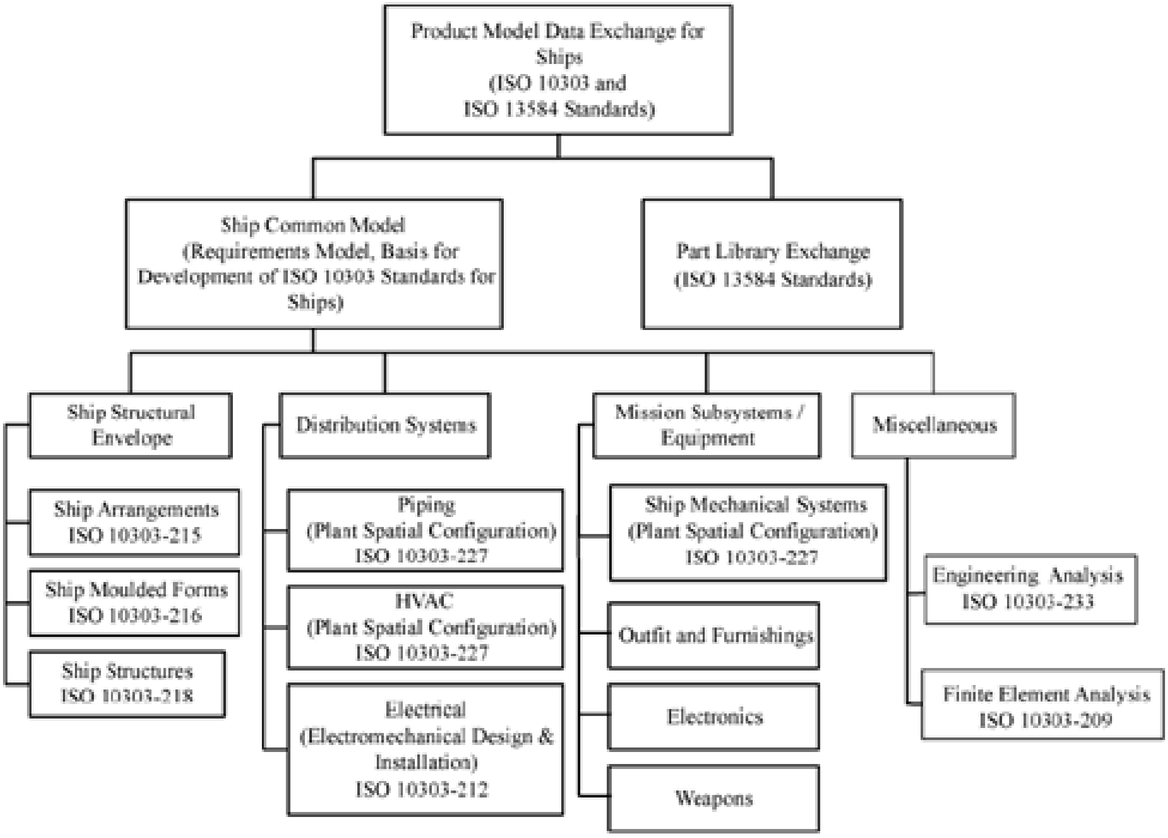


Figure 8: Initial Ship Application Protocols

- <u>AP 216: *Ship moulded forms:*</u>

Ship moulded forms and hydrostatic properties are the subject of this application protocol. It fosters the geometrical representation of the different ship moulded forms like: ship hull (mono- and multi-hull forms), rudder, propeller and other appendages, by addressing their shape and design parameters. AP 216 has been developed especially to enhance the geometry and hydrostatics exchange of the hull moulded form, from the beginning of the design process and between different design partners.

For thus, AP 216 addresses principle hull moulded form dimensions and characteristics, appendages , hydrostatic properties, and control surfaces.

- <u>*AP218 : Industry standard – Ship Structure*</u>

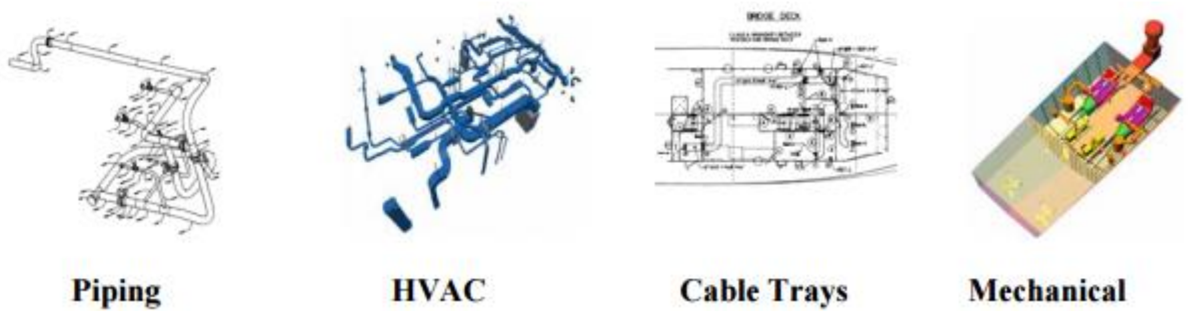
This part of ISO 10303 has been developed to improve the data exchange of ship structures between different organizations such as classification societies, shipyards, etc. in the design, production, maintenance and inspection phases during the ship's lifecycle. Therefore, tackles the transfer of product model data to support the shipbuilding activities and applications associates with the design phase and the early stages of manufacturing such as:

- Plates.
- Profiles.
- Assembly.
- Connectivity and change identification.

DISTRIBUTED SYSTEM APPLICATION PROTOCOLS (APs)

- *AP 227: Plant spatial configuration*

AP 227:2005 is an ISO standard that addresses the spatial configuration of items in process plants and ships. AP 227:2001 supports the transfer of product definition necessary to support piping design in process plant facilities. Edition 2 adds HVAC and cable tray information and distributed system information such as: flow; sizing; stress; connectivity checks; system testing; interference detection; fabrication; assembly and installation instructions. Edition 2 also addresses mechanical systems, such as conveyor systems or a ship power train



The intended use of the mentioned ISO10303 Activity Model in SHIPLYS is to provide the underlying model to be used for work flow control. Therefore, it is a necessary criterion for the chosen representation to be machine readable. Due to the considerable quantity, complexity and interaction of activities involved in a ships life cycle, it is important to find a representation which is easy to read/evaluate by domain experts.

It is important to emphasize that there is a standard that structures the activities of design and production, which will facilitate the development of the project if it is used as a working methodology.

Therefore, the Activity Model based on ISO 10303 that are applicable to the project objectives in relation to Early Ship Design and LCA will be detailed below.

On the other hand, the application of this standard will allow the development of the project with a methodology already established and later to complete the standard following the needs of the project.

4.1 SHIPLYS Activity Model

The SHIPLYS activity model contains all the activities necessary for the function of the SHIPLYS tool. The SHIPLYS activity model is developed according to the guidelines of the ISO 10303 standard, with several modifications and additions in order to meet the SHIPLYS tool's particular needs.

In this section, a short presentation of the activities of the ISO 10303 standard pertinent to the SHIPLYS tool is conducted.

The ISO 10303 standard contains all the activities that describe the performance of the life cycle analysis of a ship, as they are presented in the following figure.

A0

Path Name	A0
Common Name	A0
Aliases	Perform ship lifecycle
Description	All of the lifecycle activities associated with a ship.
Activities	A3, A1, A4, A2, A5
Inputs	A0.historical data from previous designs, A0.knowledge and experience
Controls	A0.scrapping plan, A0.transportation need, A0.manufacturing restrictions, A0.product component information, A0.laws, rules and regulations
Outputs	A0.feedback, A0.ship product model data
Mechanisms	resources
Transitions	A5→A2, A2→A3, A5→A3, A5→A1, A1→A2, A1→A3, A2→A0, A2→A1, A2→A4, A2→A5, A0→A5, A3→A4, A3→A5, A3→A0, A3→A1, A4→A1, A4→A2, A4→A3, A0→A1, A4→A5, A4→A0, A3→A2, A0→A2, A0→A3, A0→A4

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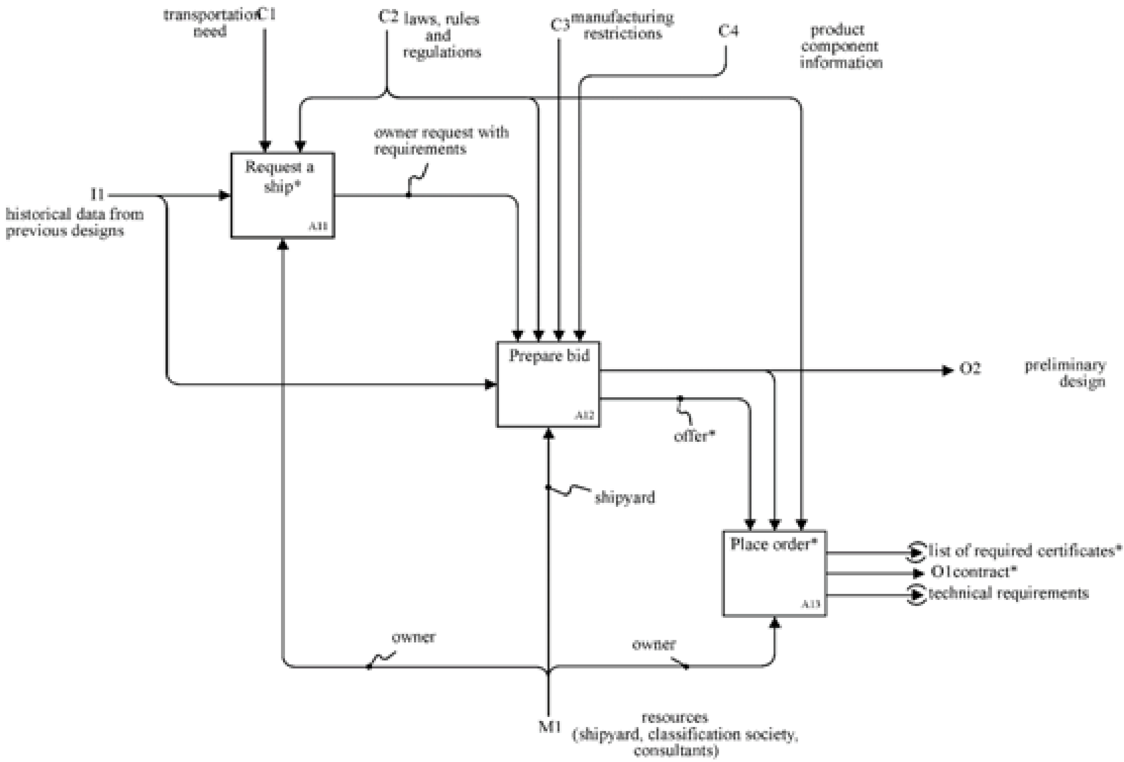


Figure 9: Node A0 Perform Ship Life Cycle

The SHIPLYS tool is an early ship design tool with life cycle analysis capabilities. Consequently, only the first node “A1: Specify ship” of the ISO model will be adopted and enhanced with life cycle analysis features, in order to meet the tool’s needs. The structure of node A1, according to ISO is presented in the following figure.

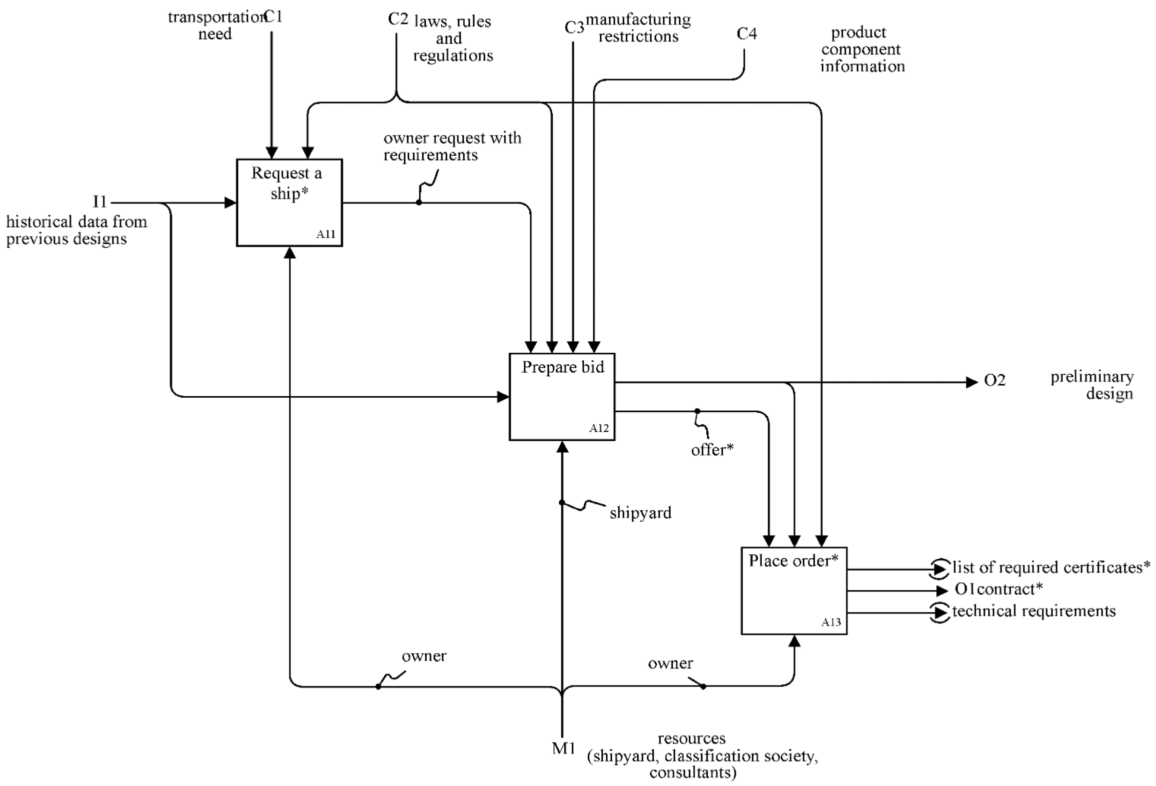


Figure 10: Node A1 Specify Ship

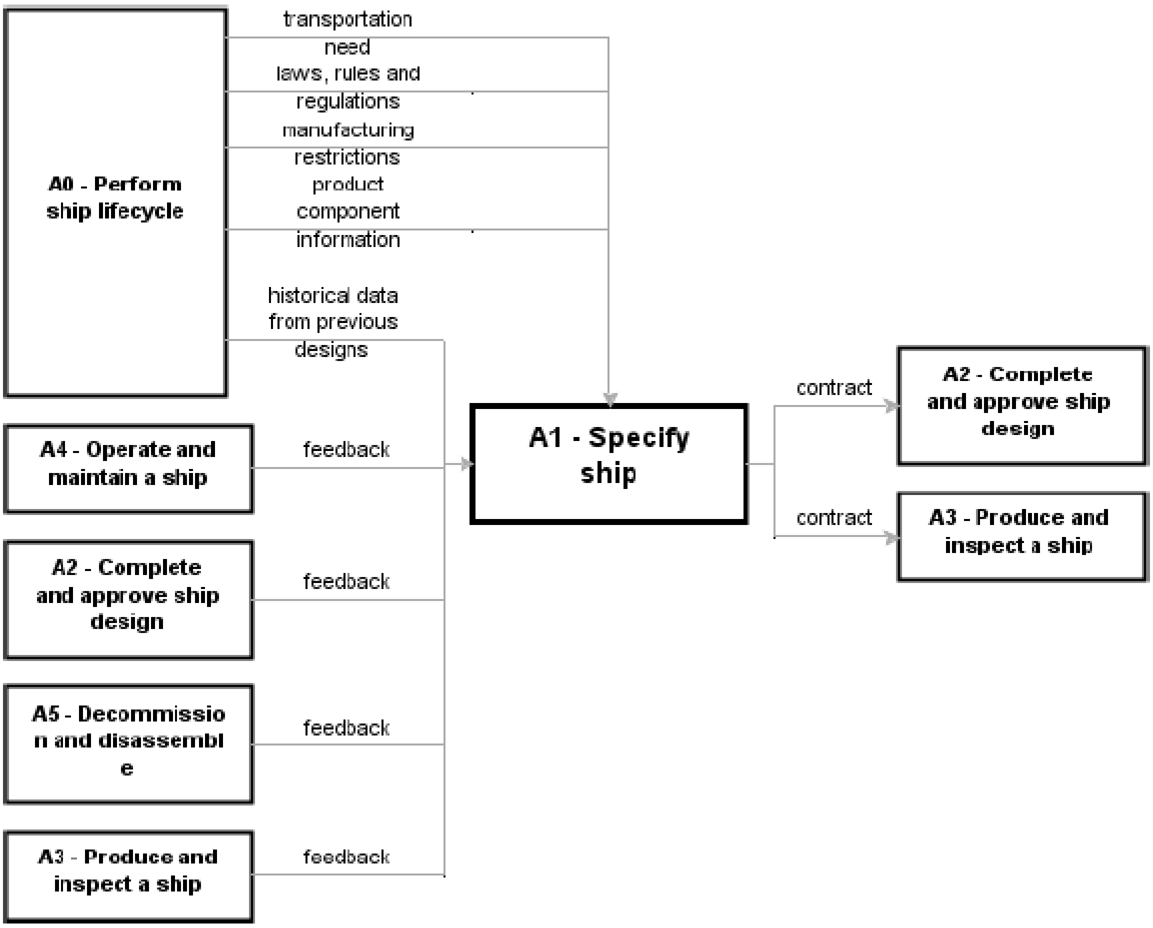
Node A1 contains all the activities associated with the production of a detailed specification of the ship prior to a contract being placed. It contains the sub-nodes A11, A12, A13, which will be briefly described in the following sections.

In the following table, a short overview of node A1 is presented. The first line, named “path name”, represents the path of nodes that led to A1. The following two are the common name and the alias of the activity. In the next, a short description of the activity is listed. The line “activities” lists all the sub-activities that are included in node A1. Inputs to the node are listed in the following line. *Controls* represent the parameters that control the function of the activity and *outputs* represent the results of the activity. *Mechanisms* refer to the organizations, people and means necessary for the implementation of the activity. The mechanism resources refer to the shipyard, the classification societies and outside consultants. The final line of the table shows the transitions between the activity and its various sub-activities. This is the form that all activity overview tables follow.

SHIPLYS

A1

Path Name	A0—A1
Common Name	A1
Aliases	Specify ship
Description	All activities associated with the production of a detailed specification of the ship prior to a contract being placed.
Activities	A12, A11, A13
Inputs	feedback, historical data from previous designs
Controls	transportation need, laws, rules and regulations, manufacturing restrictions, product component information
Outputs	contract, technical requirements, list of required certificates, preliminary design
Mechanisms	resources
Transitions	A13→A1, A1→A12, A1→A13, A11→A12, A1→A11, A12→A13, A12→A1

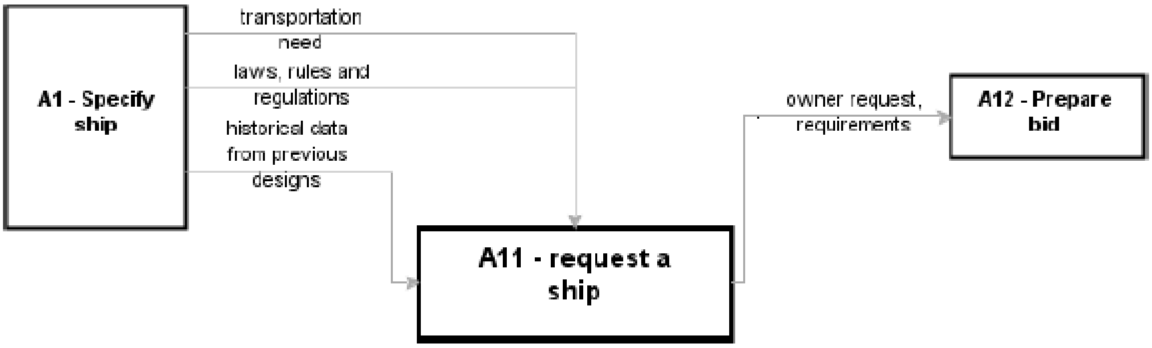


4.1.1 Request a ship (A11)

Activity "A11 Request a ship" includes the first activities of a ship owner when intending to order a ship. Having definite ideas regarding appearance and functionality of the ship, the owner expresses these ideas in an inquiry to the shipyard. Input to this activity is the historical data from previous designs which are utilized for the design of the new ship and output of the activity are the owner's request and requirements. Additionally, activity A11 contains no sub-activities, resulting in the absence of transitions. The following table is an overview of activity A11.

A11

Path Name	A0—A1—A11
Common Name	A11
Aliases	request a ship
Description	The first activities of a ship owner when intending to order a ship. Having definite ideas regarding appearance and functionality of the ship, the owner expresses these ideas in an inquiry to the shipyard.
Activities	
Inputs	historical data from previous designs
Controls	transportation need, laws, rules and regulations
Outputs	owner request, requirements
Mechanisms	owner

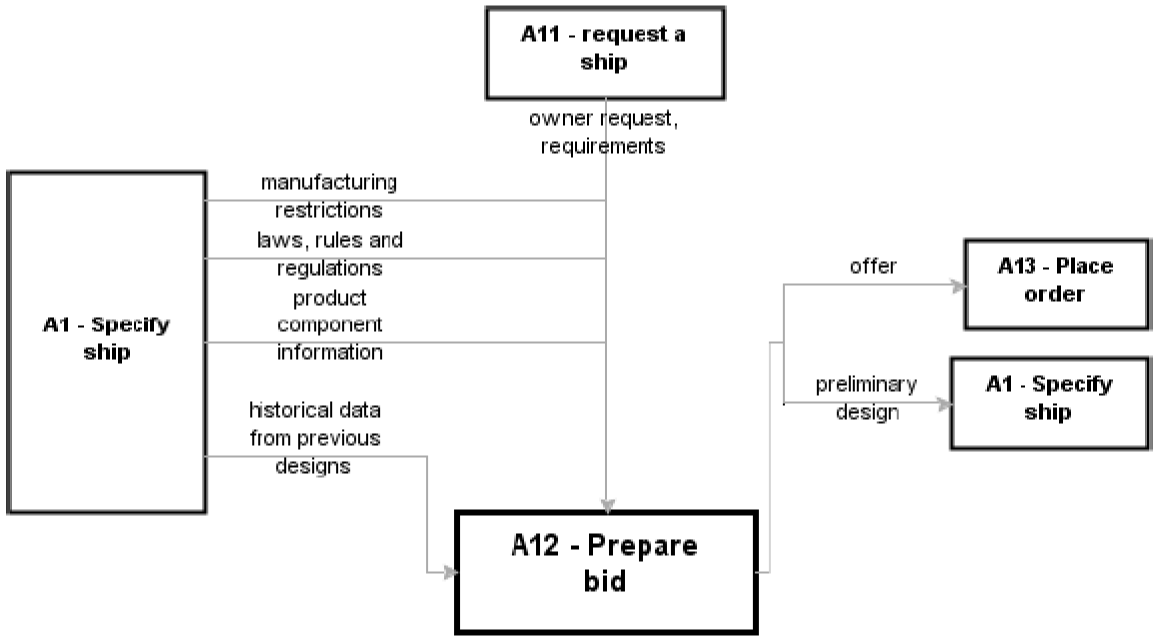


4.1.2 Prepare Bid (A12)

Activity “A12 Prepare Bid” includes all activities of the yard associated to the preparation and submission of the offer to the ship owner for the ship to be built. According to the ISO standard, it contains the sub-activities “A121 Evaluate request & schedule bid”, “A122 Create preliminary design”, “A123 Decide post-sales & maintenance support”, “A124 Calculate cost of ship”, “A125 Present offer”. The overview of activity A12 is presented in the following figure and table.

A12

Path Name	A0—A1—A12
Common Name	A12
Aliases	Prepare bid
Description	This activity includes all activities of the yard regarding preparation and submission of the offer to the ship owner for the ship to be built.
Activities	A122, A125, A123, A121, A124
Inputs	historical data from previous designs
Controls	laws, rules and regulations, manufacturing restrictions, product component information, owner request, requirements, budget
Outputs	offer, preliminary design
Mechanisms	resources
Transitions	A122→A123, A122→A124, A12→A122, A12→A123, A12→A124, A122→A125, A121→A122, A125→A12, A123→A125, A122→A12, A12→A121, A124→A125, A123→A124



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GA Ref: Ares (2016) 2353538

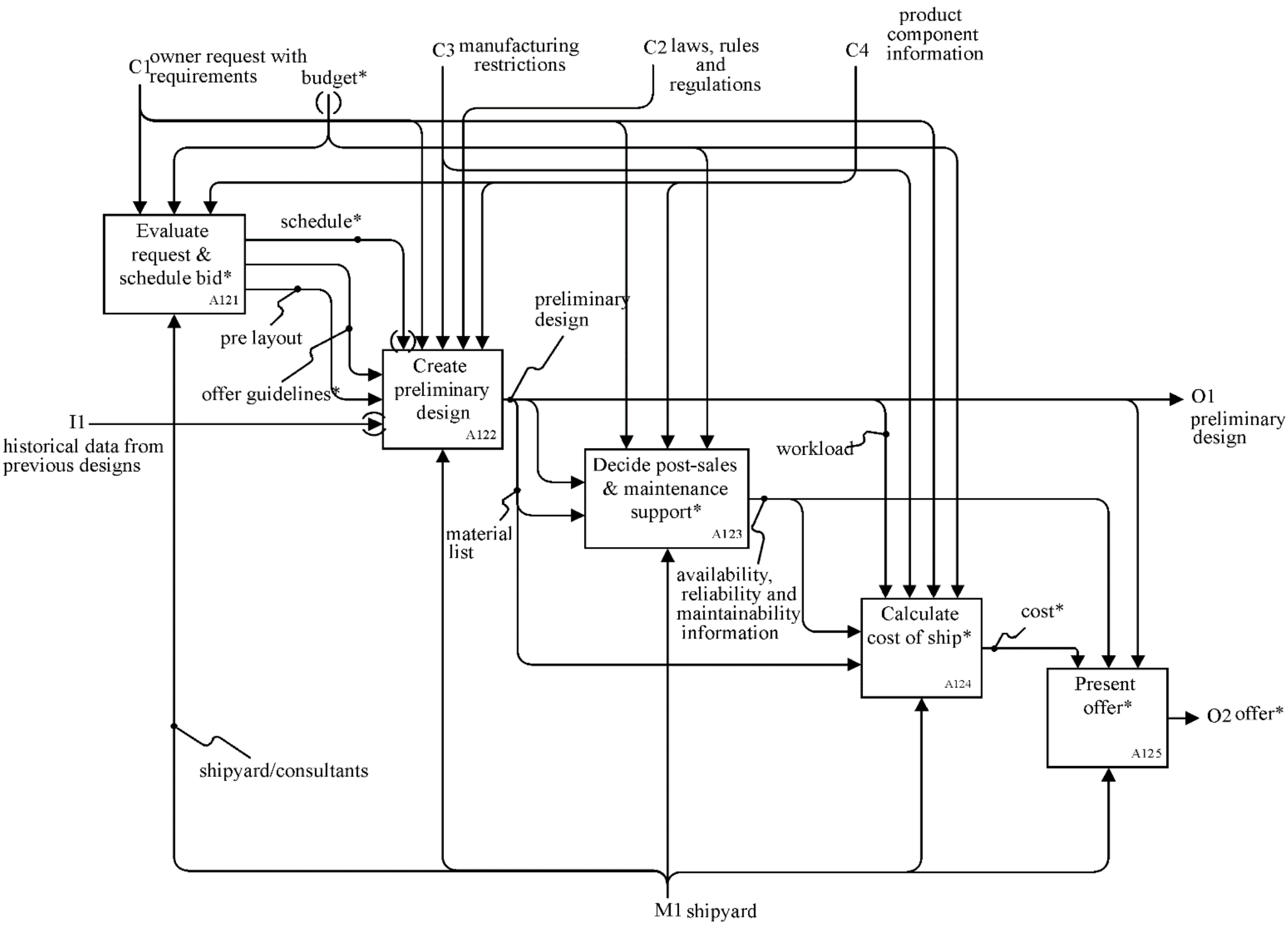


Figure 11: Node A12 Prepare Bid

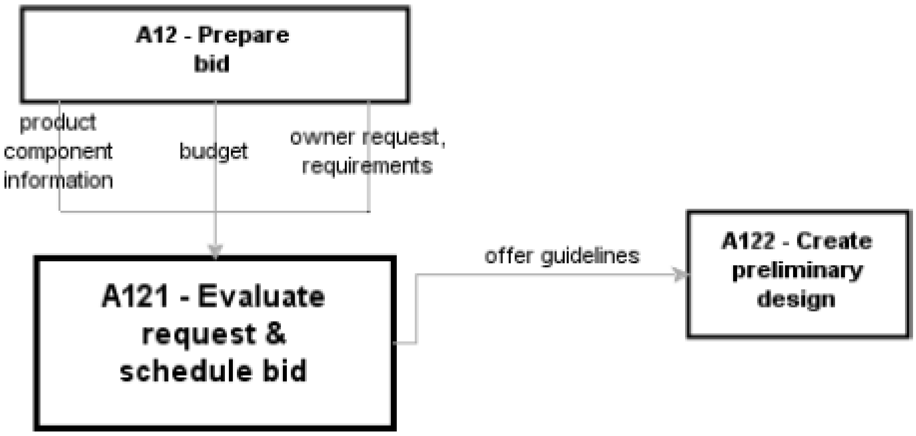
In the context of SHIPLYS, three more activities are added; "A126 Create preliminary design for retrofitting purposes"," A127 Estimation of environmental impact" and "A128 Assess risk and safety".

4.1.2.1 Evaluate request & schedule bid (A121)

Activity "A121 Evaluate request & schedule bid" describes the activities of the shipyard when evaluating the inquiry of the ship owner for a new ship and defining the basic order guidelines, scheduling the bid and creating a pre layout of the offer. Activity A121 does not contain any sub-activities.

A121

Path Name	A0—A1—A12—A121
Common Name	A121
Aliases	Evaluate request & schedule bid
Description	This describes the activities of the shipyard when evaluating the inquiry of the ship owner for a new ship.
Activities	
Inputs	
Controls	product component information, budget, owner request, requirements
Outputs	offer guidelines, schedule, pre layout
Mechanisms	shipyard and consultants



4.1.2.2 Create preliminary design (A122)

Activity "A122 Create preliminary design" includes all the design activities relevant to a very preliminary stage of ship design in consideration of classification society rules, national/international demands, shipyard constraints and owner requirements. The aim of this task is to make a shipyard offer. It contains sub-activities "A1221 Create preliminary hull form", "A1222 Create preliminary general arrangements", "A1223 Estimate hydrodynamics and powering", "A1224 Create preliminary structure design", "A1225 Create preliminary machinery design" and "A1226 Create preliminary outfitting design". The results of this activity are the materials list and the workload required for the construction of the ship, as well as the preliminary design of the ship. The overview of activity A122 is presented in the following figure and table.

A122

Path Name	A0—A1—A12—A122
Common Name	A122
Aliases	Create preliminary design
Description	All design activities relevant in a very preliminary stage of ship design in consideration of classification rules, national/international demands, shipyard constraints and owner requirements. The aim of this task is to make a shipyard offer.
Activities	A1225, A1226, A1223, A1224, A1221, A1222
Inputs	offer guidelines, pre layout, historical data from previous designs
Controls	schedule, laws, rules and regulations, manufacturing restrictions, product component information, owner request, requirements
Outputs	material list, workload, preliminary design
Mechanisms	shipyard and consultants
Transitions	A1223→A122, A1225→A122, A1226→A122, A1226→A1225, A1222→A122, A122→A1225, A1226→A1222, A1226→A1223, A122→A1222, A122→A1223, A122→A1224, A1226→A1221, A1224→A1225, A122→A1226, A1225→A1226, A1221→A1224, A1222→A1225, A1223→A1225, A122→A1221, A1224→A1221, A1221→A1222, A1222→A1224, A1223→A1226, A1225→A1223, A1221→A1223, A1222→A1223, A1225→A1222, A1224→A1222 , A1225→A1221, A1224→A122, A1223→A1221, A1221→A122, A1224→A1223, A1222→A1221

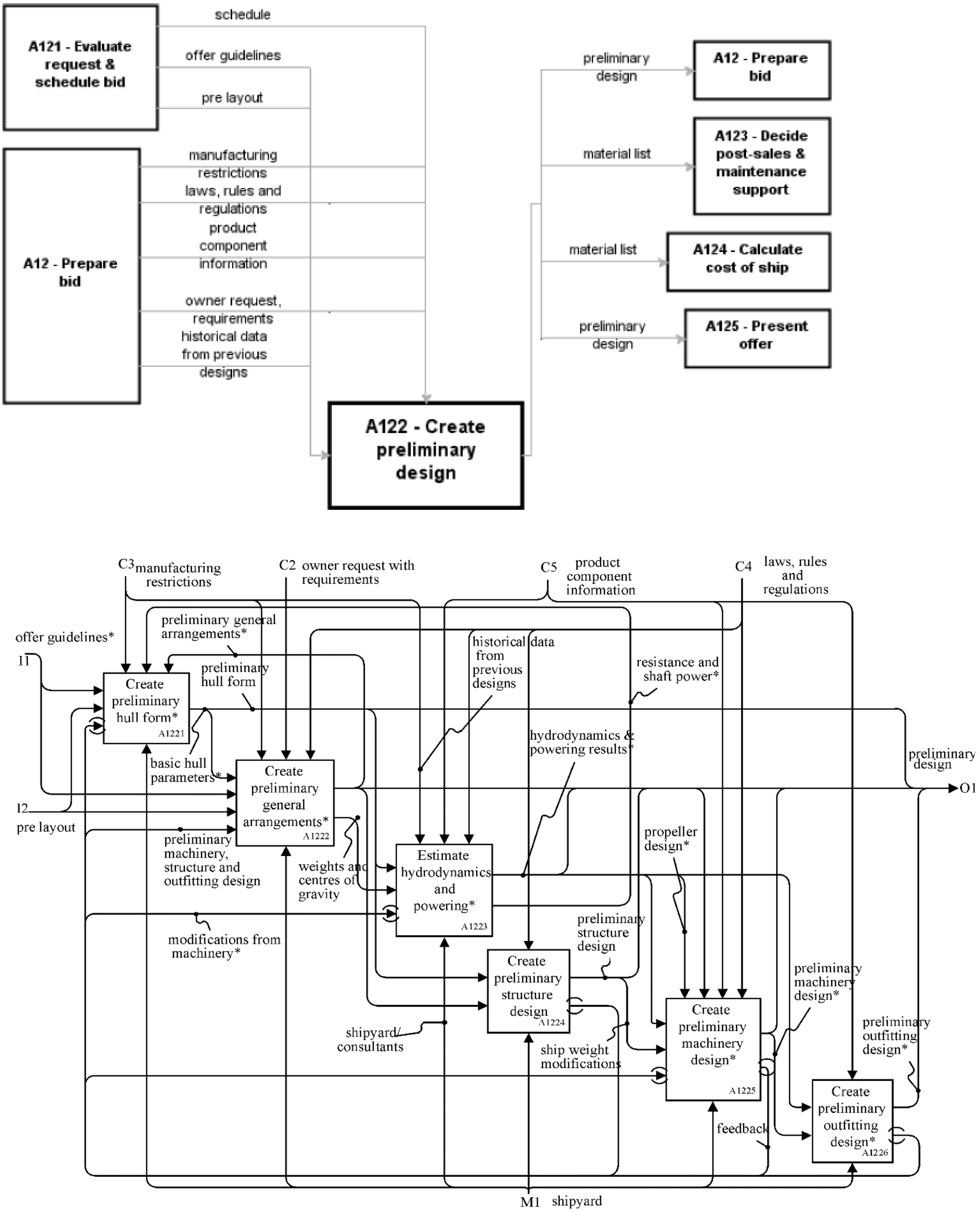


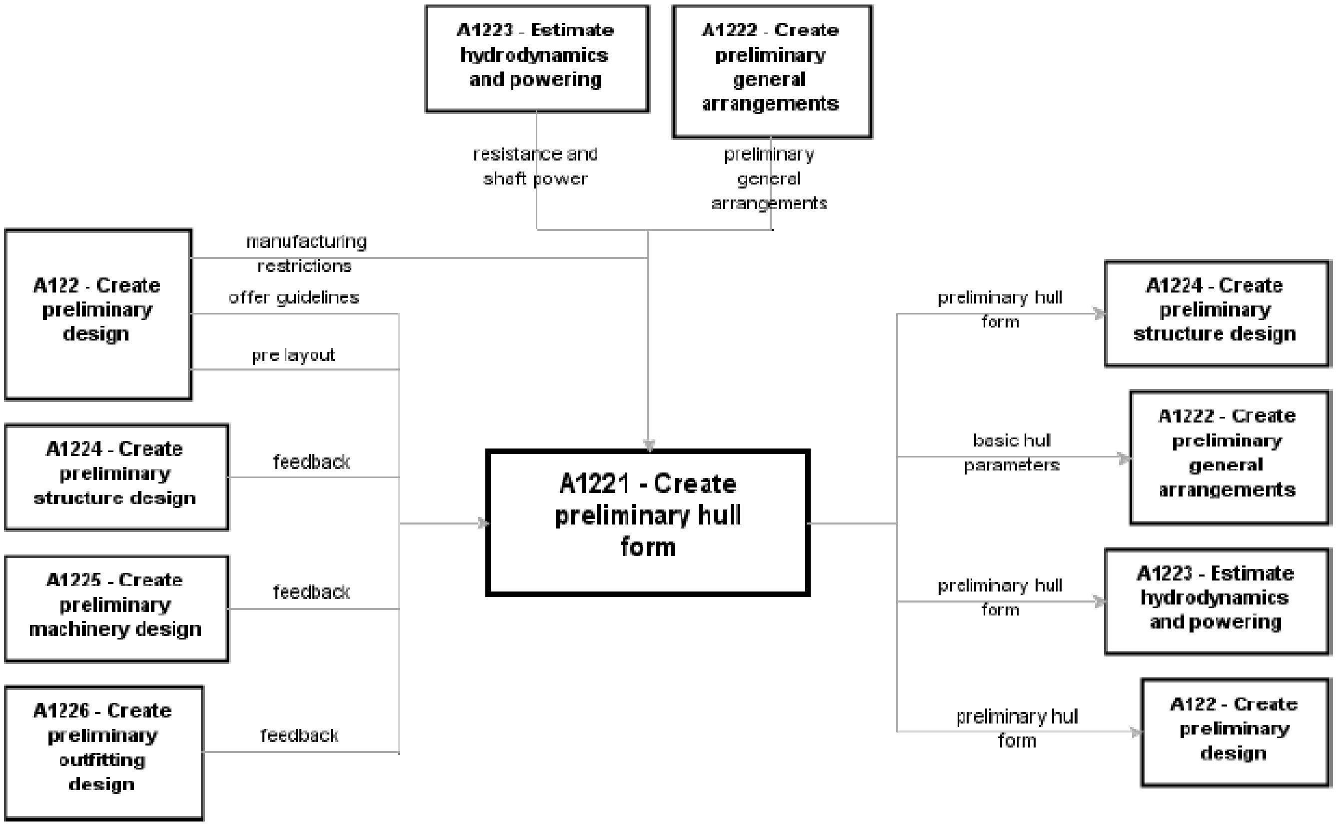
Figure 12: Node A122 Create Preliminary Design

4.1.2.2.1 Create preliminary hull form (A1221)

Activity "A1221 Create preliminary hull form" is the first step of designing a ship. Using parent ships main dimensions and form parameters, one or more preliminary hull forms can be generated. It contains sub-activities "A12211 Estimate main dimensions and parameters", "A12212 Estimate form parameters", "A12213 Do parametric variations" and "A12214 Generate initial hull form definition". The preliminary hull form output from this activity can be potentially improved through further iterations and future designs and it is very important that it is stored in a SHIPLYS database for further development and future use.

A1221

Path Name	A0—A1—A12—A122—A1221
Common Name	A1221
Aliases	Create preliminary hull form
Description	create preliminary hull form The activity that is the first step of designing a ship. Using parent ships main dimensions and form parameters one or more preliminary hull forms will be generated.
Activities	A12214, A12213, A12212, A12211
Inputs	feedback, offer guidelines, pre layout
Controls	resistance and shaft power, manufacturing restrictions, preliminary general arrangements
Outputs	basic hull parameters, preliminary hull form
Mechanisms	shipyard
Transitions	A12214→A1221, A1221→A12212, A12214→A12211, A12213→A12211, A12211→A12212, A12212→A12211, A12213→A12214, A1221→A12213, A1221→A12214, A1221→A12211, A12212→A12213

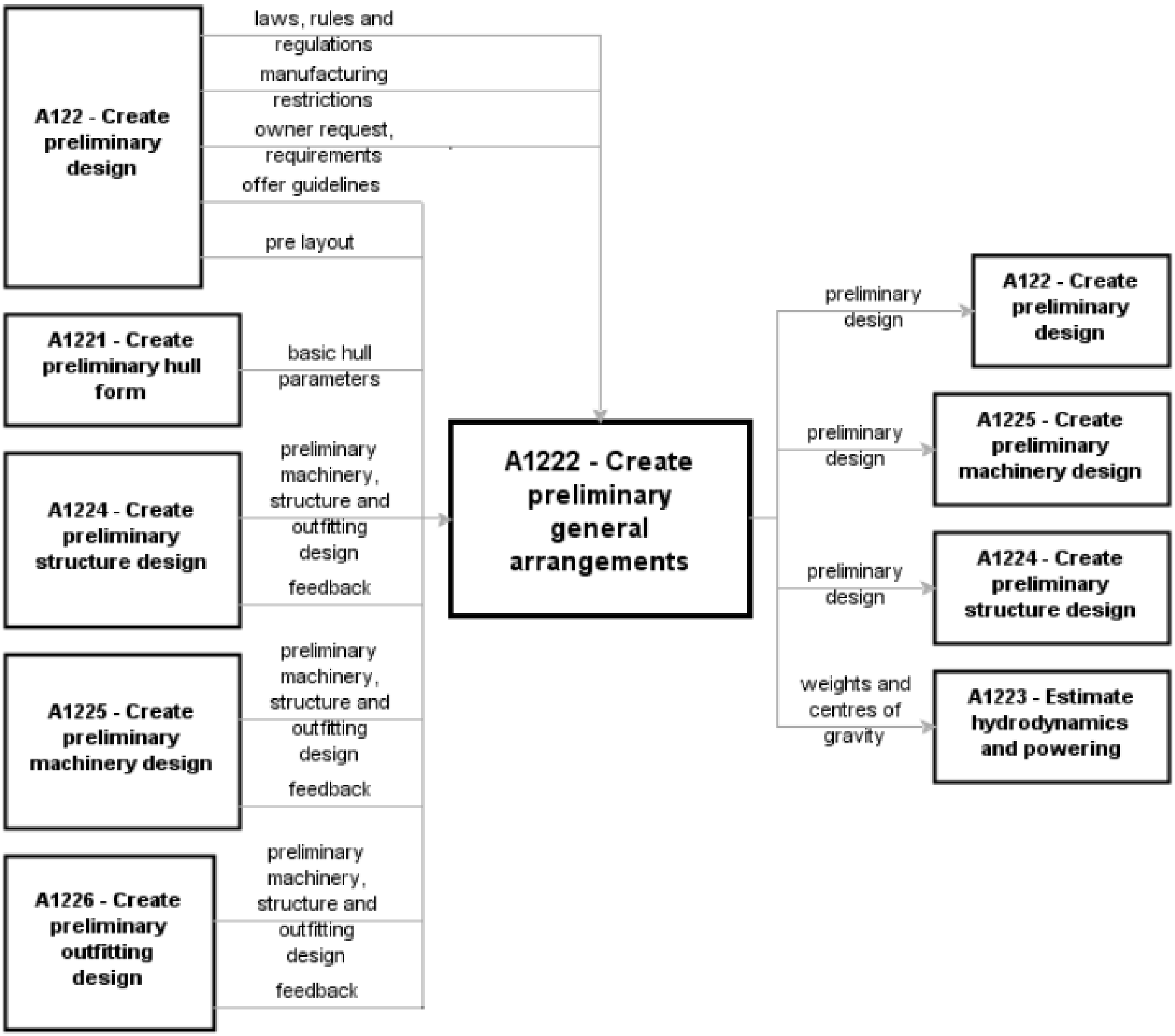


4.1.2.2.2 Create preliminary general arrangements (A1222)

Activity “A1222 Create preliminary general arrangements” produces the preliminary Compartmentalized plans from the preliminary hull form definition. It contains sub-activities “A12221 Define compartments”, “A12222 Calculate capacities”, “A12223 Estimate weight” and “A12224 Calculate stability and trim”, whereas each one of them contains further sub-activities. Activity A1222 outputs a preliminary general arrangement necessary for the preliminary design, weights and centers of gravity estimation and trim and stability parameters calculations.

A1222

Path Name	A0—A1—A12—A122—A1222
Common Name	A1222
Aliases	Create preliminary general arrangements
Description	The activity that produces the preliminary compartmentation plans from the preliminary hull form definition.
Activities	A12222, A12223, A12221, A12224
Inputs	offer guidelines, feedback, pre layout, preliminary machinery, structure and outfitting design, basic hull parameters, floodable curves
Controls	manufacturing restrictions, laws, rules and regulations, owner request, requirements
Outputs	weights and centres of gravity, trim, stability parameter, preliminary design
Mechanisms	shipyard
Transitions	A12221→A12224, A12221→A12223, A12222→A12224, A1222→A12222, A12221→A12222, A1222→A12223, A1222→A12224, A12223→A12221, A12224→A12221, A12222→A12221, A12223→A1222, A12224→A1222, A1222→A12221, A12223→A12224, A12221→A1222

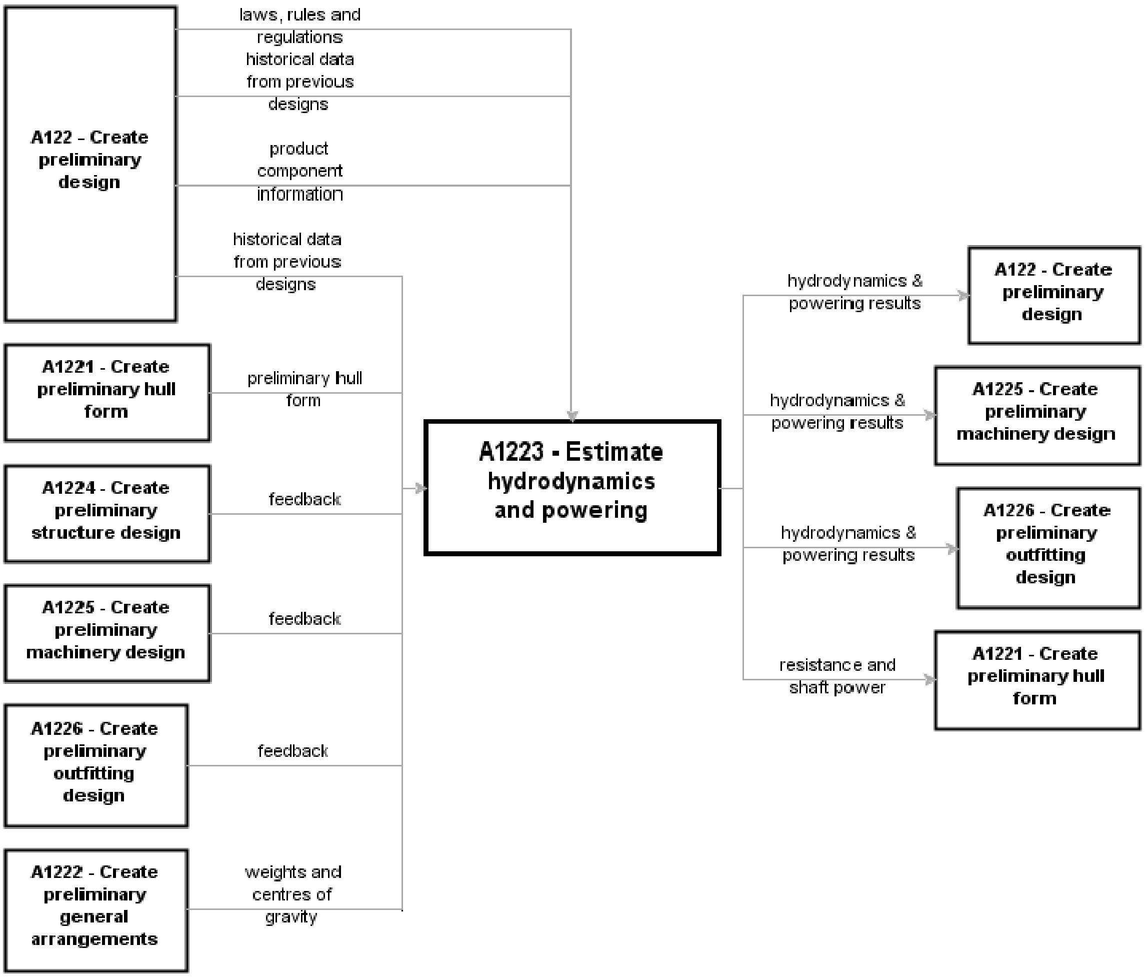


4.1.2.2.3 Estimate hydrodynamics and powering (A1223)

Activity "A1223 Estimate hydrodynamics and powering" estimates the hydrodynamic properties data such as resistance, propulsion, seakeeping and maneuverability for the preliminary hull form. Its sub-activities are "A12231 Estimate resistance and powering", "A12232 Estimate sea-keeping" and "A12233 Estimate maneuverability", whereas each one of them contains further sub-activities. Activity A1223 outputs the ship's resistance and shaft power necessary for the selection of main engine, maneuvering results, short and long term responses and hydrodynamics and powering results.

A1223

Path Name	A0—A1—A12—A122—A1223
Common Name	A1223
Aliases	Estimate hydrodynamics and powering
Description	The activity that approximates hydrodynamic properties data calculations such as resistance, propulsion, seakeeping and manoeuvrability for the preliminary hull form.
Activities	A12232, A12231, A12233
Inputs	feedback, weights and centres of gravity, historical data from previous designs, loading conditions, preliminary hull form
Controls	laws, rules and regulations, historical data from previous designs, product component information
Outputs	resistance and shaft power, manoeuvring results, short and long term responses, hydrodynamics & powering results
Mechanisms	shipyard
Transitions	A12231→A12212, A1223→A12231, A12233→A1223, A1223→A12233, A1223→A12232, A12232→A1223, A12231→A1223

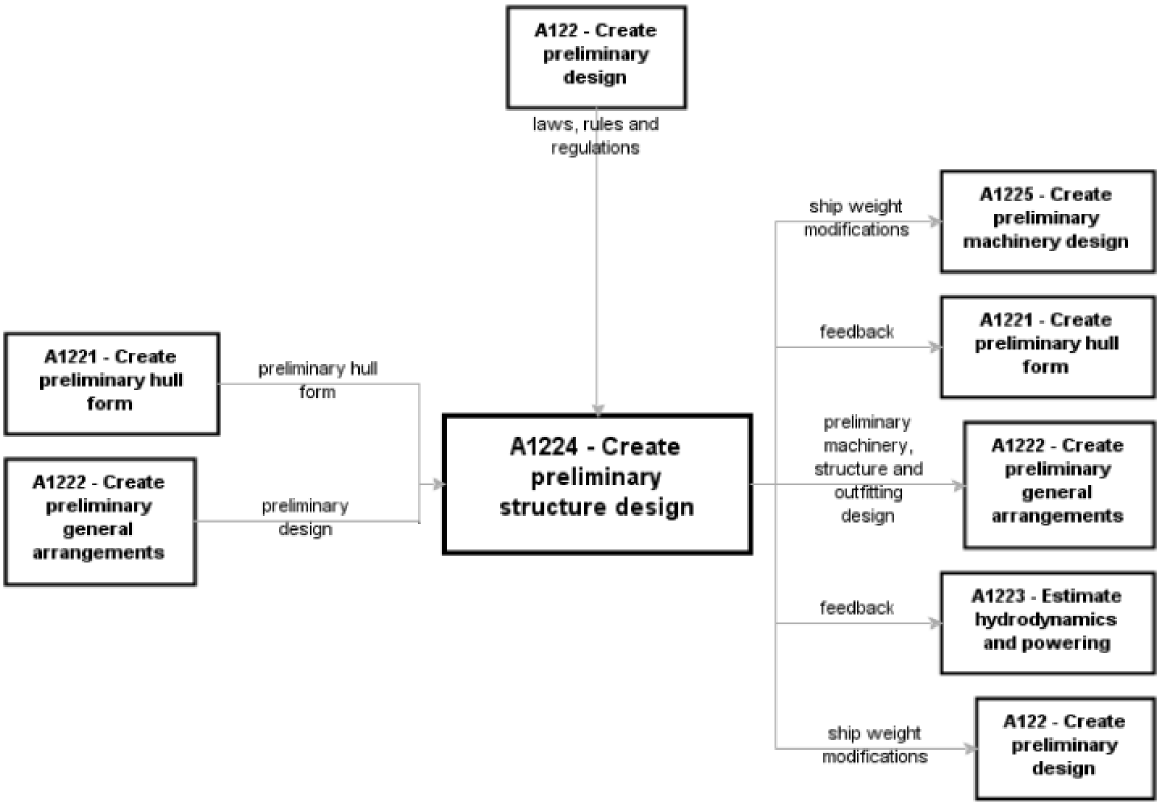


4.1.2.2.4 Create preliminary structure design (A1224)

Activity "A1224 Create preliminary structure design" produces the preliminary steel structure design, including the arrangement of the primary structural members. According to ISO 10303, A1224 contains no sub-activities. However, in the context of SHIPLYS some sub-activities need to be developed and utilized in the preliminary design phase. These sub-activities are "A12241 Calculate longitudinal strength", "A12242 Define midship section scantlings", "A12243 Define other transverse sections scantlings" and "A12244 Carry out preliminary superstructures structural design".

A1224

Path Name	A0—A1—A12—A122—A1224
Common Name	A1224
Aliases	Create preliminary structure design
Description	The activity that produces the preliminary steel structure design, including the arrangement of the primary structural members.
Activities	
Inputs	preliminary design, preliminary hull form
Controls	laws, rules and regulations
Outputs	feedback, preliminary machinery, structure and outfitting design, ship weight modifications
Mechanisms	shipyard

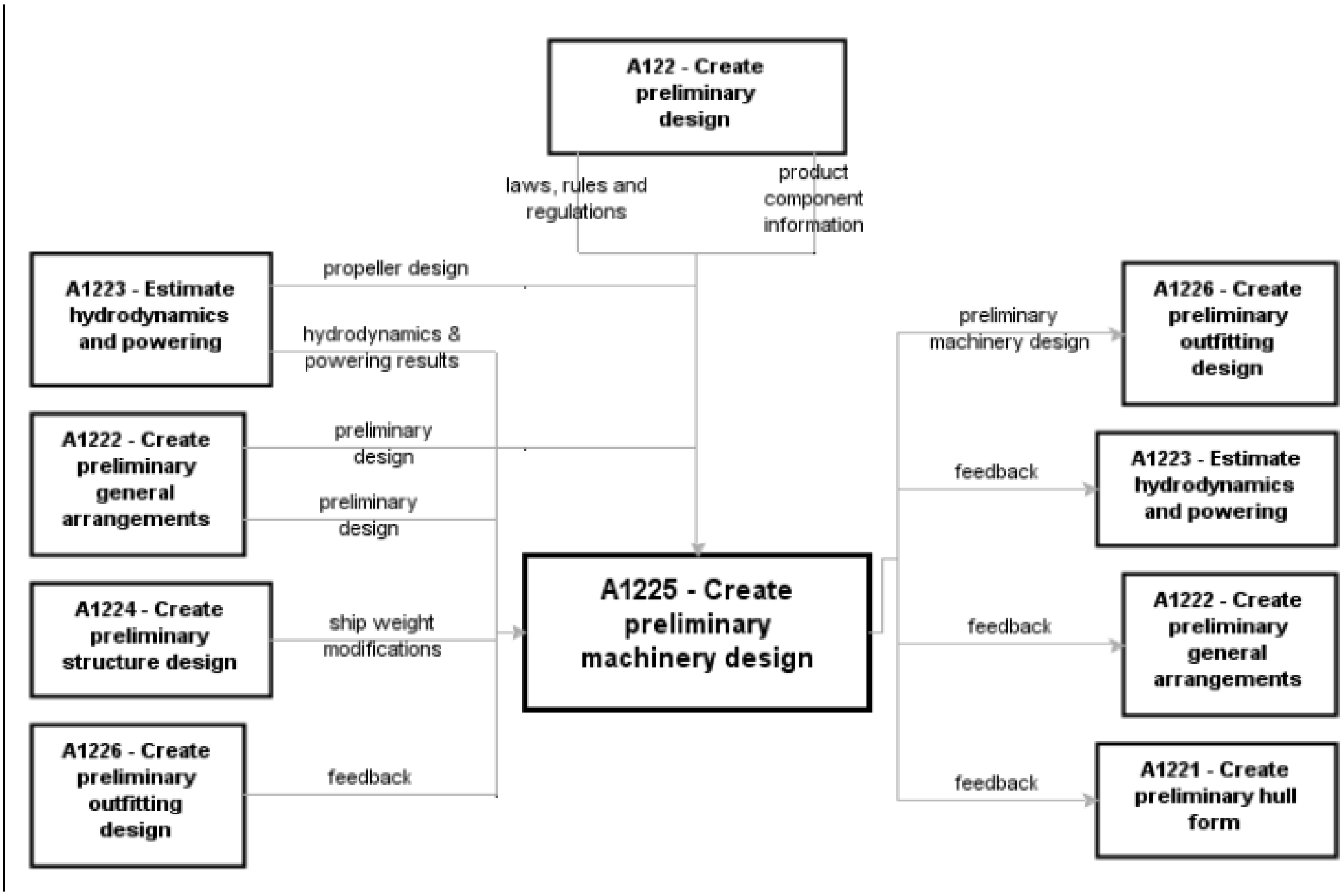


4.1.2.2.5 Create preliminary machinery design (A1225)

Activity "A1225 Create preliminary machinery design" produces the preliminary designs for the ship machinery, including the prime mover, shaft system, fuel system, power systems and cargo handling equipment. Its sub-activities are "A12251 Select main engine", "A12252 Design transmission system", "A12253 Select auxiliary equipment", "A12254 Design maneuvering systems" and "A12255 Select deck machinery", whereas each one of them contains further sub-activities. A1225 outputs the preliminary machinery design, the deck machinery, the auxiliary equipment and the maneuvering system.

A1225

Path Name	A0—A1—A12—A122—A1225
Common Name	A1225
Aliases	Create preliminary machinery design
Description	The activity that produces the preliminary designs for the ship machinery; including the prime mover, shaft system, fuel system, power systems and cargo handling equipment.
Activities	A12255, A12253, A12254, A12251, A12252
Inputs	feedback, hydrodynamics & powering results, preliminary design, ship weight modifications
Controls	laws, rules and regulations, product component information, propeller design, preliminary design
Outputs	feedback, auxiliary equipment, manoeuvring system, preliminary machinery design, deck machinery
Mechanisms	shipyard
Transitions	A12251→A12253, A12251→A12252, A1225→A12251, A1225→A12252, A12252→A12253, A12252→A12254, A1225→A12253, A12255→A1225, A1225→A12255, A12254→A1225, A12253→A1225, A1225→A12254, A12251→A12254

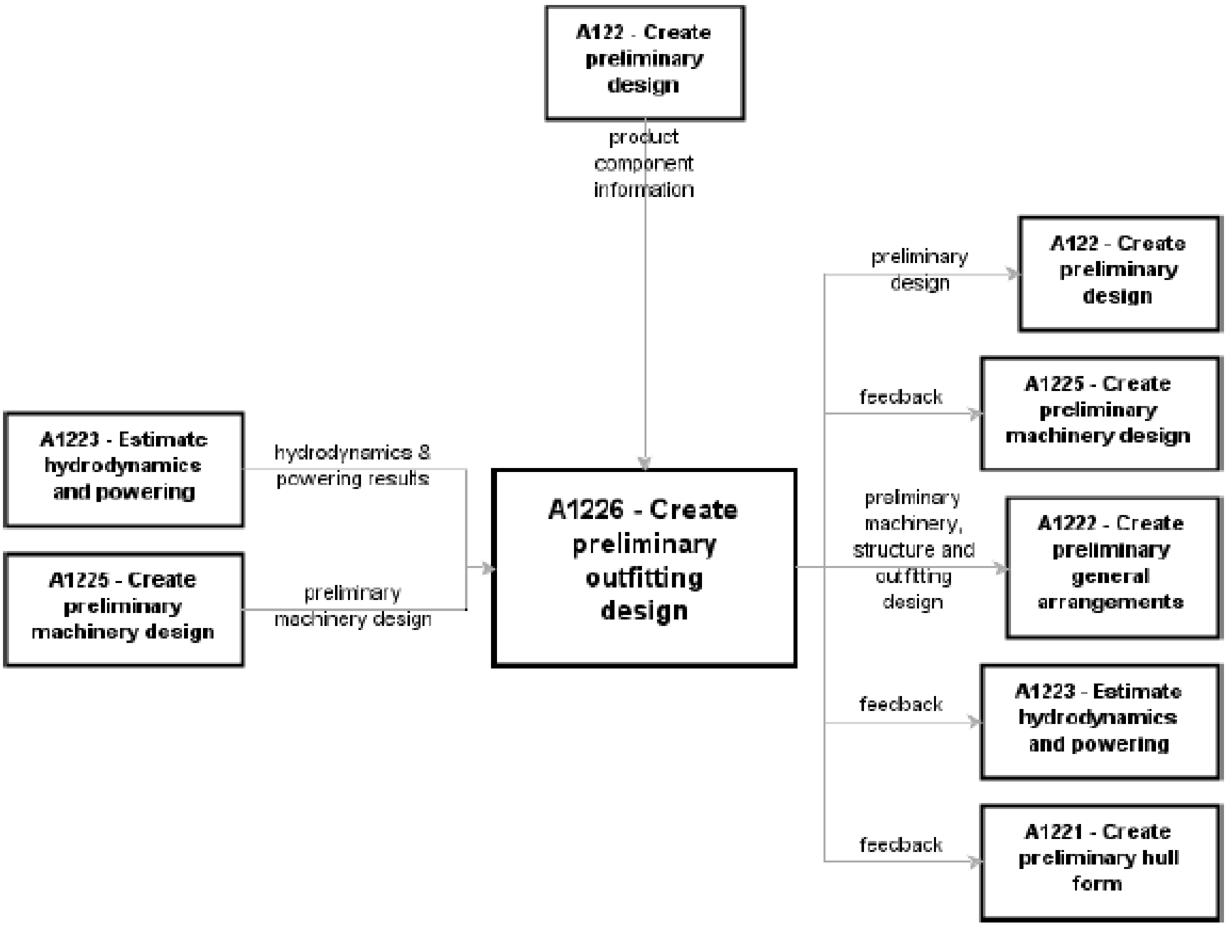


4.1.2.2.6 Create preliminary outfitting design (A1226)

Activity “A1226 Create preliminary outfitting design” produces the preliminary design for the ship’s outfitting, including systems such as piping and electrical systems. According to ISO 10303, A1226 contains no sub-activities. However, in the context of SHIPLYS some sub-activities need to be developed and utilized in the preliminary design phase. These sub-activities are “A12261 Calculate Equipment Number “ and “A12262-Generate equipment list”.

A1226

Path Name	A0—A1—A12—A122—A1226
Common Name	A1226
Aliases	Create preliminary outfitting design
Description	The activity that produces the preliminary design for the ship?s outfitting, including distributed systems, such as piping and electrical systems.
Activities	
Inputs	preliminary machinery design, hydrodynamics & powering results
Controls	product component information
Outputs	feedback, preliminary machinery, structure and outfitting design, preliminary design
Mechanisms	shipyard

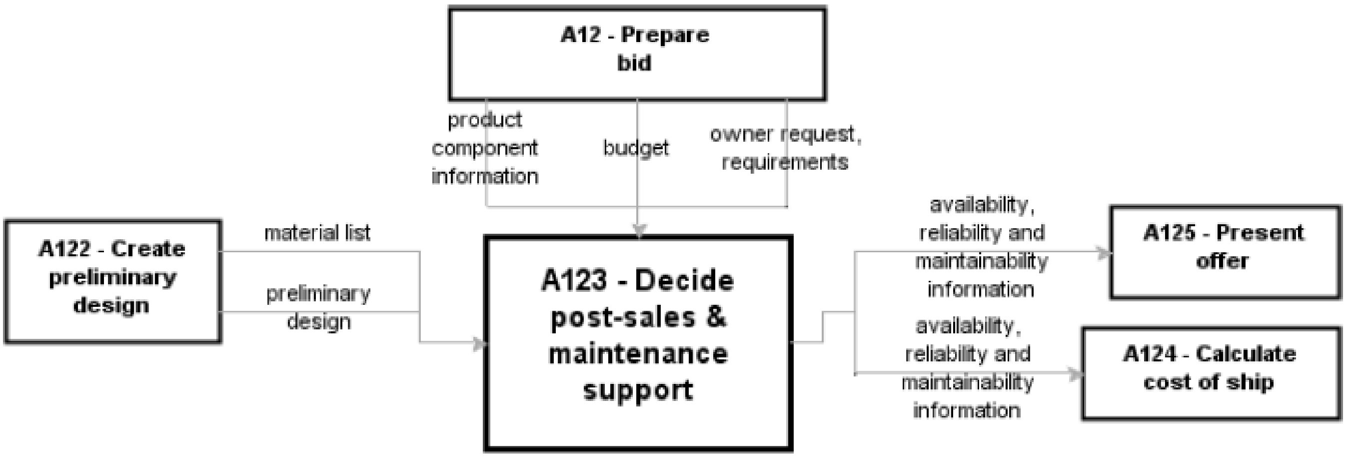


4.1.2.3 Decide post-sales & maintenance support (A123)

Activity "A123 Decide post-sales & maintenance support" puts together the maintenance package for the ship. This is part of the tender document and includes the post-sales support. It does not contain any sub-activities.

A123

Path Name	A0—A1—A12—A123
Common Name	A123
Aliases	Decide post-sales & maintenance support
Description	The activity that puts together the maintenance package for the ship. This is part of the tender document and includes the post sales support.
Activities	
Inputs	material list, preliminary design
Controls	product component information, budget, owner request, requirements
Outputs	availability, reliability and maintainability information
Mechanisms	shipyard and consultants

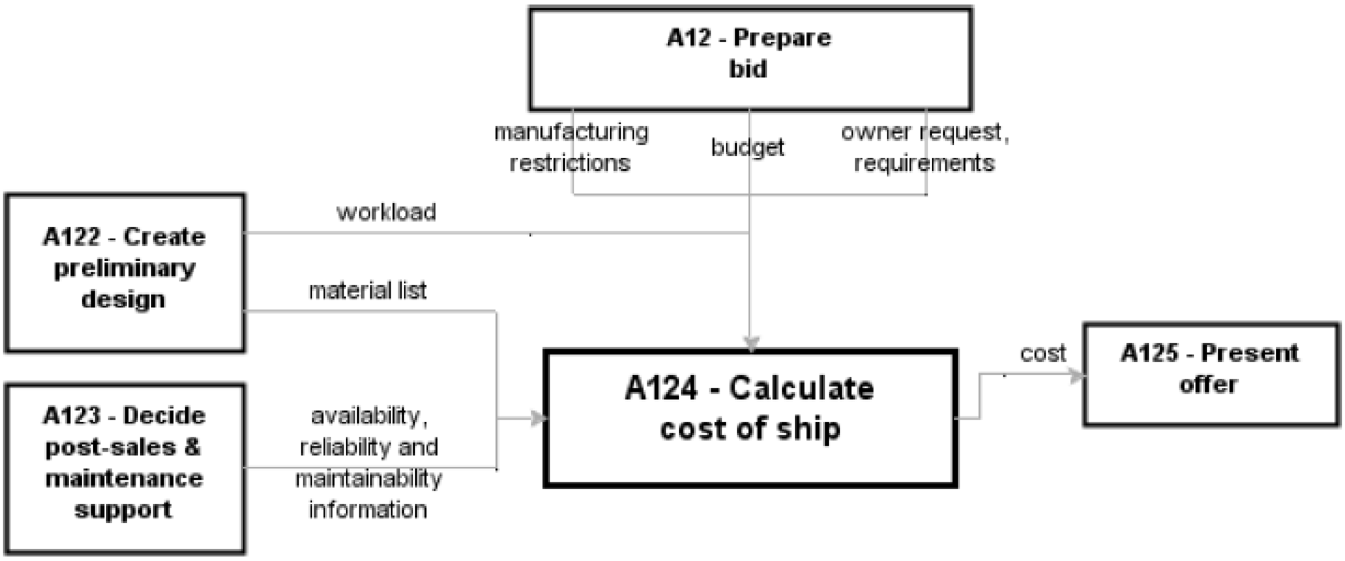


4.1.2.4 Calculate cost of ship (A124)

Activity "A124 Calculate cost of ship" describes the creation of negotiating documents based on technical product data and their estimated manufacturing cost. The results of this activity may contain sale price documents, financing support plan and documents describing funding and possible loans.

A124

Path Name	A0—A1—A12—A124
Common Name	A124
Aliases	Calculate cost of ship
Description	This activity describes creation of negotiating documents based on technical product data and their estimated manufacturing cost. The results of this activity may contain sale price documents, financing support plan and documents describing funding and possible loans.
Activities	
Inputs	material list, availability, reliability and maintainability information
Controls	manufacturing restrictions, workload, owner request, requirements, budget
Outputs	cost
Mechanisms	shipyard



According to ISO 10303, A124 contains no sub-activities. However, in the context of SHIPLYS some sub-activities need to be developed and utilized in the preliminary design phase. Some of them are part of "later" activities of the ISO 10303 model. These sub-activities are "A1241 Calculate cost of design", "A1242 Calculate cost of construction ", "A1243 Calculate cost of operation", "A1244 Calculate cost of maintenance/retrofitting/risk" and "A1245 Calculate cost of scrapping". In resume, the tree of sub-activities will be as follows:

A1241 Calculate cost of design

A12411 Estimate labor cost (incl. overheads, management, software …)

A12412 Estimate cost of Classification

A12413 Estimate cost of external experts (model tests, CFD analyses …)

A1242 Calculate cost of construction

A12421 Estimate hull cost

A12422 Estimate machinery cost

A12423 Estimate accommodation cost

A1243 Calculate cost of operation

A12431 Estimate insurance cost

A12432 Estimate crew cost

A12433 Estimate administration cost

A12434 Estimate consumables cost (fuel, oil …)

A12435 Estimate port cost

A1244 Calculate cost of maintenance/retrofitting/risk

A12441 Estimate cost of preventive maintenance

A12442 Estimate cost of corrective maintenance

A12443 Estimate docking cost

A12444 Estimate labour cost

A12445 Estimate material/spares cost

A12446 Estimate cost of potential risk (loss of cargo, human loss, damage ...)

A1245 Calculate cost of scrapping

A12451	Estimate transport cost
A12452	Estimate recycled material / reused equipment profit
A12453	Estimate hazardous waste disposal costs
A12454	Estimate dismantling cost

4.1.2.4.1 Calculate cost of Design (A1241)

Activity "A1241 Calculate cost of Design" calculates all the costs associated with the design of the ship. Such costs are the labor cost, the cost of obtaining the necessary software, the cost of the design and computing hardware, the cost of the necessary databases, etc.

Based on this activity SHIPLYS will include new sub-activities like A12411 Estimate labor cost, A12412 Estimate cost of classification and A12413 Estimate cost of external experts. All these sub-activities will be very important for fulfill the objectives of SHIPLYS and especially the needs of different shipyard that integrate the project.

In resume, this activity will include:

- A12411 Estimate labor cost (incl. overheads, management, software …)
- A12412 Estimate cost of Classification
- A12413 Estimate cost of external experts (model tests, CFD analyses …)

It´s very important to remark that, these sub-activities currently are not included in ISO 10303, but in the next work packages will be considered with the target of include them in the SHIPLYS tool.

4.1.2.4.2 Calculate cost of Construction/Retrofitting (A1242)

Activity "A1242 Calculate cost of Construction" calculates all the costs related to the construction of the ship. Such costs are the labor cost, the cost of materials (steel, aluminum, etc.), the welding cost, the cost of the necessary equipment. In resume, this activity will include:

- <u>A1242 Calculate cost of construction</u>
  - A12421 Estimate hull cost
    - A124211 Estimate cost of purchase of material
    - A124212 Estimate cost of cutting
    - A124213 Estimate cost of bending
    - A124214 Estimate cost of welding
    - A124215 Estimate cost of coating
    - A124216 Estimate cost of outfitting (including piping, wiring …)
  - A12422 Estimate machinery cost
    - A124221 Estimate cost of purchase of machinery
    - A124222 Estimate cost of installation
  - A12423 Estimate accommodation cost
    - A124231 Estimate cost of purchase of material
    - A124232 Estimate cost of cutting
    - A124233 Estimate cost of welding
    - A124234 Estimate cost of coating
    - A124235 Estimate cost of outfitting (including piping, wiring …)

Like the last sub-activity, it´s very important to remark that these sub-activities currently are not included in ISO 10303 but in the next work packages will be considered with the target of include them in the SHIPLYS tool.

4.1.2.4.3 Calculate cost of Operation (A1243)

Activity "A1243 Calculate cost of Operation" calculates all the costs related to the operation of the ship. Such costs are the cost of the crew, the fuel and lubricant cost, the cargo insurance cost, the taxation cost, etc.

In resume, this activity will include:

- A1243 Calculate cost of operation
  - A12431 Estimate insurance cost
  - A12432 Estimate crew cost
  - A12433 Estimate administration cost
  - A12434 Estimate consumables cost (fuel, oil …)
  - A12435 Estimate port cost

Like the other sub-activities, it´s very important to remark that these sub-activities currently are not included in ISO 10303 but in the next work packages will be considered with the target of include them in the SHIPLYS tool.

4.1.2.4.4 Calculate cost of Maintenance/Risk (A1244)

Activity "A1244 Calculate cost of Maintenance/Retrofitting/Risk" calculates all the costs associated with the maintenance and the retrofitting of the ship. Such costs are the labor cost, the docking cost, the spares cost, the retrofitting planning cost, etc. In resume, this activity will include:

- A1244 Calculate cost of maintenance/retrofitting/risk
  - A12441 Estimate cost of preventive maintenance
  - A12442 Estimate cost of corrective maintenance
  - A12443 Estimate docking cost
  - A12444 Estimate labor cost
  - A12445 Estimate material/spares cost
  - A12446 Estimate cost of potential risk (loss of cargo, human loss, damage ...)
  - A12447 Estimation cost for machineries maintenance

Like the other sub-activities, it´s very important to remark that these sub-activities currently are not included in ISO 10303 but in the next work packages will be considered with the target of include them in the SHIPLYS tool.

4.1.2.4.5 Calculate cost of Scrapping (A1245)

Activity "A1245 Calculate cost of Scrapping" calculates all the costs related to the scrapping of the ship. Such costs are the labor cost, the cost of the scrap material handling, the cost of transport to scrap, the cost of the ship breaking yard, etc. In resume, this activity will include:

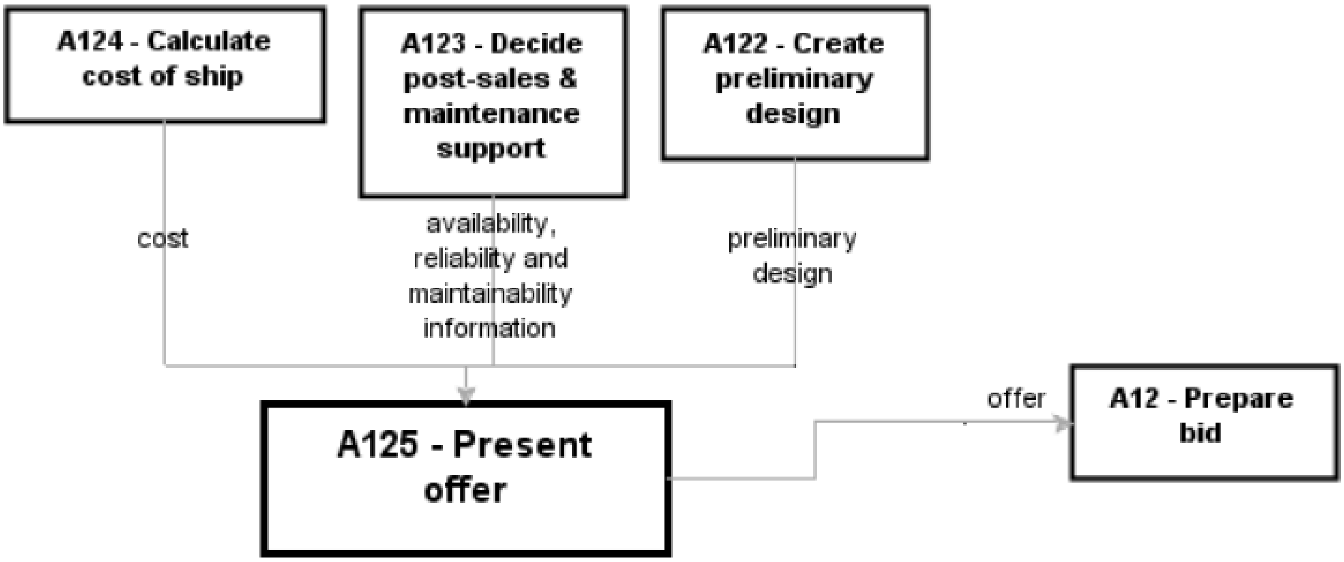
- A1245 Calculate cost of scrapping
  - A12451 Estimate transport cost
  - A12452 Estimate recycled material / reused equipment profit
  - A12453 Estimate hazardous waste disposal costs
  - A12454 Estimate dismantling cost.

Like the other sub-activities, it´s very important to remark that these sub-activities currently are not included in ISO 10303 but in the next work packages will be considered with the target of include them in the SHIPLYS tool.

4.1.2.5 Present offer (A125)

Activity "A125 Present offer" refers to the presentation of the offer to build the ship to the prospective ship owner

Path Name	A0—A1—A12—A125
Common Name	A125
Aliases	Present offer
Description	The activity concerned with presentation of the offer to build the ship to the prospective ship owner.
Activities	
Inputs	
Controls	cost, availability, reliability and maintainability information, preliminary design
Outputs	offer
Mechanisms	shipyard



4.1.2.6 Create preliminary design for retrofitting purposes (A126)

Activity "A126 Create preliminary design for retrofitting purposes" contains all the required activities for the planning of a retrofit of an existing vessel. Retrofitting requires several special preliminary tasks, such as the detailed designs of the ship's spaces where the retrofit is going to be applied. First, it is necessary to evaluate the information provided by the shipowner in order to evaluate the scope of the work to be carried out.

The information that the shipyard needs to be able to offer and plan the works has three different sources:

- Three-dimensional model supplied by the shipowner or developed by the shipyard (3D model).
- Two-dimensional model supplied by the shipowner or developed by the shipyard (Model 2D).
- Three-dimensional scanning done by the shipyard. (3D scanning)

Consequently, activity A1261contains some dedicated sub-activities, as follows.

4.1.2.6.1 Create preliminary machinery and outfitting design (A1261)

Sub-activity "A1261 Create preliminary machinery and outfitting design" refers to the creation of the preliminary designs of the spaces (include outfitting and machinery), where the retrofit is going to take place. 3D scanning technology will facilitate specific information for SHIPLYS tool.

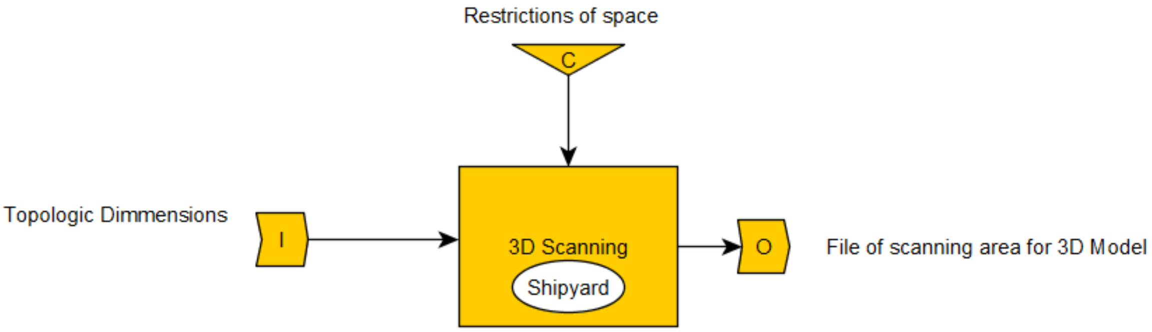


Figure 13: Node A1261 Retrofitting

Like the other sub-activities, it´s very important to remark that this sub-activity currently is not included in ISO 10303 but in the next work packages will be considered with the target of include them in the SHIPLYS tool.

4.1.2.6.2 Create 2D model (A1262)

Sub-activity “A1262 Create 2D model” refers to the 2D model generation of the ship space and containing the retrofit itself. There are two ways of obtaining plans, one is through the shipowner's supply or, if not, developed by the shipyard. Below you can see the flowchart in which is defined the needs of shipyard want integrate or used in SHIPLYS tool.

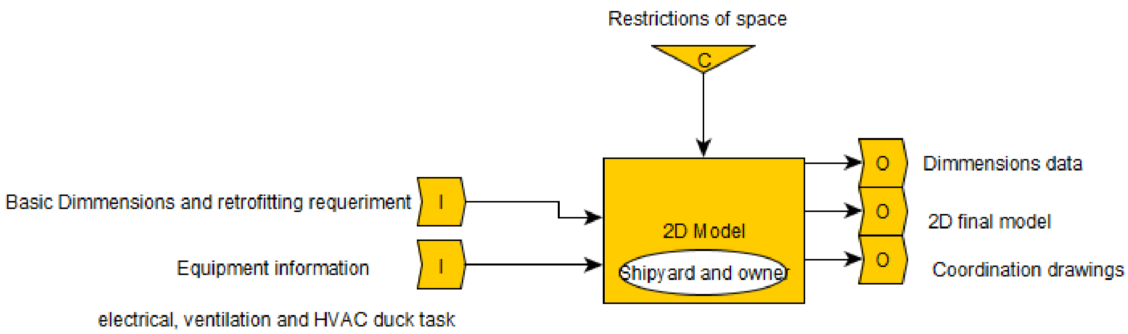


Figure 14: Node A1262 Retrofitting

Like the other sub-activities, it´s very important to remark that this sub-activity currently is not included in ISO 10303 but in the next work packages will be considered with the target of include them in the SHIPLYS tool.

4.1.2.6.3 *Create 3D model (A1263)*

Sub-activity "A1263 Create 3D model" refers to the 3D model generation of the ship space and the 3D model of the retrofit. There are two ways of obtaining plans, one is through the shipowner's supply or, if not, developed by the shipyard. Below you can see the flow diagram linked to the 3D model with the aim of obtain data with which the shipyard can make decisions related to the retrofitting´s works

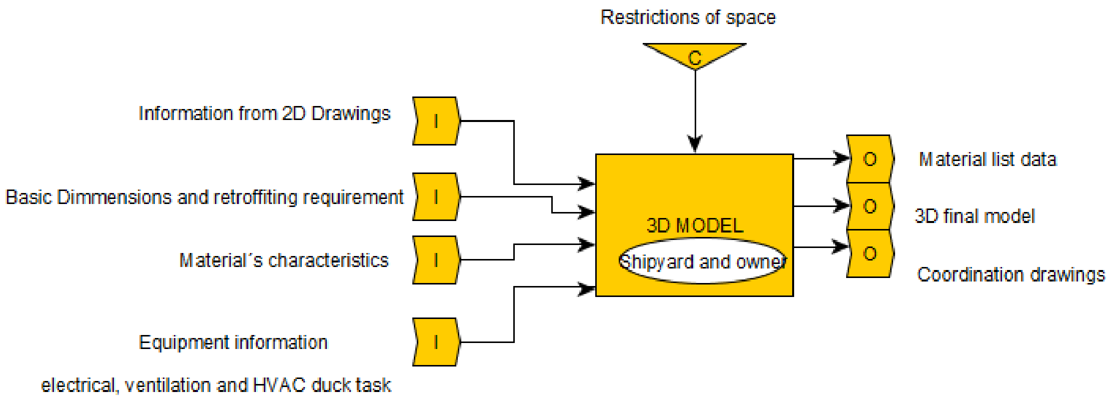


Figure 15: Node A1263 Retrofitting

Like the other sub-activities, it´s very important to remark that this sub-activity currently is not included in ISO 10303 but in the next work packages will be considered with the target of include them in the SHIPLYS tool.

It´s very important to remark what is the different between INPUTS, OUTPUTS, CONTROLS and MACHINERY, consequently, below is a summary with the different inputs, outputs, controls and Machinery linked with the flowchart.

Concerning to "INPUTS" are the data that comply the next items:

- Real objects or Data needed to perform a function (in this case, Function would be 3D Scanning, 2D model and 3D model).
- Objects or Data transformed by a Function.
- Labeled with a noun or noun phrase.

On the other hand, "OUPUTS" will be those as:

- Objects or data produced as a result of the Function.
- Labeled with a noun o noun phrase.

In the case of "CONTROLS" will be those as:

- That which governs the accomplishment of the Function.
- Thing that influence or determine the Outputs.
- Labeled with a noun or noun phrase.

And in the last case, “MACHINERY” will be those as:

- Person, device or data which carries out the Function.
- The means by which the function is performed.
- Labeled with a noun or noun phrase.

Function	Inputs	Outputs	Controls	Machinery	software used	type of output
3D Scanning	Topologic dimensions	File of scanning area for 3D Model	Restrictions of space	Shipyard	FARO	not available
						not available
						not available
2D Model	Equipment information (electrical, ventilation and HVAC duck task)	Dimension data, 2D final Model and Coordination drawings	Restrictions of space	Shipyard or owner	AutoCAD	.dwg
2D Model	Basic Dimensions and retrofitting requirement					
3D Model	Information from 2D Drawing	Material list, 3D final Model and Coordination drawings	Restrictions of space	Shipyard or owner	Solidworks	.sldprt
3D Model	Basic Dimensions and retrofitting requirement					.sldasm
3D Model	Material´s Characteristics					.step
3D Model	Equipment information (electrical, ventilation and HVAC duck task)					others

4.1.2.7 Estimate environmental impact (A127)

Activity “A127 Estimate environmental impact” is a new activity not included in the ISO standard and estimates the environmental impact of the ship’s life cycle from construction till scrapping with the following sub-activities. Each sub-activity contains several sub-activities for special calculations on estimations concerning each phase of the lifecycle of the ship.

A1271 Estimate environmental impact of construction

A12711 Estimate Global Warming Potential (GWP)

A12712 Estimate Acidification Potential (AP)

A12713 Estimate Eutrophication Potential (EP)

A12714 Estimate Photochemical Oxidant Creation Potential (POCP)

A1272 Estimate environmental impact of operation

A12721 Estimate Global Warming Potential (GWP)

A12722 Estimate Acidification Potential (AP)

A12723 Estimate Eutrophication Potential (EP)

A12724 Estimate Photochemical Oxidant Creation Potential (POCP)

A1273 Estimate environmental impact of maintenance

A12731 Estimate Global Warming Potential (GWP)

A12732 Estimate Acidification Potential (AP)

A12733 Estimate Eutrophication Potential (EP)

A12734 Estimate Photochemical Oxidant Creation Potential (POCP)

A1274 Estimate environmental impact of retrofitting

A12741 Estimate Global Warming Potential (GWP)

A12742 Estimate Acidification Potential (AP)

A12743 Estimate Eutrophication Potential (EP)

A12744 Estimate Photochemical Oxidant Creation Potential (POCP)

A1275 Estimate environmental impact of scrapping

A12751 Estimate Global Warming Potential (GWP)

A12752 Estimate Acidification Potential (AP)

A12753 Estimate Eutrophication Potential (EP)

A12754 Estimate Photochemical Oxidant Creation Potential (POCP)

Below, it´s introduced a brief description concerning to the different sub-activities that born of Estimate environmental impact (A127).

4.1.2.7.1 Estimate environmental impact of construction (A1271)

Sub-activity “A1271 Environmental impact of construction” is responsible for the assumption of the environmental impact of the construction of the ship.

Energy demands and emissions during the construction phase are used to evaluate the environmental impact of this phase in the life of a ship. To further aim the implementation of the LCA methodology, the sub-activities below are suggested, following the main impact categories used for evaluating environmental impact:

A12711 - Global Warming Potential (GWP)

A12712 - Acidification Potential (AP)

A12713 - Eutrophication Potential (EP)

A12714 - Photochemical Oxidant Creation Potential (POCP)

4.1.2.7.2 Estimate environmental impact of operation (A1272)

Sub-activity “A1272 Environmental impact of operation” is responsible for the assumption of the environmental impact of its operation taking into account the engine and machinery emissions.

Regarding environmental impact during operation, it is necessary to define different aspects that influence the environmental impact:

In the case of Vessel voyage and operational profile: The power and heating load demand of a vessel depends on the operational profile of a vessel and varies significantly for different type of vessels. For a given vessel the load again varies for different modes of operation, affecting environmental impact:

- Port condition
    - Load port
    - Discharge port
- Manoeuvring
- Full steaming at sea
- Varying Hotel and accommodation services load
- Cargo heating/cooling/refrigeration
- Offshore operations
- Lay-up periods

The description of the above given modes of operation annually/over a given time period can be used to average the power supply demand and hence the consumable supply can be determined approximately.

The consumable supply for operations: Consumables supply data can be used to determine the emissions and effluents form the operations of a vessel. Below is a very broad list of consumables for vessel operation in which influences environmental impact:

- Fuel Oil
- Lube Oil & Cylinder Oil (2-stroke engines)
- Paints
- Chemicals, additives cleaning agents etc.
- Power consumed in case of shore power supply.
- Spare parts inventories and discarded parts during maintenance
- Cleaning materials like rags, saw-dust etc.
- Equipment for Crew and Passengers

Waste & Effluents Generated from operations: Vessel operations not only cause emissions but generate other wastes and effluents as well. The data pertaining to the waste generated over the operational period. Typical wastes generated from ship operations can be like the following:

- Waste oil from bilges and separators.
- Effluents from bilges (Oily Water Separators and slops)
- Volatile Organic Compounds from tanker operations and others
- Sludge/muck
- Garbage like plastics and other harmful wastes

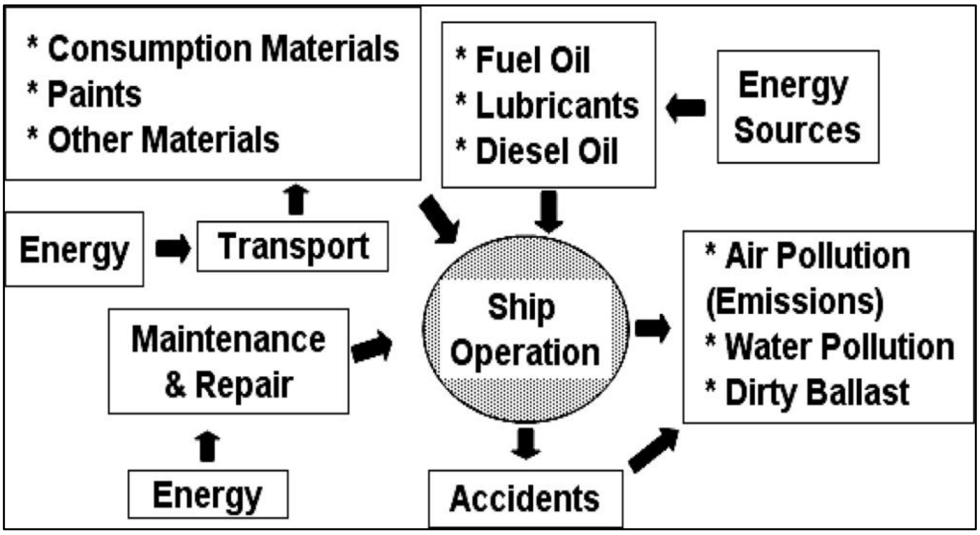


Figure 16: Energy and Environment in Ship Operations

4.1.2.7.3 Estimate environmental impact of maintenance (A1273)

Sub-activity "A1273 Environmental impact of maintenance" estimates the environmental impact of the maintenance. Regarding environmental impact of maintenance it is very important to remark that every vessel undergoes scheduled docking and in some cases emergency docking in the event of accidents or failures during the operation life. During operation minor work on the hull may be performed. Larger repair work or rebuilding may occur as a part of maintenance. The following major works are carried out at dockings and it have influencing in environmental impact:

- Steel-work
- Grit blasting and painting
- Shaft seal repairs
- Sea chest and sea valve repairs
- Sacrificial Anodic protection renewal
- Tank cleaning etc.

4.1.2.7.4 Estimate environmental impact of retrofitting (A1274)

Sub-activity "A1274 Environmental impact of retrofitting" estimates the environmental impact of the retrofitting of the ship. Regarding the environmental impact of retrofitting, it must be measured by the impact on the environment of one of the productive retrofitting activities that take place in the shipyard:

- Steel-work
- Grit blasting and painting
- Water consumption.
- Electricity consumption.

- Emissions to the atmosphere due to productive processes
- Waste due to productive processes
- Recycling of materials

4.1.2.7.5 Estimate environmental impact of scrapping (A1275)

Finally, sub-activity “A1275 Environmental impact of scrapping” estimates the environmental impact of scrapping.

The energy demand and environmental releases of ship scrapping procedures are used to estimate the environmental impact of this phase. Ship scrapping products also include usable materials, equipment, machinery, repairable engines, machinery, equipment etc.

In order to follow the main impact categories used for evaluating environmental impact, the sub-activities below are suggested as part of the designed ISO model:

A12751 - Global Warming Potential (GWP)

A12752 - Acidification Potential (AP)

A12753 - Eutrophication Potential (EP)

A12754 - Photochemical Oxidant Creation Potential (POCP)

4.1.2.8 Estimation of risk (A128)

This activity should estimate risk regarding new construction and retrofitting. For example, it should be able to calculate probability of structural failure and other risks. It´s divided in the follow sub functionalities

A1281 A-Identify hazard of new ship design

A1282 B- Identify hazard of retrofitting design

A1283 C- Identify hazard of maintenance

A1284 D- Identify hazard of retrofitting construction

A1285 Risk assessment: A, B, C and D

A1286 Estimate risk control options: A, B, C and D

A1287 Cost benefit assessment: A, B, C and D

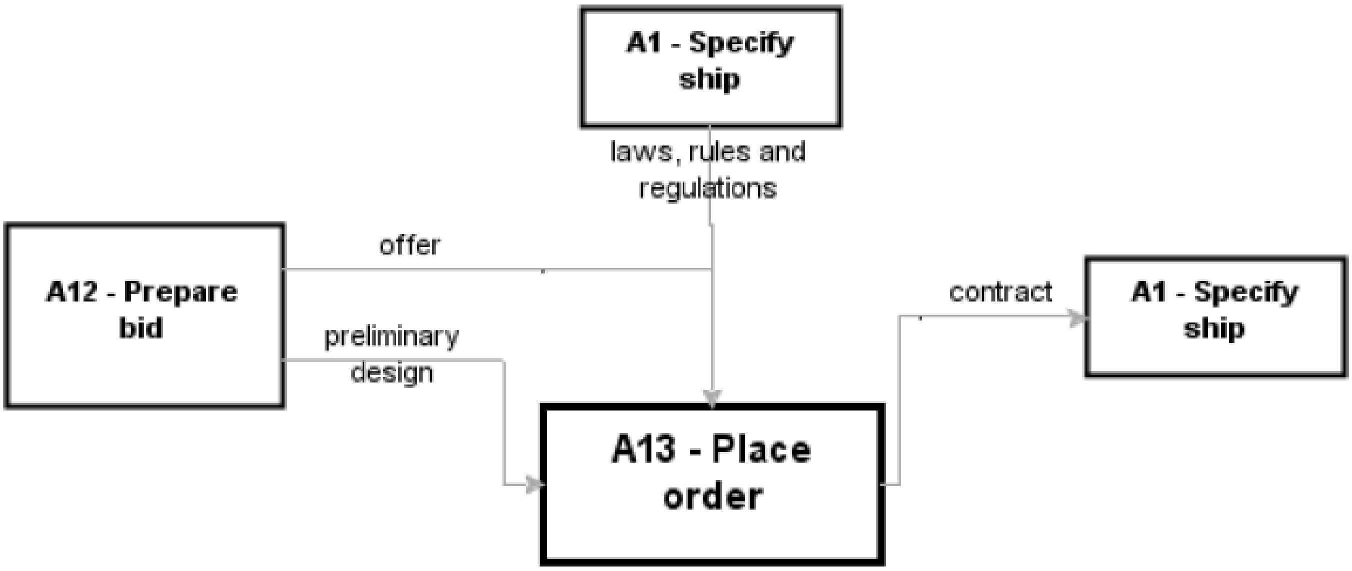
A1288 Recommendation and decision: A, B, C and D

4.1.3 Place Order (A13)

Activity "A13 Place order" refers to the phase that owner places an order for a ship from the bids that have been submitted. This activity leads to the signing of a contract between the shipyard and the ship owner.

A13

Path Name	A0—A1—A13
Common Name	A13
Aliases	Place order
Description	The owner places an order for a ship from the bids that have been submitted. From this a contract is awarded.
Activities	
Inputs	A0.preliminary design
Parameters	A0.offer, A0.laws, rules and regulations
Outputs	A0.contract, A0.technical requirements, A0.list of required certificates
Participants	resources



4.2 Data structures

4.2.1 Internal data structures

The Early Design tool to be developed in the context of the SHIPLYS project will be composed by individual software modules, implementing the specific activities described in the previous sections. The input data required for the execution of these modules, as well as the output data produced by each activity, follow in general the multifarious internal information flow, feeding subsequent activities or importing data from external sources. During this process many activities may operate on common input data and, at the same time, many parameters may be updated by diverse software modules. It seems, thus, natural that the various parameters used internally by the tool, to be stored in a global database (data structure), in order to avoid duplicate instances or errors in parameter updating.

The full range of the parameters composes a data structure describing the current design, i.e. the 'Ship model'. The internal data base may contain various instances of this data structure, resembling diverse designs, following, for example, the results of an optimization process. The current design, the full range or selected members of the produced designs may be also stored for future exploitation, composing a database of 'available designs'.

The parameters stored in the internal database may be grouped together under the following categories:

Design requirements

The first level input for the design, containing the owner's requirements, offer guidelines and parameters like:

- Vessel type
- Principal Particulars (Length, Breadth, Depth, Draught, etc)
- Deadweight
- Design speed
- Service speed
- Number of crew
- Number of passengers
- Cargo density
- Container load
- Water density
- Ship autonomy
- Initial arrangement layout
- Initial machinery layout

Hull form data

- Hull lines data store
- Hull surfaces data store
- Hull form coefficients (C_b, C_m, C_p,C_w, etc)
- Section offset tables

Hydrostatics and Stability Data

- Bonjean curves
- Hydrostatics table
- Trim tables (displacement correction due to trim, etc.)
- Load line data
    - Deadweight scale and freeboard particulars

General Arrangement

- Bulkhead arrangement
- Watertight subdivision
- Machinery arrangement
- 3d Virtual model of ship arrangement

Tank data

- Tank plan
- Tank capacities
- Tank centers of gravity

Ship Resistance and Hydrodynamics

- Calm water resistance curve
- Wind resistance
- Added resistance in waves, sea margin
- Propeller – hull interaction coefficients
    - Wake fraction
    - Thrust deduction factor
    - Relative rotative efficiency
    - Hull efficiency
- Propeller design
    - Propeller No.
    - Blade No.
    - Propeller geometry (Blade area, pitch, etc)
    - Cavitation check
    - Propeller efficiency
- Shafting efficiency
- Reduction gear efficiency
- Total propulsive efficiency
- Shaft power curves (SHP vs RPM, SHP vs Vship)
- Shaft speed curves (Vship vs RPM)

Machinery Data

- Number of main engines

- Main eng. fuel type
- Main eng. specific consumption
- Main eng. rating (CSR,MCR)
- Number of auxiliary engines
- Aux. eng. fuel type
- Aux. eng. specific consumption
- Aux. eng. rating

Structural Design

- Longitudinal strength data
    - Bending moments
    - Shear forces
- Frame space data
- Midship section scantlings

Weight data

- Lightship weight
    - Hull structure weight
    - Internal structure weight
    - Superstructure weight
    - Machinery weight
    - Outfitting weight
    - Machinery weight
- Loading Data
- Loading conditions
    - Trim data
    - Stability data
    - Longitudinal strength data

4.2.2 External data bases

In contrast to the internal databases, which hold the parameter values for the current design, the external databases store data from previous designs necessary for the new design, like raw material properties and costs, industrial standards, life cycle parameters and costs, etc.

It is evident that the storage scheme used in the external databases may not be compatible with the internal data structures, thus special interfaces may be required for the integration of these units into the SHIPLYS tool.

A number of relevant databases have been used by the consortium in the past for research purposes and some data are available from past relevant studies and EU projects. Data regarding ship and shipping economic statistics are gathered by organizations like Lloyd's Fairplay and Clarksons in dedicated databases. The aforementioned databases can be used in the SHIPLYS project but access to these databases requires annual subscription.

More specifically, Lloyd's Fairplay is a complete guide to the worldwide merchant fleet. Published since 1764, this four-volume collection draws from Lloyd's proprietary databases to provide the most thorough details on all sea-going, self-propelled merchant ships of 100 GT and above, irrespective of their classification. The List of Shipowners & Managers complements the Register of Ships by providing details of shipowners and the fleets they manage. Every subscriber receives access to Shipfinder Online, a daily updated ship reference.

Clarksons Shipping Intelligence Network is a searchable ship registry of over 42,000 existing vessels and nearly 10,600 ships on order, with searchable data on owners, builders, flags, fleets, fixtures, and sales, in addition to market reports on more than 20 sectors, time series and graphs generation, and full text access to Clarkson Shipping Intelligence weekly and monthly reports.

Preliminary evaluations of operating costs for the designed vessels can also be performed with the use of neural networks, based on parameters defined by the shipping industry and the global market.

In addition to the above, many other cost databases (GaBi, CML, ECO-REFITEC, RECIPE etc.), and, also shipyard databases containing previous designs, can be linked to the SHIPLYS tool for the cost evaluation of the following items:

Calculate cost of design

- Labor cost per hour
- Cost for the purchase of existing designs
- Cost for the purchase of software
- Cost for the purchase of databases
- Total energy footprint of the design procedures, i.e. energy footprint from the use of software/hardware

Calculate cost of Construction

- Cost of steel per ton
- Cost of equipment
- Cost of outfitting
- Cost of piping
- Cost of wiring
- Cost of engine/ER
- Cost of machinery
- Welding length
- Welding cost per meter
- Cutting Steel/Cost per m length
- Sanding Steel/Cost per m^2
- Shipyard average energy consumptions
- Average waste for the ship construction

- Total procedure emissions
- Average Paint used/painting costs
- Other Chemicals
- Labor cost

Calculate cost of Operation

- Average sailing days per year loaded
- Average sailing days per year in ballast
- Average days per year at port loading
- Average days per year at port discharging
- Average days per year idling or at anchorage
- Average days per year for maintenance/dry-docking/surveys
- Crew number/position
- Average daily fuel /lube oil/other consumables consumption when sailing loaded
- Crew wages & fees
- Average daily fuel/lube oil/other consumables consumption when sailing in ballast
- Average daily fuel/lube oil/other consumables consumption when at port loading
- Average daily fuel/lube oil/other consumables consumption when at port discharging
- Average daily fuel/lube oil/other consumables consumption when Idling/anchorage
- Average waste/sludge/garbage produced
- Average sailing emissions
- Average emissions at port

Calculate cost of Maintenance

- Average paint/chemicals consumed per year for scheduled & unscheduled maintenance
- Average paint/chemicals consumed during dry-docking/repair period
- Spares cost during dry-docking/repair period
- Spares cost for scheduled & unscheduled maintenance
- Average waste
- Average emissions
- Average energy consumed

Calculate cost of Retrofitting

- Description of the system(s) to retrofit
- Energy consumption for the installation of the equipment
- Emissions

Calculate cost of Scrapping

- Transport to scrap yard
- Scrap material
- Scrap recycled

- Equipment reused

4.3 Controls

The flow of the activities in the tool are controlled by external information, provided by applicable rules and regulations, contractual obligations, budgetary restrictions, manufacturing limitations, etc. An indicative list of these controls is presented below.

Owner request, requirements: The requirements document that is submitted to the shipyard by the owner upon the invitation to tender.

Contract: The contract is the output from the activity which involves placing the order for the ship. The contract is used as a constraint in subsequent activities such as final design and approval and production.

Historical data from previous designs: Data held by the shipyard or model basin on previous ship designs and used to estimate the hydrodynamics, powering requirements and sea- keeping.

Laws, rules and regulations: National laws, statutory regulations and classification society rules that are used to control the design, manufacture, operation, maintenance and scrapping of the ship.

List of classification items: The list of items required by the classification society, e.g. midship section, bulkheads, shell profile arrangement and machinery foundations.

Certificates: The certificates issued by the Classification Society on completing the ship.

List of required certificates: The result of placing an order, this is the list supplied by the owner for certificate requirements.

Design modifications: Comments and recommendations on the design (red-marking).

Modification for classification: A feedback from the modification for classification when designing the ship structure.

Product component information: Include information about several product components, e.g. technical data of main engine.

Budget: The budget is a plan for the careful use of money necessary to control expenditures for all items.

Building capacities of yard: The production abilities available to the yard.

Building sequences: The sequences of producing a ship, as input for preparing the section plans.

Building specification: The information which specifies the detailed framework for the construction of the ship.

Capacities for lifting, drydock spaces and production lines: The information resulting from estimating drydock resources, which includes scheduling and assignment of a dry dock.

Availability, reliability and maintainability information: Information about components, required for both installing them in the ship and for planning maintenance.

Manufacturing restrictions: Constraints on the ship construction and design processes governed by available technology and shipyard facilities.

Material allocation/ordering: Data describing the necessary material supply for production.

Quality assurance: Rules applied by an organization within the shipyard that has the task to audit the shipyard organization and applied processes in a manner such that the quality of the resulting product is assured.

4.4 Existing software tools

After a number of iterations, a 'Master Matrix' (MM) has been developed to match the functionality required within SHIPLYS with existing software packages (Applications) from 3rd sources and 'in-house' within the consortium. The in-house Applications either already exist in some form or shall be developed within the SHIPLYS project in other Work Packages. The primary aim of the MM is to identify the Applications to be integrated on the SHIPLYS platform. The MM is also being used to develop a detailed matrix for the sub-functionalities identified.

The MM is attached in the Appendix. There is a SHIPLYS Design Team and a Software integration team responsible for the task of identifying the Applications to be used for the purpose of SHIPLYS.

4.5 Tools to be developed within SHIPLYS

It´s very important to remark that, with the aim of complying with the objectives of the project, it will be necessary to develop activities that are not included in ISO 10303. To this aim, it is very important to identify which are these activities. For this, the deliverable D3.2 will be divided into two kind of activities,

1. *Activities included in ISO standard activities and*
2. *New additional SHIPLYS tool activities.*

Below it is introduced the distribution tree concerning the new activities developed and the activities that are included in ISO model and can be used in the project. The activities in cursive will be the new activities to be developed in the course of the project.

A121 Evaluate request & schedule bid

A122 Create preliminary design

A1221 Create preliminary hull form

A12211 Estimate main dimensions and parameters

A12212 Estimate form parameters

A12213 Do parametric variations

A12214 Generate initial hull form definition

A1222 Create preliminary general arrangement

A1223 Estimate hydrodynamics and power

A1224 Create preliminary structural design

A1225 Create preliminary machinery design

A1226 Create preliminary outfitting design

A123 Decide post-sales & maintenance support

A124 Calculate cost of ship

A1241 Calculate cost of design

A12411 Estimate labor cost (incl. overheads, management, software …)

A12412 Estimate cost of Classification

A12413 Estimate cost of external experts (model tests, CFD analyses …)

A1242 Calculate cost of construction

A12421 Estimate hull cost

A124211 Estimate cost of purchase of material

A124212 Estimate cost of cutting

A124213 Estimate cost of bending

A124214 Estimate cost of welding

A124215 Estimate cost of coating

A124216 Estimate cost of outfitting (including piping, wiring …)

A12422 Estimate machinery cost

A124221 Estimate cost of purchase of machinery

A124222 Estimate cost of installation

A12423 Estimate accommodation cost

A124231 Estimate cost of purchase of material

A124232 Estimate cost of cutting

A124233 Estimate cost of welding

A124234 Estimate cost of coating

A124235 Estimate cost of outfitting (including piping, wiring …)

A1243 Calculate cost of operation

A12431 Estimate insurance cost

A12432 Estimate crew cost

A12433 Estimate administration cost

A12434 Estimate consumables cost (fuel, oil …)

A12435 Estimate port cost

A1244 Calculate cost of maintenance/retrofitting/risk

A12441 Estimate cost of preventive maintenance

A12442 Estimate cost of corrective maintenance

A12443 Estimate docking cost

A12444 Estimate labor cost

A12445 Estimate material/spares cost

A12446 Estimate cost of potential risk (loss of cargo, human loss, damage ...)

A1245 Calculate cost of scrapping

A12451 Estimate transport cost

A12452 Estimate recycled material / reused equipment profit

A12453 Estimate hazardous waste disposal costs

A12454 Estimate dismantling cost

A125 Present offer

A126 Create preliminary design for retrofitting purposes

A1261 Create preliminary machinery and outfitting design via three-dimensional scanning

A1262 Create preliminary machinery and outfitting design via two-dimensional drawings

A1263 Create preliminary machinery and outfitting design via three-dimensional drawings

A127 Estimate environmental impact

A1271 Estimate environmental impact of construction

A12711 Estimate Global Warming Potential (GWP)

A12712 Estimate Acidification Potential (AP)

A12713 Estimate Eutrophication Potential (EP)

A12714 Estimate Photochemical Oxidant Creation Potential (POCP)

A1272 Estimate environmental impact of operation

A12721 Estimate Global Warming Potential (GWP)

A12722 Estimate Acidification Potential (AP)

A12723 Estimate Eutrophication Potential (EP)

A12724 Estimate Photochemical Oxidant Creation Potential (POCP)

A1273 Estimate environmental impact of maintenance

A12731 Estimate Global Warming Potential (GWP)

A12732 Estimate Acidification Potential (AP)

A12733 Estimate Eutrophication Potential (EP)

A12734 Estimate Photochemical Oxidant Creation Potential (POCP)

A1274 Estimate environmental impact of retrofitting

A12741 Estimate Global Warming Potential (GWP)

A12742 Estimate Acidification Potential (AP)

A12743 Estimate Eutrophication Potential (EP)

A12744 Estimate Photochemical Oxidant Creation Potential (POCP)

A1275 Estimate environmental impact of scrapping

A12751 Estimate Global Warming Potential (GWP)

A12752 Estimate Acidification Potential (AP)

A12753 Estimate Eutrophication Potential (EP)

A12754 Estimate Photochemical Oxidant Creation Potential (POCP)

A128 Assess risk and safety

A1281 A-Identify hazard of new ship design

A1282 B- Identify hazard of retrofitting design

A1283 C- Identify hazard of maintenance

A1284 D- Identify hazard of retrofitting construction

A1285 Risk assessment: A, B, C and D

A1286 Estimate risk control options: A, B, C and D

A1287 Cost benefit assessment: A, B, C and D

A1288 Recommendation and decision: A, B, C and D

5 Preliminary Design

In the early stages of conceptual and preliminary design, it is necessary to develop a consistent definition of a candidate design in terms of just its dimensions and other descriptive parameters such as L, B, T, CB , LCB, etc. This description can then be optimized with respect to some measure(s) of merit or subjected to various parametric tradeoff studies to establish the basic definition of the design to be developed in more detail. Because more detailed design development involves significant time and effort, even when an integrated Simulation Based Design (SBD) environment is available, it is important to be able to reliably define and size the vessel at this parameter stage.

Activity A122 is an activity which is related to different sub-activities with the aim of create preliminary design. The figure below detailsthe different relationship between the sub-activities.

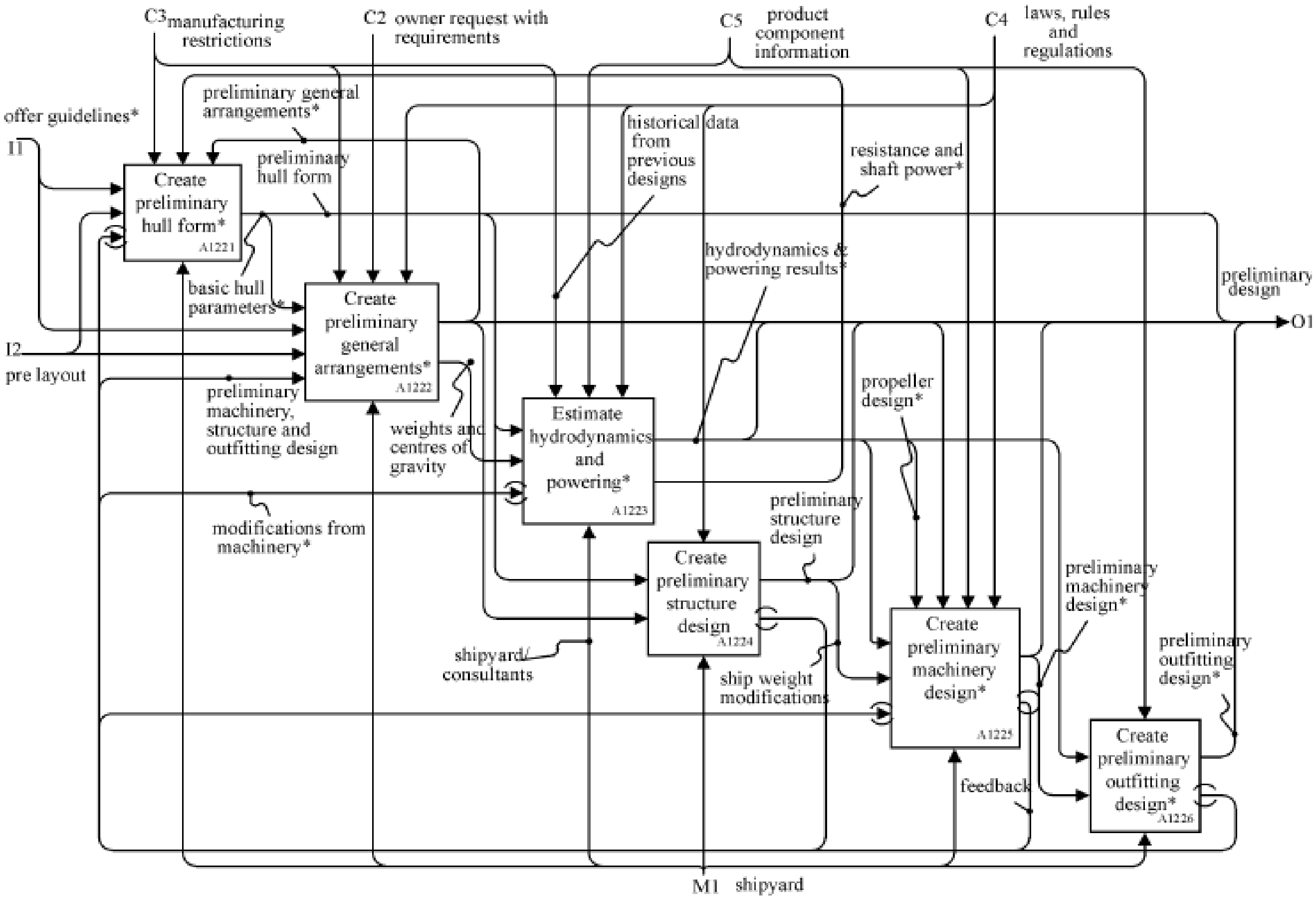


Figure 17: Node A122

A122

Path Name	A0—A1—A12—A122
Common Name	A122
Aliases	Create preliminary design
Description	All design activities relevant in a very preliminary stage of ship design in consideration of classification rules, national/international demands, shipyard constraints and owner requirements. The aim of this task is to make a shipyard offer.
Activities	A1225, A1226, A1223, A1224, A1221, A1222
Inputs	A0.offer guidelines, A0.pre layout, A0.historical data from previous designs
Parameters	A0.manufacturing restrictions, A0.product component information, A0.owner request, requirements, A0.laws, rules and regulations, A0.schedule
Outputs	A0.workload, A0.material list, A0.preliminary design
Participants	shipyard and consultants
Transitions	fromA1226toA122, fromA1222toA122, fromA1226toA1221, fromA122toA1226, fromA1224toA1223, fromA1226toA1225, fromA122toA1222, fromA1222toA1221, fromA122toA1224, fromA122toA1223, fromA1224toA122, fromA1221toA1224, fromA1223toA1221, fromA1222toA1225, fromA1223toA1226, fromA1224toA1225, fromA1225toA1226, fromA1225toA1221, fromA1226toA1223, fromA122toA1221, fromA1223toA1225, fromA1221toA122, fromA1222toA1224, fromA1221toA1222, fromA1225toA1223, fromA1224toA1221, fromA1224toA1222, fromA1226toA1222, fromA1222toA1223, fromA1225toA1222, fromA1221toA1223, fromA1223toA122, fromA122toA1225, fromA1225toA122

5.1 Hull Form (A1221)

A1221

Path Name	A0—A1—A12—A122—A1221
Common Name	A1221
Aliases	Create preliminary hull form
Description	create preliminary hull form The activity that is the first step of designing a ship. Using parent ships main dimensions and form parameters one or more preliminary hull forms will be generated.
Activities	A12214, A12213, A12212, A12211
Inputs	A0.pre layout, A0.feedback, A0.offer guidelines
Parameters	A0.resistance and shaft power, A0.manufacturing restrictions, A0.preliminary general arrangements
Outputs	A0.preliminary hull form, A0.basic hull parameters
Participants	shipyard
Transitions	fromA1221toA12214, fromA12214toA1221, fromA12214toA12211, fromA12213toA12211, fromA1221toA12213, fromA1221toA12211, fromA12212toA12213, fromA12212toA12211, fromA12213toA12214, fromA1221toA12212, fromA12211toA12212

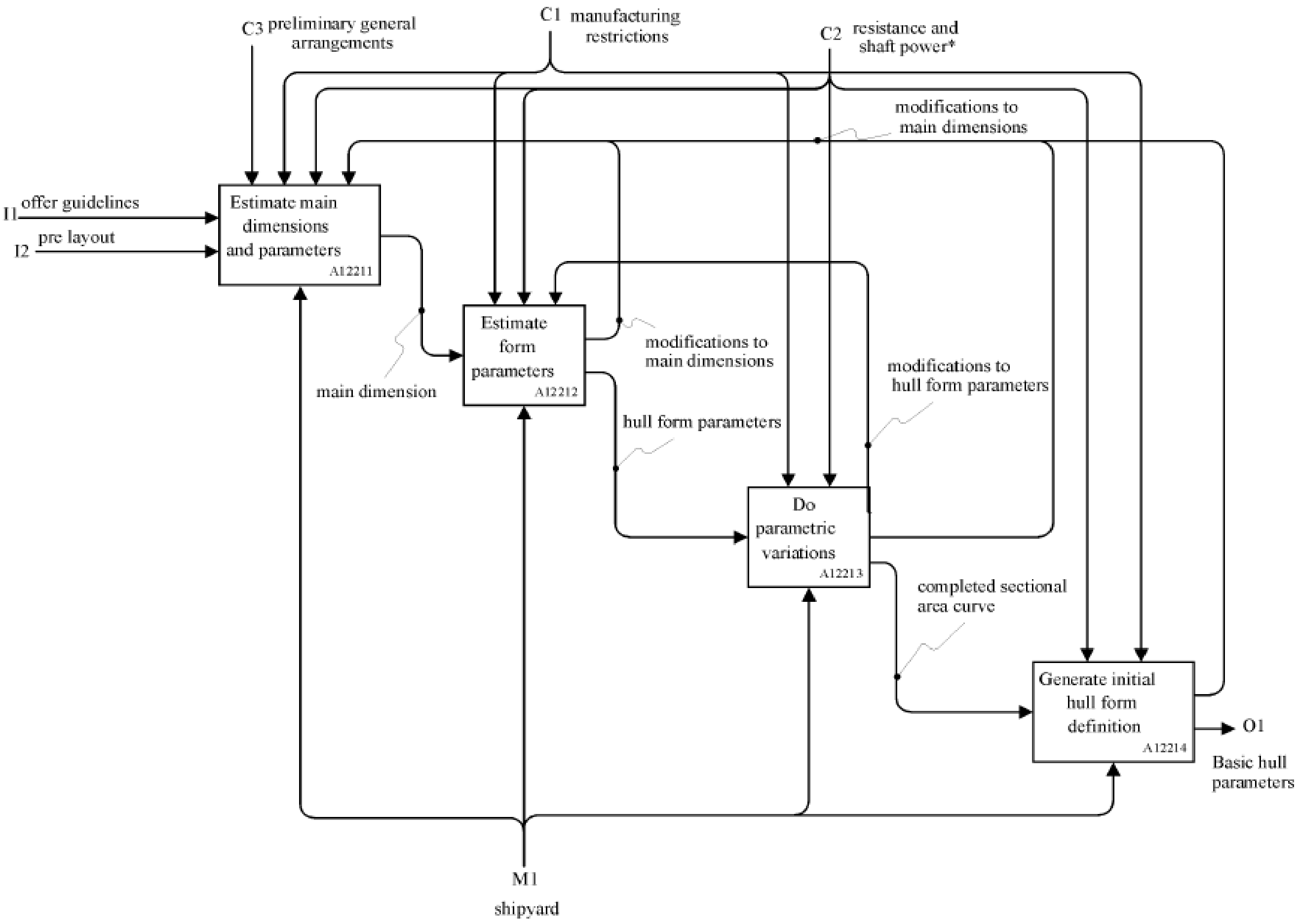
- **<u>Ship Main particulars and characteristic:</u>**

The ship main particulars are the main characteristics of the ship that can be grouped as follows:

- Capacities
  - Deadweight (DW)
- Cargo deadweight (CDW)
- Number of passengers
  - Lane length
  - Number of containers
    - In Cargo holds
    - On deck
    - Refrigerated
    - Total
  - Gross Tonnage (GT)
  - Net Tonnage (NT)

- Hull main dimensions
    - Length, overall (Loa)
    - Length, between perpendiculars (Lbp)
    - Breadth, moulded (B)
    - Depth, moulded (D)
    - Draught, at summer freeboard (T)
  - Draught, scantlings (Tsct)
- Propulsion system
  - Main machinery
  - Maximum Continuous Rating (MCR)
  - Rotation speed (RPM)
- Service speed (Vs)
- Complement (number of crew members)
- Class society
- Class notation

The ship main particulars can be specified with different levels of detail. At the lower level is the information listed above which is normally specified in the General Arrangement drawing. At a higher level, such as found in an Outline Specification, additional data can be specified on auxiliary systems, cargo equipment, lifesaving equipment, anchoring and mooring equipment.



Inputs: • I1. Offer guidelines • I2. Pre layout • I3. Feedback (if existing)	Controls • C1. Manufacturing restrictions • C2. Resistance and shaft power • C3. Preliminary general arrangement
Processes • Estimate main dimensions and parameters (from shipyard A12211 • Estimate form parameter A12212 • Do parametric variation A12213 • Generate initial hull form definition A12214	Outputs • O1. Basic Hull parameters • O2. Preliminary Hull form (Hull surfaces)

Relation with processes:

a) Predecessors

This uses as input:

- I1."Offer guidelines" comes from an output of "Evaluate request & schedule bid" (A121)
- I2."Pre layout" comes from "Create preliminary design (A122)"
- I3. "Feedback if existing, It comes from Create preliminary design (A122), in particular from:
    - A1224 Create preliminary structure design
    - A1225 Create preliminary machinery design
    - A1226 Create preliminary outfitting design

b) Internal Processes
- Estimate main dimensions and parameters (from shipyard database) A12211
- Estimate form parameter A12212
- Do parametric variation A12213
- Generate initial hull form definition A12214. The hull form can be generated from standard series, from parent designs selected through the concept design phase, from given templates, etc.

c) Connected Processes (Successors)

The basic hull parameters are inputs for:

- Define compartments (A12221)
- Define compartments arrangement (A12211)

Hull form is used as input to ship intact stability analysis. They can be used as input to some performance analysis tools (resistance calculations, seakeeping, etc.). They can also be used in costs assessment.

Considerations related with optimal design

Most of the ship particulars are determined to comply with the terms of the bid (e.g. deadweight, service speed). However, a number of additional attributes are determined as a consequence of the design options and configurations considered and can be considered for optimization (propulsive power, lightweight).

- **Hull lines / Hull shape (IST)**

The hull lines / hull shape is the description of the hull geometry. At the early stage of the ship design, the hull shape is initially characterized by a set of main dimensions, form coefficients and parameters.

This numeric description provides support for the estimate of a number of hull properties such as hydrostatics characteristics, volumes, surfaces, in the absence of a real geometric description.

- Hull main dimensions (Loa, Lpp, Lwl, B, D, T)
- Hull form coefficients (Cb, Cm, Cp, Cwl)

At a later stage of the concept design a simplified geometry description can be produced, which requires some additional information:

- Hull shape parameters
    i. Deadrise
    ii. Longitudinal position of the section with maximum area
    iii. Length of the parallel middle body
    iv. Longitudinal position of the centre of buoyancy
- Section Area Curve (SAC)

To define more precisely the shape of the bow

- Existence of a bulb
- Type of bulb section shape (e.g. delta, nabla, elliptical)
- Draught, ballast
- Existence of bow thruster(s)
- Bulb shape parameters (length forward of the fore perpendicular, height of the nose)
- Bulb shape coefficients (transverse section area coefficient, longitudinal section area coefficient, volume coefficient)

To define more precisely the shape of the stern it is required a more detailed knowledge about:

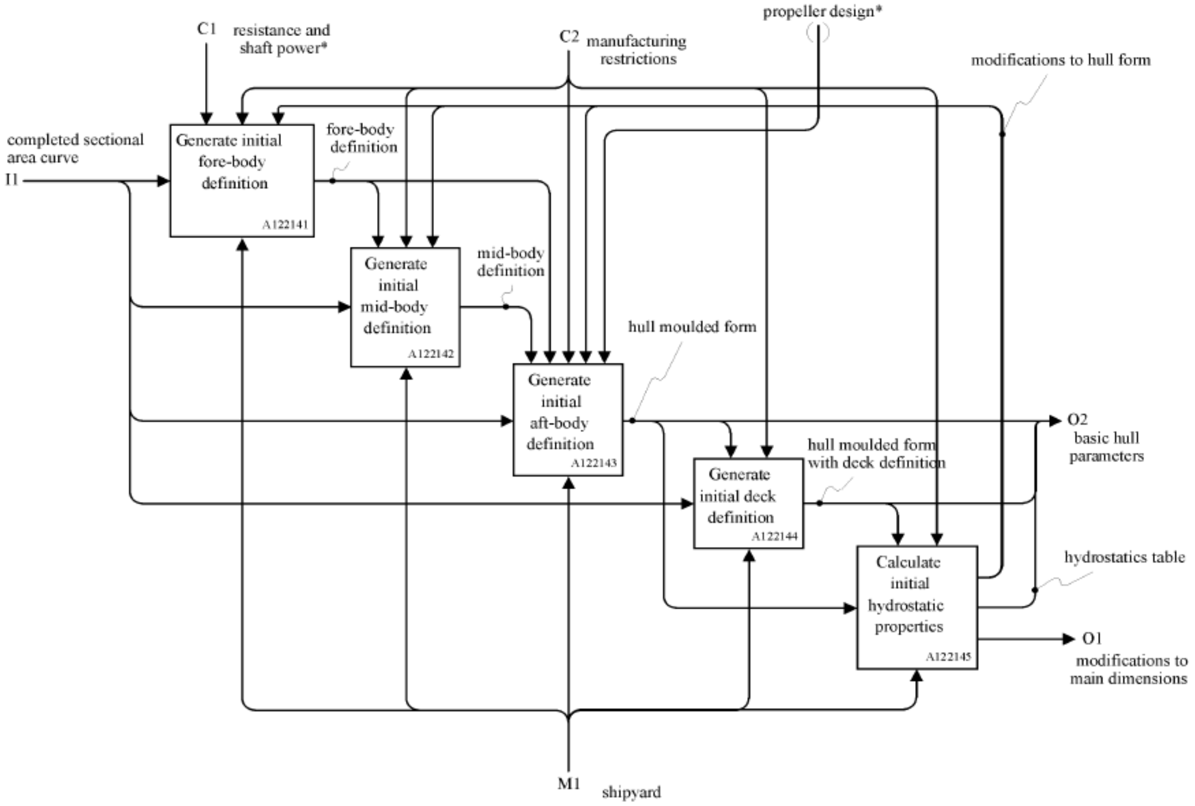
- Type of propulsion system (
- Vertical position of the shaft line axis
- Type of propulsor (propeller, ducted propeller)
- Diameter of the propeller
- Type of manoeuvring equipment
- Type of rudder
- Dimensions of the rudder

At the concept stage, the fairness of the hull is not a request and hull appendages such as do not need to be specified. The initial hull description is intended to be sufficient to determine the displacement and to estimate some hydrostatic properties associated to the design load condition. This information is enough to estimate the hull resistance and propulsive power.

- When ship loading conditions other than the design draught need to be evaluated (eg. ballast condition), an improved hull description is needed. A description based on a set of cross sections is sufficient not only to carry out hydrostatics computations for all the possible draughts but also to provide support for the preliminary design of the hull compartment layout.

- A wireframe description composed by a network of cross sections, waterlines (horizontal sections) and buttocks (longitudinal sections) provides already a reasonable 3D geometric description of the hull shape.
- The more precise and complete geometric description of the hull shape is provided by a surface model. In such a model, it is possible to obtain not only the coordinates of all the points on the hull required, but also additional information about normal vectors, curvatures, etc.

Inputs: • I1. Complete sectional area curve	Controls • C1.Resistance and shaft power • C2. Manufacturing restrictions
Processes • Generate initial fore-body definition A122141 • Generate initial mid-body definition A122142. • Generate initial aft-body definition A122143 • Generate initial deck definition A122144 • Calculate initial hydrostatic properties A122145	Outputs • O1. Modifications to main dimensions • O2. Basic Hull parameters



The lines have to be consistent with Ship Main particulars and characteristics. They are interacting with the general arrangement and structural definition.

Relation with processes

Line definition Processes

- Generate initial fore-body definition A122141
- Generate initial mid-body definition A122142
- Generate initial aft-body definition A122143
- Generate initial deck definition A122144
- Calculate initial hydrostatic properties A122145

Considerations related to optimal design

The hull shape is of most importance because it influence not only the cargo capacity of the ship but also its performance, static and dynamic behaviour. To perform lines optimisation, typically one of those aspects is the driver of the optimisation. The final hull shape is often the result of a number of modelling operations in a procedure highly interactive.

For optimisation purposes, there is the need to identify a number of dimensions and shape parameters to be used as design variables but the modelling procedure must be able to be automated, and so a predefined modelling sequence is required. In addition to the interactive process, hull shapes can be obtained from systematic series, from the alteration of a parent hull or by parametric modelling.

3. Virtual prototyping

Parametric modelling is one of the possible alternatives to create a hull shape. This is particularly relevant for concept design.

The data required includes:

- Hull main dimensions (Loa, Lpp, Lwl, B, D, T)
- Hull form coefficients (C_b, C_m, C_p, C_{wl})
- Hull shape parameters
    - Deadrise
    - Longitudinal position of the section with maximum area
    - Length of the parallel middle body
    - Longitudinal position of the centre of buoyancy
- Existence of a bulb (yes/no)
- Type of bulb section shape (eg. delta, nabla, elliptical)
- Draught, ballast
- Existence of bow thruster(s)
- Bulb shape parameters (length forward of the fore perpendicular, height of the nose)
- Bulb shape coefficients (transverse section area coefficient, longitudinal section area coefficient, volume coefficient)
- Type of propulsion system
- Vertical position of the shaft line axis
- Type of propulsor (propeller, ducted propeller)
- Diameter of the propeller
- Type of manoeuvring equipment (rudders/azimuthal thrusters)
- Type of rudder
- Dimensions of the rudder

The hull forms generated by parametric modelling are not required to have very faired lines. The objective is to use a reduced set of dimension and parameters and produce a hull shape that can support with a reasonable accuracy, the assessment of resistance, volumes, stability.

Relation with other data (Activity model revision)

Inputs come from the main particulars of the ship and are similar to those required by Lines

Relation with processes

The following internal processes are identified:

- Parametric modelling of the midship section.
- Parametric modelling of longitudinal control curves.
- Parametric modelling of longitudinal property curves.
- Parametric modelling of vertical property variation curves.

Considerations related with optimal design

Virtual prototyping is quite important in the scope of optimization procedures because it provides the necessary level of automation of creation of hull shapes using a limited number of design variables.

5.2 General Arrangement (A1222)

A1222

Path Name	A0—A1—A12—A122—A1222
Common Name	A1222
Aliases	Create preliminary general arrangements
Description	The activity that produces the preliminary compartmentation plans from the preliminary hull form definition.
Activities	A12222, A12223, A12221, A12224
Inputs	A0.floodable curves, A0.basic hull parameters, A0.feedback, A0.offer guidelines, A0.pre layout, A0.preliminary machinery, structure and outfitting design
Parameters	A0.laws, rules and regulations, A0.owner request, requirents, A0.manufacturing restrictions
Outputs	A0.weights and centres of gravity, A0.trim, A0.preliminary design, A0.stability parameter
Participants	shipyard
Transitions	fromA12224toA12221, fromA12222toA12221, fromA1222toA12221, fromA12221toA12222, fromA12221toA12224, fromA1222toA12222, fromA1222toA12224, fromA1222toA12223, fromA12221toA12223, fromA12224toA1222, fromA12223toA1222, fromA12223toA12221, fromA12222toA12224, fromA12221toA1222, fromA12223toA12224

The allocation of the main functional spaces is initially defined in 2D in the profile and cross sectional views of the hull. The first target is to allow the estimate of the extents of the main functional spaces (engine and machinery rooms, cargo spaces, ballast spaces) based on the initial characterization of the hull shape.

At an early stage of concept design the detail must be sufficient to allow the evaluation of the volumes of the main functional spaces of the ship (cargo, machinery, ballast, consumables) and also to estimate the corresponding centres of volume, to carry out assessments of trim and stability.

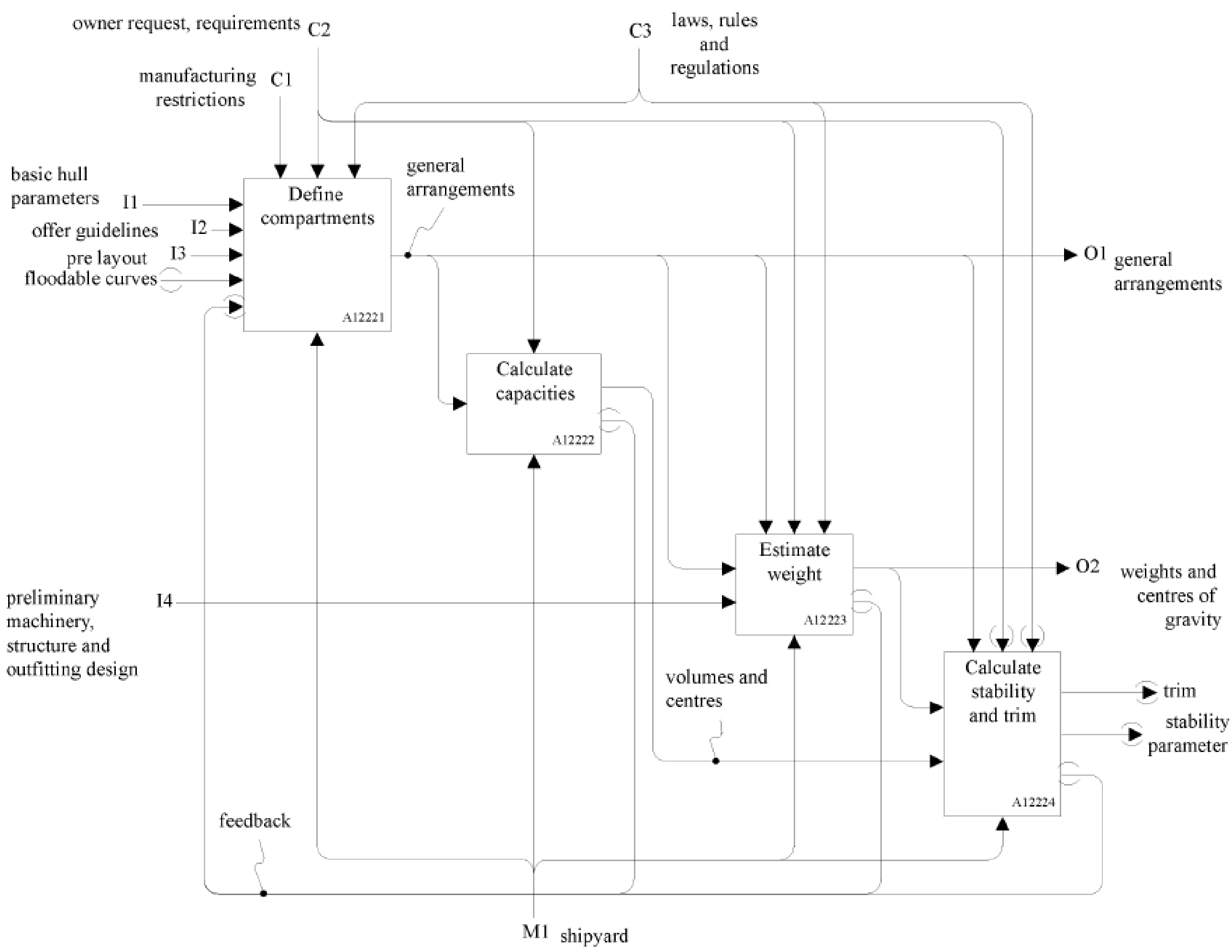
The discretization of the volumes in the individual spaces (holds, tanks, etc.) and the definition of all the tanks on board is only carried out at a later stage of the design process.

Relations with other data (accordingly with Activity Map)

- The ship cargo capacity must comply with the bid requirements.
- The ship ballast tanks capacity and layout must sufficient to guarantee ship trim and stability in the different load conditions associated with the mission profile.
- The dimensions of the engine room are closely related with the type of propulsion system adopted and with the power of the main machinery.
- A122314 - Predict brake power and service speed

Relation with processes

- A122211 - Define compartment arrangement
- A122213 - Define compartment properties
- A122221 - Calculate capacities, holds, bunker space
- A122222 - Calculate underdeck space
- A122223 - Calculate tonnage, freeboard



To perform compartment optimisation, the layout has to be efficiently driven by a small number of design variables such as the longitudinal positions of the transverse bulkheads, and a set of parameters that describe the internal compartment layout. This compartment layout, at least in the cargo area, is associated with a predefined geometrical configuration of the cross-section which can be categorized as a function of the ship type (tanker, bulker, container carrier, ro/ro) and described by the values of the respective parameters, such as the height of the double-bottom, the width of the side tanks, the number and the height of twee decks, etc. The values of these parameters can be used as design variables of an optimization procedure in which the objectives can be associated with capacities, stability, etc.

5.3 Hydrodynamics and Powering (A1223)

A1223

Path Name	A0—A1—A12—A122—A1223
Common Name	A1223
Aliases	Estimate hydrodynamics and powering
Description	The activity that approximates hydrodynamic properties data calculations such as resistance, propulsion, seakeeping and manoeuvrability for the preliminary hull form.
Activities	A12232, A12231, A12233
Inputs	A0.weights and centres of gravity, A0.preliminary hull form, A0.historical data from previous designs, A0.Loading conditions, A0.feedback
Parameters	A0.laws, rules and regulations, A0.historical data from previous designs, A0.product component information
Outputs	A0.resistance and shaft power, A0.manoeuvring results, A0.short and long term responses, A0.hydrodynamics & powering results
Participants	shipyard
Transitions	fromA1223toA12231, fromA12231toA12212, fromA1223toA12232, fromA1223toA12233, fromA12233toA1223, fromA12231toA1223, fromA12232toA1223

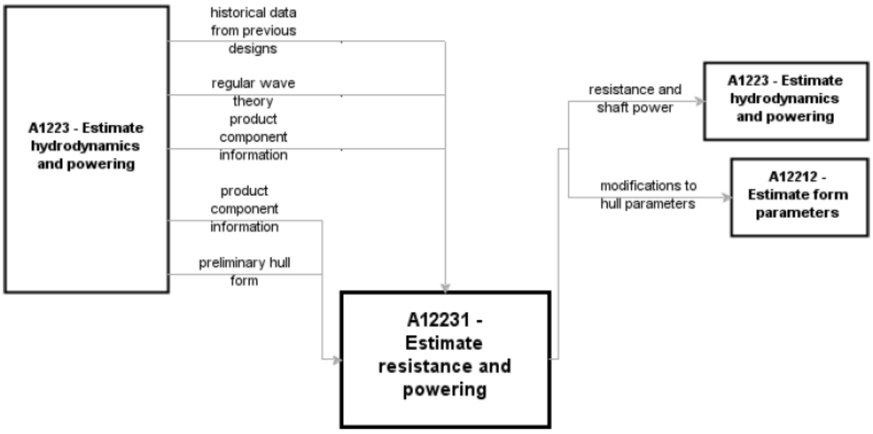
Estimate hydrodynamic and powering is an activity that it is relationship with different activities and sub activities since, feed the needs which it is necessary for its. Develop. As it´s showed in the point 4 of this document, A1223 – Estimate hydrodynamics and powering depend of A1221, A1222, A1224, A1225 and A1226, which feed to A1223. Aspect as laws, rules and regulations, product component information or weights and centres of gravity are very important, since they influence all the steps of defining the early design. From this activity (A1223) very important information will be obtained that feed again activities like A1221 A1226, A1225 and A122.

For example, with the aim of to estimate the powering, it will be necessary to know the type of Main engine including the Gen set Power and the Reduction gear type if exist. As in the A1222, at an early stage of concept design the detail must be sufficient to allow the evaluation of the engines and forms of the vessel and with this data, to estimate hydrodynamic and powering.

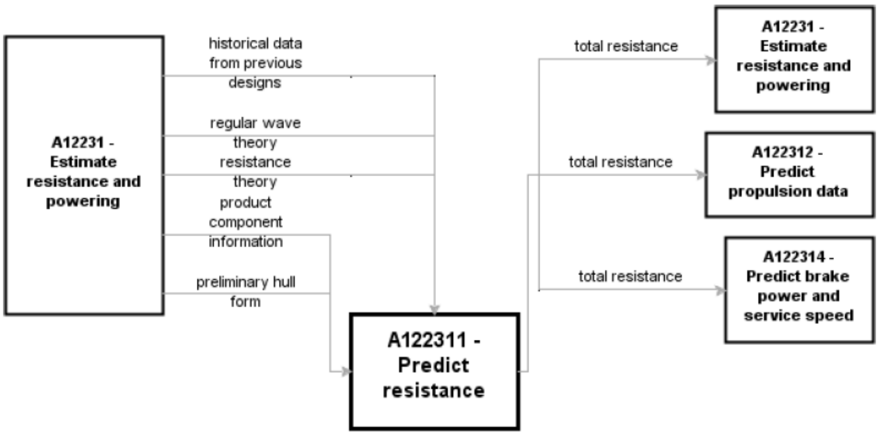
With the target to obtain the estimation hydrodynamic and powering (A1223) will be carried out calculations based on historical data for producing powering and resistance data for the initial preliminary design and additionally calculations for the theoretical behaviour of a ship in seaway and an approximation of the manoeuvrability of the ship and comparison of the model testing results with design requirements.

Relation with processes

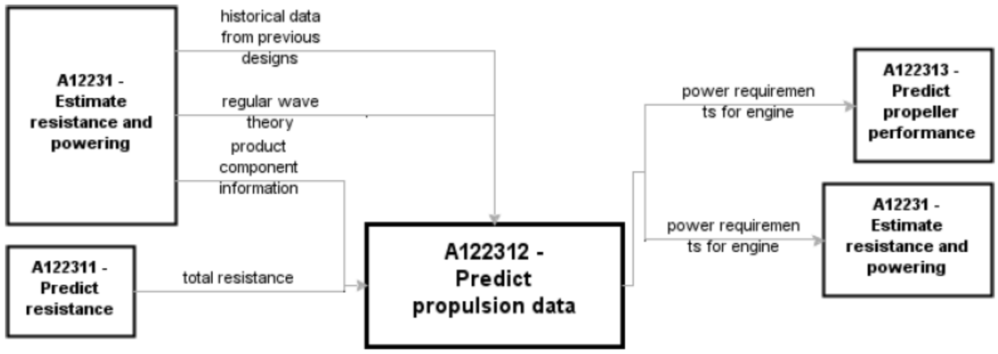
- A12231 – Concerning to Estimate resistance and powering



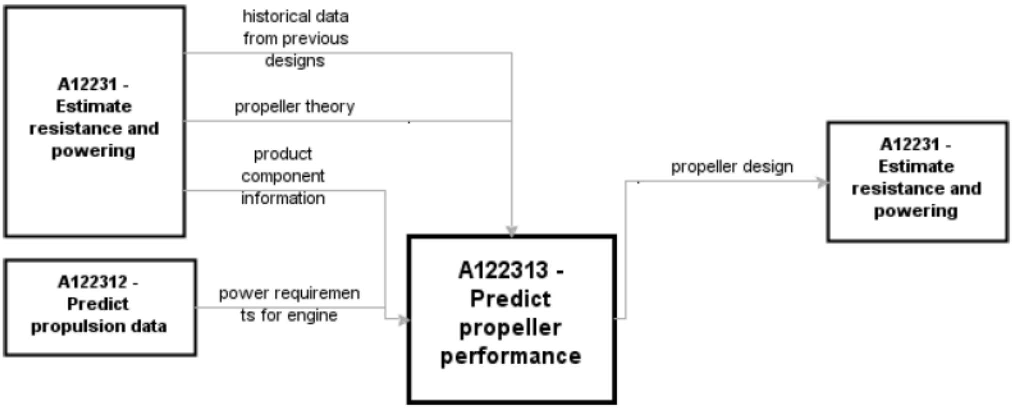
  - A122311- Concerning to predict resistance. Estimate the wet-able surface area of the ship for seaway resistance:



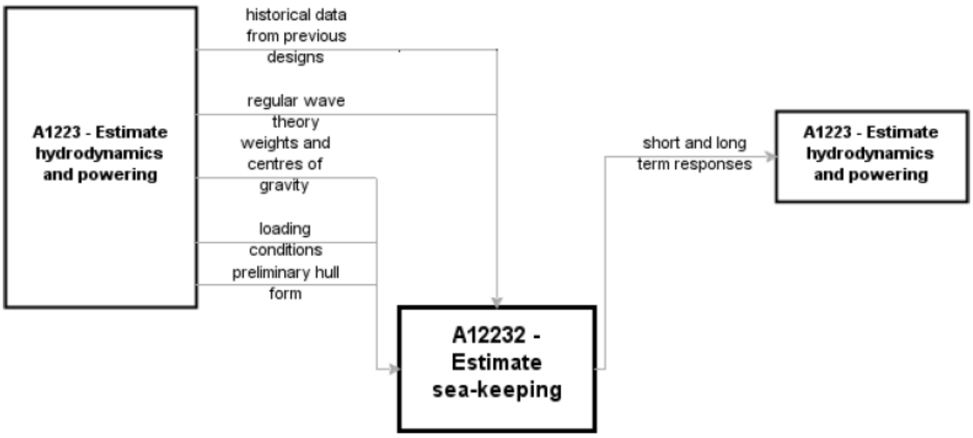
  - A122312: Concerning to Predict propulsion data. Calculate the propulsion requirements of the ship



- A122313- Estimate propulsion requirements data to produce a preliminary propeller design.



- A12232 – Concerning to Estimate sea keeping. Calculations for the theoretical behaviour of a ship in seaway



- A12233- Approximation of the manoeuvrability of the ship and comparison of the model testing results with design requirements.

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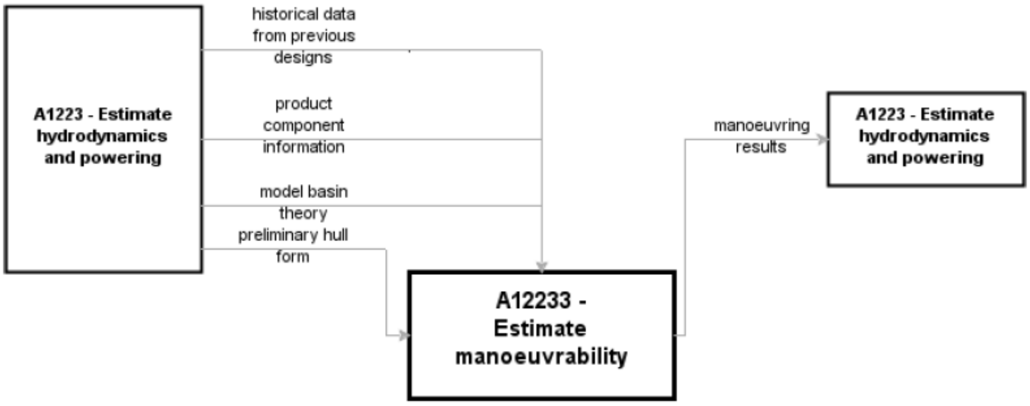
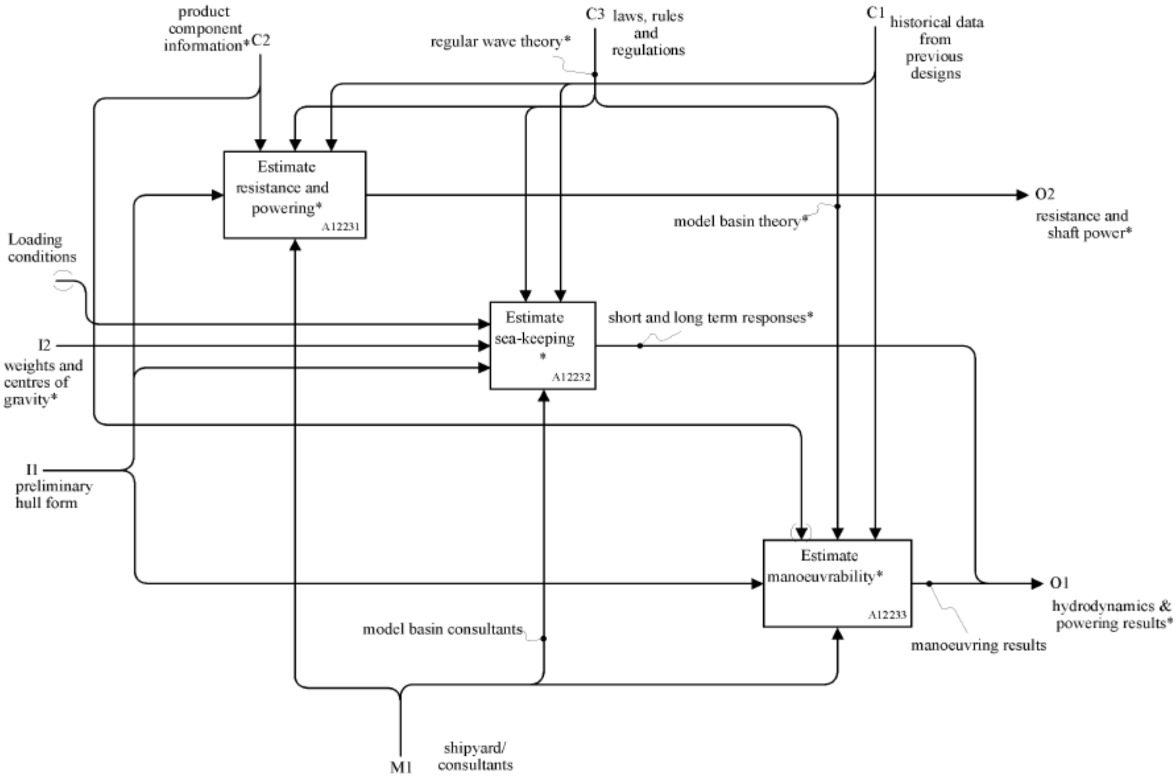
GA Ref: Ares (2016) 2353538



So, the conceptual design of a vessel must utilize physics-based methods to simulate the propulsion, manoeuvring, and seakeeping hydrodynamic performance of the evolving design based only upon the dimensions, parameters, and intended features of the design. An **early estimate** of resistance is needed to establish the machinery and engine room size and weight, which will directly influence the required overall size of the vessel. Maneuvering and seakeeping should also be checked at this stage of many designs since the evolving hull dimensions and parameters will affect this performance and, thus, the maneuvering and seakeeping requirements may influence their selection.



5.4 Preliminary structural design (A1224)

A1224

Path Name	A0—A1—A12—A122—A1224
Common Name	A1224
Aliases	Create preliminary structure design
Description	The activity that produces the preliminary steel structure design, including the arrangement of the primary structural members.
Activities	
Inputs	A0.preliminary hull form, A0.preliminary design
Parameters	A0.laws, rules and regulations
Outputs	A0.feedback, A0.preliminary machinery, structure and outfitting design, A0.ship weight modifications
Participants	shipyard

The initial design of the midship section provides support for a more accurate estimate of the hull structures weight. It also supports a more elaborated estimate of the cost building the hull split into cost of material and cost of labour.

At the concept design stage is enough to specify the configuration of the midship section, which is characteristic of the cargo area. This midship section specifies the geometric configuration of the section, the number and location of longitudinal girders, the scantlings of plates and stiffeners of all the panels (bottom, shell, deck, double-bottom, longitudinal bulkheads. The scantlings of the typical web frame are also specified in the midship section. In accordance to the classification societies' requirements, the scantlings abovementioned are to be kept constant in an extent of 40% of the ship's length, amidships.

At a higher level of detail, the type (planar, corrugated) and number of transverse bulkheads is defined and the scantlings of a typical bulkhead can be determined.

Relations with other data (accordingly with Activity Map)

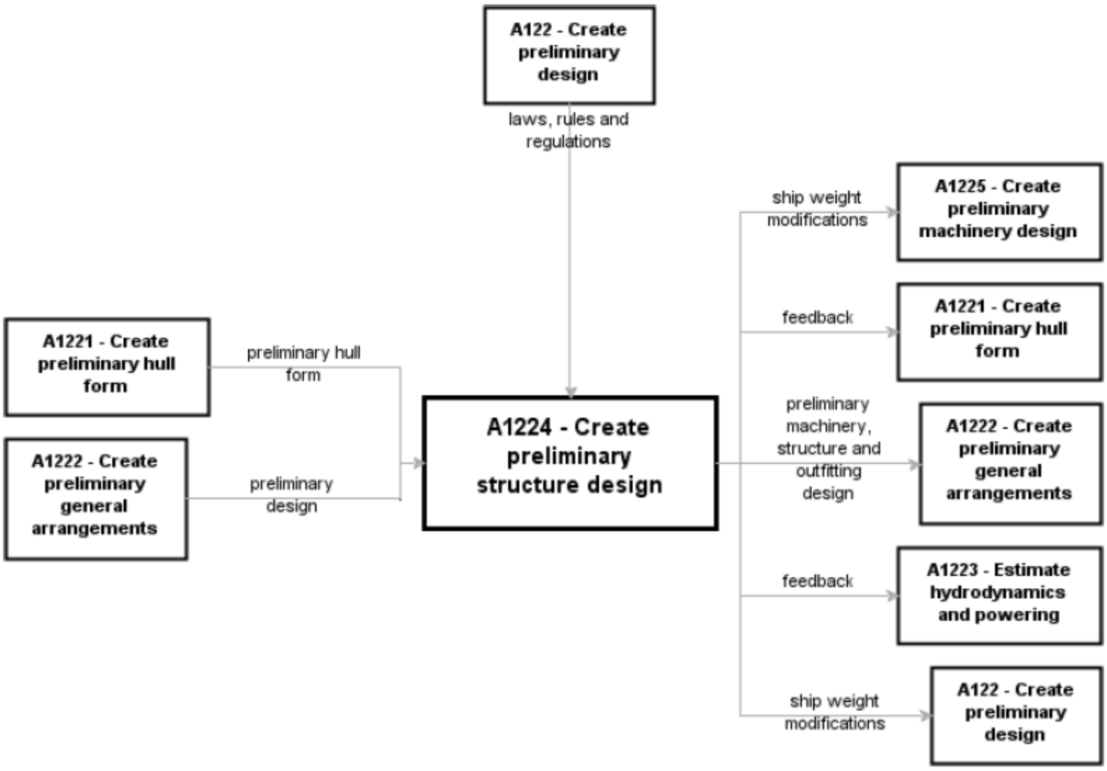
- The configuration the structural layout is closely related with the hull shape and the spaces arrangement.
- The results can be supplied to the activities related with weights estimate and with shipbuilding cost.

Relation with processes

- A1224 - Create preliminary structure design
- A124 - Calculate cost of ship

Considerations related to optimal design

The optimization of the structure at the concept design can be associated obviously with the hull strength assessment. The design variables can be the scantlings of plates and stiffeners and also the spacing of longitudinal stiffeners and of web frames.


A122 - Create preliminary design
laws, rules and regulations
A1221 - Create preliminary hull form
preliminary hull form
A1222 - Create preliminary general arrangements
preliminary design
A1224 - Create preliminary structure design
ship weight modifications
A1225 - Create preliminary machinery design
feedback
A1221 - Create preliminary hull form
preliminary machinery, structure and outfitting design
A1222 - Create preliminary general arrangements
feedback
A1223 - Estimate hydrodynamics and powering
ship weight modifications
A122 - Create preliminary design

5.5 Preliminary machinery design (A1225)

A1225

Path Name	A0—A1—A12—A122—A1225
Common Name	A1225
Aliases	Create preliminary machinery design
Description	The activity that produces the preliminary designs for the ship machinery; including the prime mover, shaft system, fuel system, power systems and cargo handling equipment.
Activities	A12255, A12253, A12254, A12251, A12252
Inputs	feedback, hydrodynamics & powering results, preliminary design, ship weight modifications
Controls	laws, rules and regulations, product component information, propeller design, preliminary design
Outputs	feedback, auxiliary equipment, manoeuvring system, preliminary machinery design, deck machinery
Mechanisms	shipyard
Transitions	A12251→A12253, A12251→A12252, A1225→A12251, A1225→A12252, A12252→A12253, A12252→A12254, A1225→A12253, A12255→A1225, A1225→A12255, A12254→A1225, A12253→A1225, A1225→A12254, A12251→A12254

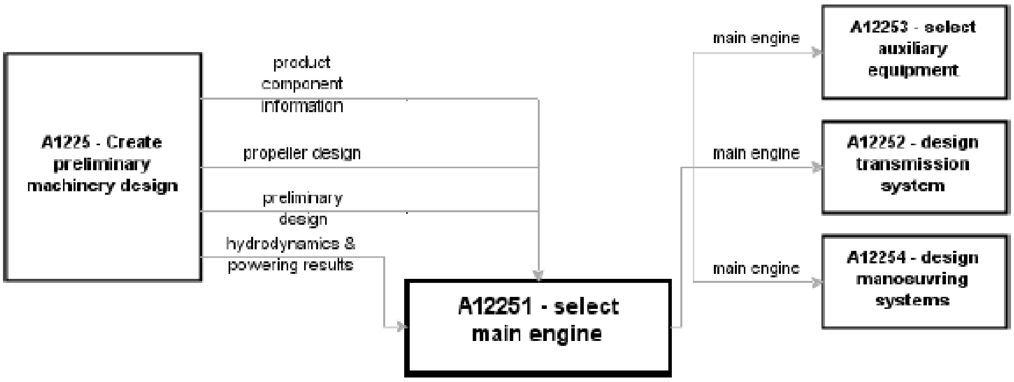
This activity produces the preliminary design for the ships machinery, including prime mover, shaft system, fuel system, power systems and cargo handling equipment. With inputs from previous activities like A1223 and consideration of classification rules, the outputs from this activity enables the calculation of construction costs and also it will impact significantly on the cost, environmental and risk impact in the following life stages, especially, operation phase which the operation costs and environmental and risk issues are concerned by ship operators. There are five sub-activities related to this activity in order to create a comprehensive design for ships machinery system:

- A12251- Select main engine.
- A12252 - Design transmission system.

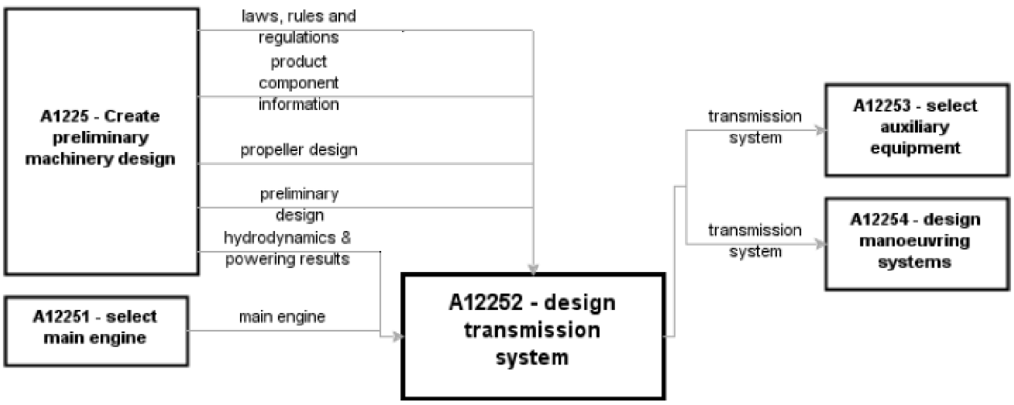
- A12253 - Select auxiliary equipment.
- A12254 - Design manoeuvring systems
- A12255 - Select deck machinery

Relation with processes

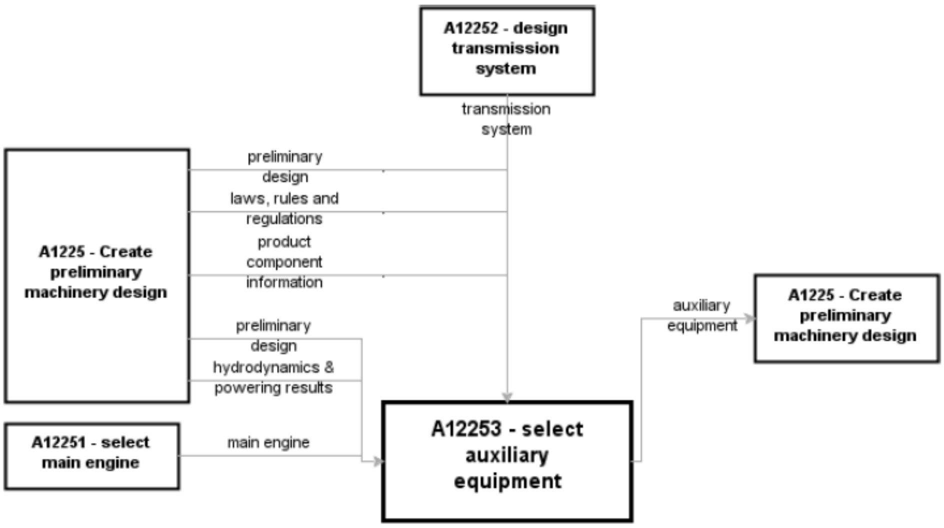
- A12251- Select main engine. The activities which lead to the selection of the main engine by the shipyard.



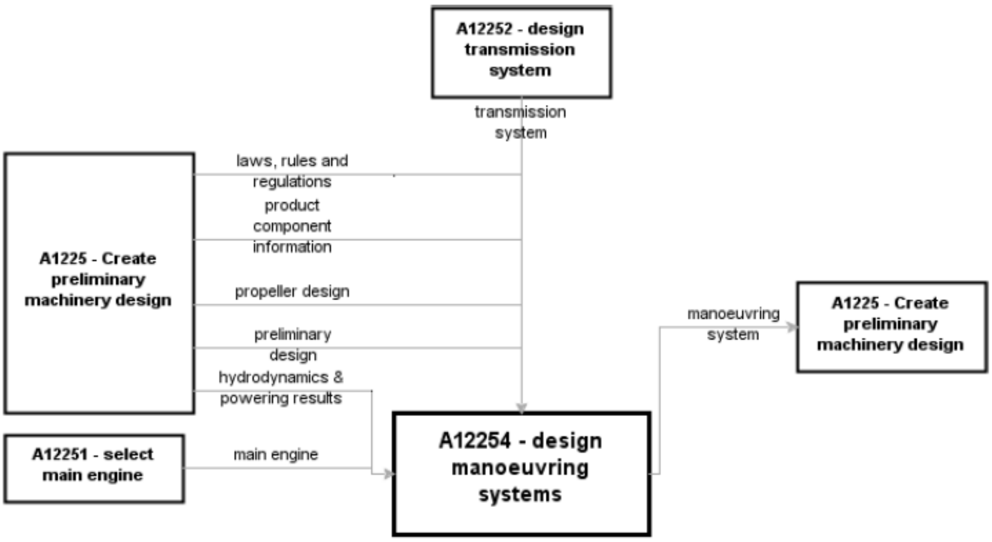
- A12252 - Design transmission system. The activities which leads to design of the ship main mechanical transmission system.



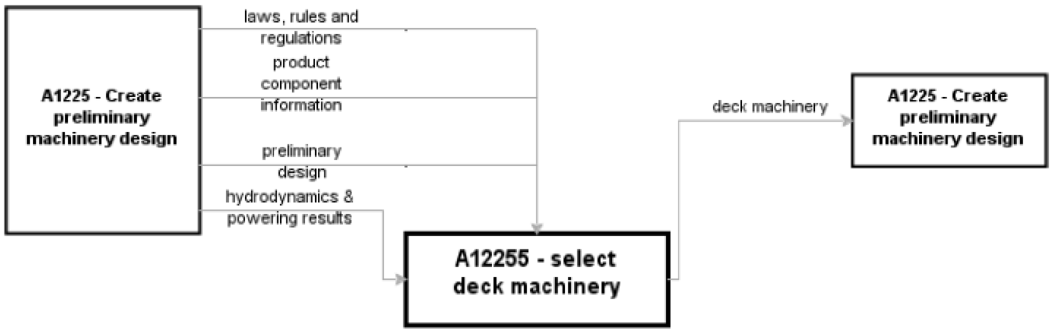
- A12253 - Select auxiliary equipment. The activities which lead to the selection of auxiliary equipment.

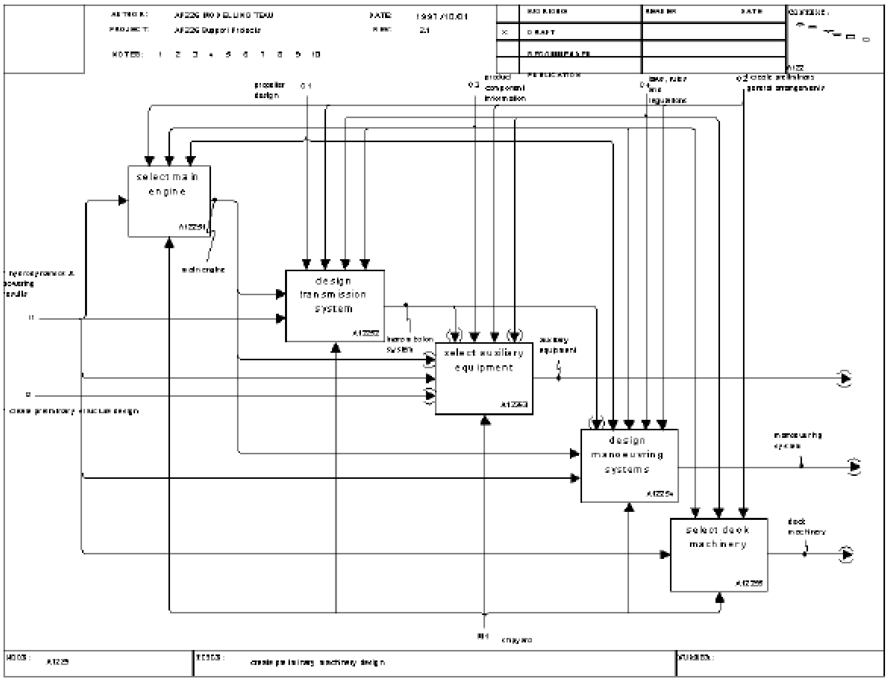


- A12254 - Design manoeuvring systems – The activities which lead to design of the manoeuvring system by the shipyard for the ship.



- A12255 - Select deck machinery - The activity which leads to the selection of deck machinery.


A1225 - Create preliminary machinery design
laws, rules and regulations
product component information
preliminary design
hydrodynamics & powering results
A12255 - select deck machinery
deck machinery
A1225 - Create preliminary machinery design


select main engine
design transmission system
select auxiliary equipment
design manoeuvring systems
select deck machinery

5.6 Preliminary outfitting design (A1226)

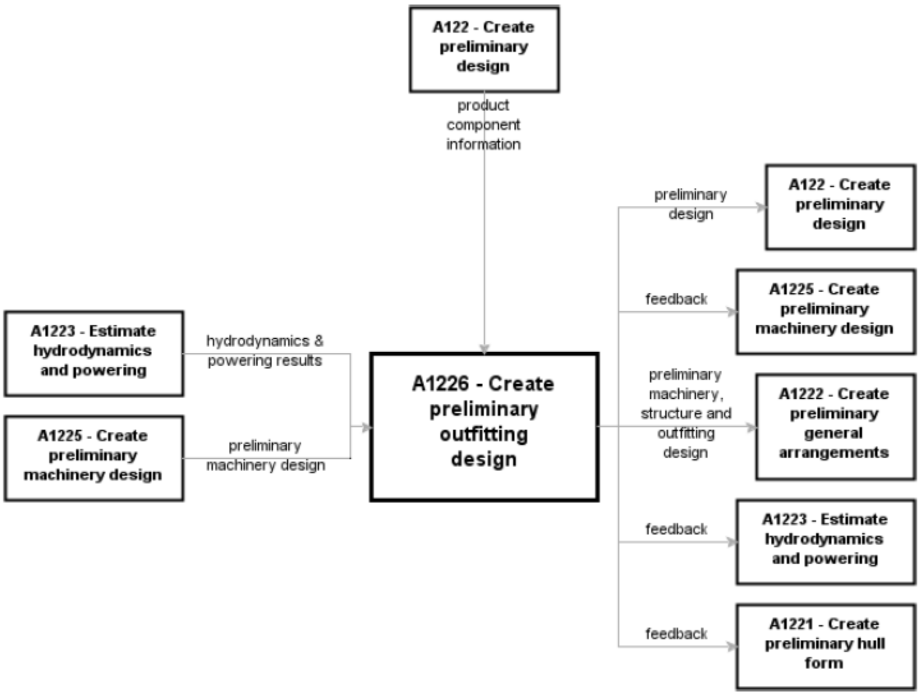
A1226

Path Name	A0—A1—A12—A122—A1226
Common Name	A1226
Aliases	Create preliminary outfitting design
Description	The activity that produces the preliminary design for the ship?s outfitting, including distributed systems, such as piping and electrical systems.
Activities	
Inputs	preliminary machinery design, hydrodynamics & powering results
Controls	product component information
Outputs	feedback, preliminary machinery, structure and outfitting design, preliminary design
Mechanisms	shipyard

This activity include the preliminary design for the ships outfitting, including distributed systems, such as piping and electrical systems. It is very important to define a preliminary outfitting in early stage, so that a more accurate offer can be made in the cases of retrofitting.

Create a preliminary outfitting design is an activity that it is related with different activities and sub activities since, it feeds the needs which are necessary for its development. As it´s showed in the point 4 of this document, A1226 depend of A1223 and A1225 and then due to preliminary outfitting design will feed others sub-activities (including activity A122) like A1221, A1222, A1223 and A1225. It is very important to remark, since all activities are interconnected and if it carried out a bad definition, it can affect future supply at all levels.

Relation with processes



6 Calculate cost of ship (A124)

According to ISO10303, describing all lifecycle activities associated with a ship, activity A124 "describes creation of negotiating documents based on technical product data and their estimated manufacturing cost. The results of this activity may contain sale price documents, financing support plan and documents describing funding and possible loans".

The purpose of the life cycle analysis for a product is generally to estimate its impact on various aspects, such as cost and environmental impacts, by tracing cash and energy flows for the whole life stages ranging from raw material exploitation, material production, manufacturing (construction), operation (utilisation), maintenance, dismantling to recycle. The scope of life cycle model for SHIPLYS project is to set up with five main phases of the ship's life: ship design, ship's construction, operation, maintenance and dismantling. Ship Life Cycle Costing methodologies usually include design phase to their estimations [**Error! Reference source not found.**]. Although design stage is very important for successful shipbuilding, it is quite a bit difficult to define the parameters determining design costs, particularly in LCA, as there is almost no energy flow and no emissions, and the costs are not easily estimated.

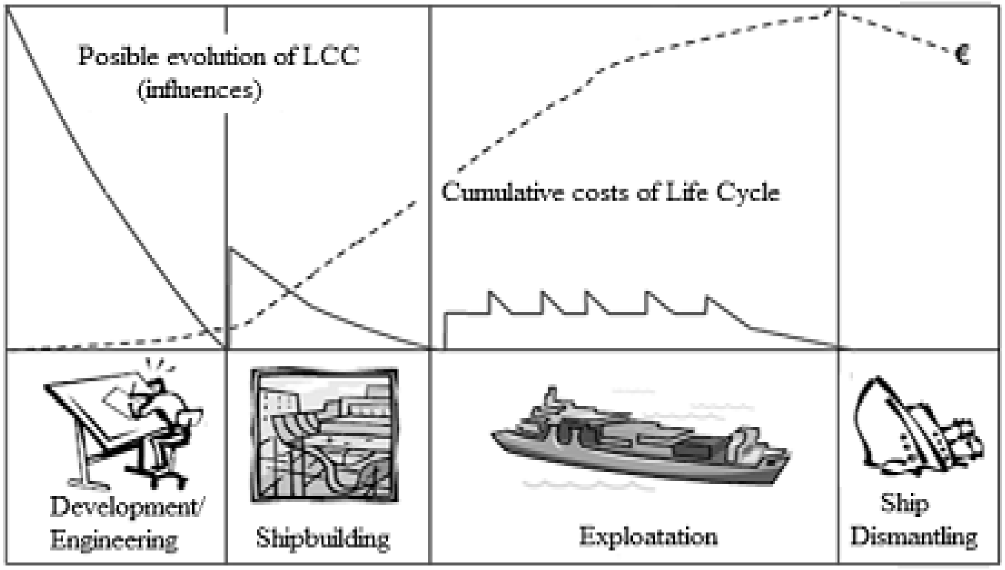


Figure 18: Life Cycle Costing (LCC)

Meanwhile, the raw material exploitation will not be considered, as the ship builder (ship yard) normally starts the construction with purchasing manufactured materials, such as steel plates. In this project, in order to develop an appropriate decision making tool, the focus is placed on three assessments: cost, environmental and risk assessments. Therefore, the considerations of ship life cycle should cover the evaluation of its cost, environmental impact and risk level during the whole life cycle processes.

As part of the development of the Life Cycle Tool (LCT) for the SHIPLYS project purposes, project partners have agreed to further extend activity A124 to additional activities and sub-activities that will be used to describe the procedures and data requirements for performing life cycle costing, environmental and risk assessment.

A124

Path Name	A0—A1—A12—A124
Common Name	A124
Aliases	Calculate cost of ship
Description	This activity describes creation of negotiating documents based on technical product data and their estimated manufacturing cost. The results of this activity may contain sale price documents, financing support plan and documents describing funding and possible loans.
Activities	
Inputs	A0.availability, reliability and maintainability information, A0.material list
Parameters	A0.budget, A0.manufacturing restrictions, A0.workload, A0.owner request, requirements
Outputs	A0.cost
Participants	shipyard

Figure 19: Activity A124

The sub-activities selected in order to extend activity A124 are based on the phases of the ship's life and are configured as follows:

- A1241 – Cost of Design
- A1242 – Cost of Construction
- A1243 – Cost of Operation
- A1244 – Cost of Maintenance/Retrofitting
- A1245 – Cost of Scrapping

The categories of the selected sub-activities follow the life cycle of a ship that is used in LCC estimations. Each sub-activity will require a number of cost data from the specific life phase and the parameters that affect each phase. For this purpose, a list of cost parameters (along with design parameters) for each life phase of a ship has been created with the contribution from various partners of the SHIPLYS project. This list will be used as a template for the life cycle tool and the structure of the required data.

The layout of LCA model that will be developed for the SHIPLYS project is presented in the figure below. Using ship's parameters and other data, the analysis for each phase will be individually carried out using weighted factors and then the results of each phase will be summed up to evaluate the overall impacts of the ship's life cycle. This LCT model will then be applied as a multi-criteria decision making tool. During the analysis, series of databases will be connected with the LCT model to provide fundamental data for ship's life cycle analysis.

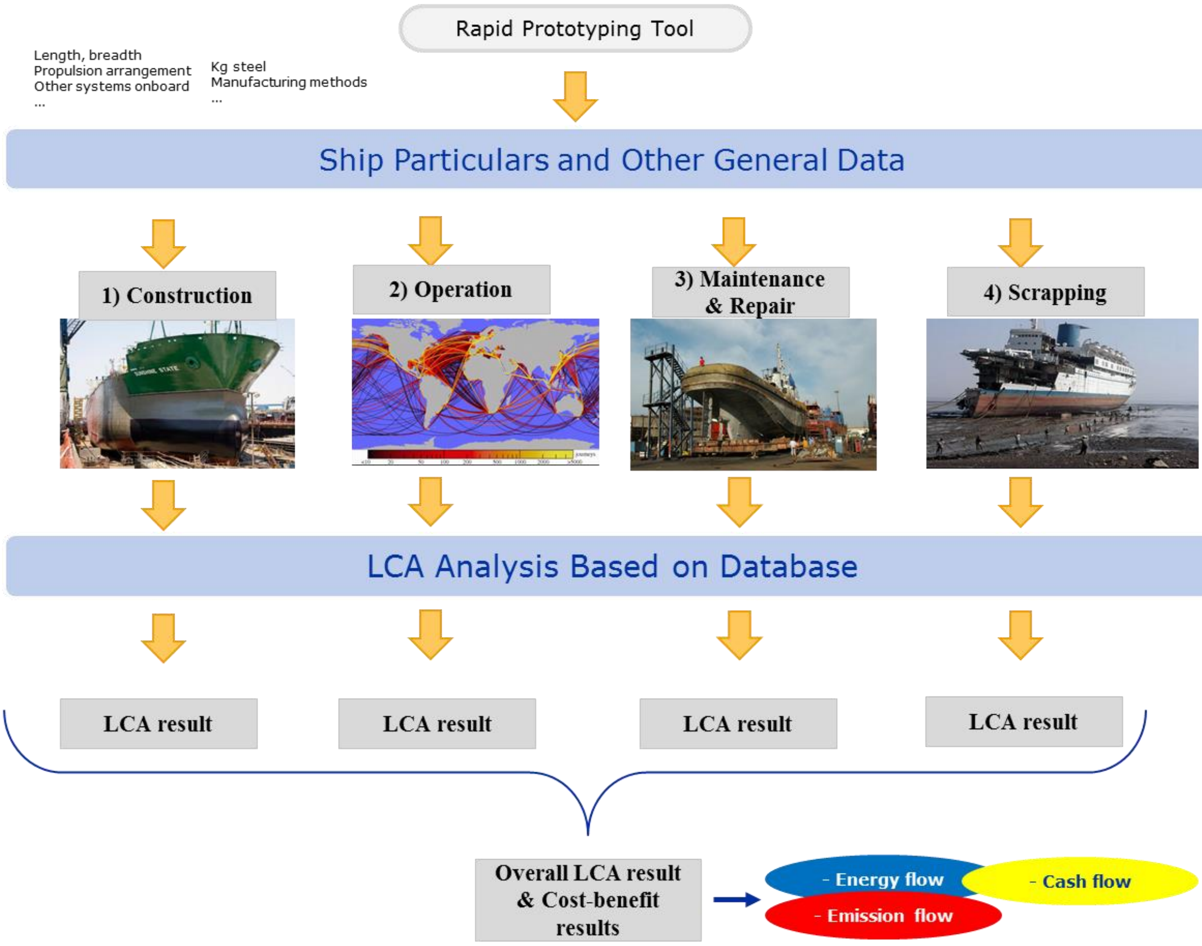


Figure 20: Flowchart of ship LCA model

A top-bottom strategy is applied to identify database elements. Due to lack of data and also considering their significance, the database will be limited so that it is helpful and convenient to find out the boundaries of the LCA model with this strategy.

Construction:

In the construction phase, there are three main parts to be considered: hull, machinery and accommodation. Several significant processes should be considered in hull construction: material transportation, cutting, bending, welding and assembling, and coating. There are also many different types of machineries: engine, boiler, ballast water treatment system and so on. For accommodation, superstructure should be well-considered especially on materials and assembling.

All databases should provide different technologies from both shipyard and literatures with the energy consumptions of technologies and emission released. With the price of energy, the costs of these processes can be obtained. For some processes, there are also materials input, such as welding. The material consumption and prices should be provided in the database as well.

Another energy and fuel database should be considered separately because most of the electricity used in shipyard is supplied by local electricity supplier and sometimes fuel oils will be used for power generation. Electricity database should include regions and source types of the supplier with the price. For fuel database, the heat values of fuels and emission conversion factor should be provided.

Operation:

Operation phase will use database from construction phase to conduct LCA. The most significant results from this phase are operation cost, emission released and risk assessment. For operation cost, the fuel costs is the most important one as all the energy and electricity are supplied by consuming fuel in engines and generators. The engines and generators have been selected in the database for construction phase. With the fuel consumption, the emission, like CO_2 and SOx, can be derived according to selected fuel properties (Risk).

Hence, no database is necessary in this phase but the operation profile is essential to obtain the fuel consumption for a typical voyage.

Maintenance:

Different to operation phase, maintenance phase need several new database for evaluation. For ship hull, cleaning, re-coating (similar to coating database) and inspection and repairs techniques should be gathered to establish database, because these processes are necessary maintenance for ship hull. For machinery, there are beyond many items to be inspected and repaired which results in too many but insignificant database. In this project, assumptions are made to maintenance phase in order to reduce the redundant but unnecessary database. The assumptions are made on maintenance plans which indicate the times of maintenances in a ship lifetime. These assumptions could be referred to and based on manufactures and previous experiences.

Therefore database is not required in this phase and maintenance plans will be significantly important to maintenance evaluations.

Scrapping:

As scrapping is relative new in shipping industry, the technologies applied in scrapping should be considered based on processes. First of all, old ships for dismantling will be docked in the scrapping facilities so the docking technologies can be collected as a database. During dismantling, cutting and de-coating are another two important processes so database for both of them are necessary just like docking database. In this phase, cutting database is similar to construction phase.

In order to assess the ship life cycle, the consideration based on the global characteristics about how they are involved with life cycle estimations is necessary. The main considerations are the cost (LCCA), environmental impact (LCA) and risk assessments (RA) with which the evaluation of ship life cycle performance can be determined. However, not all these characteristics are applicable for life cycle analysis, so it is essential to identify and indicate these significant ones with their usage in the evaluations.

LCCA (Life Cycle Cost Analysis)

Life Cycle Cost (LCC) is defined as the total cost of owning, operating, maintaining, and disposing a product over its life time. Life Cycle Cost Analysis (LCCA) is an economic evaluation technique that determines the total cost of owning and operating a product over its life time [**Error! Reference source not found.**].

In the shipping industry, LCCA basically focuses on the costs along the ship life span such as construction materials purchases, operation fuel and energy costs, dismantling energy costs and so on. However, not all of them are directly connected to ship initial characteristics but they may be constrained by them. For example, the service speed, ship parameters and others will impact the selection of main engines which will also influence the fuel cost during the operation phase. Therefore, in this part, the impacts of global characteristics on design stage will be focused and the influences in other phases will not be discussed in detail here.

The main ship characteristics and design parameters affecting LCCA estimations are listed below:

1. Type of Ship
2. DWT (if applicable)
3. Flag and Register port
4. Class (if applicable)
5. Expected lifetime
6. Shipyard's location
7. Ship's building number
8. Ship's dimensions and hull parameters
9. Service speed
10. Power and engine parameters

CapEx & OpEx

This section will discuss and present the cost assessment algorithm in order to figure out and quantify the costs during the whole ship life.

- **CapEx (capital expenditures)** is to determine the initial costs of a product by breaking downs in the construction phase into several sub-parts (i.e. hull, machinery, accommodation parts). To apply CapEx, the costs for raw materials, machineries, labors, consumers, energy usage, etc for each part should be listed up for estimating CapEx.

- **OpEx (operating expenses)** has a similar concept, but to estimate the costs of operation and maintenance by tracking the cash flow over the ship's whole operational period. For OpEx, the operation costs for each year should include the all category of costs associated with ships' lifelong activities, such as fuel and energy consumption, repair, maintenance and so on.

Determining the value of a project is challenging because of the time value of money (TVM), money in the present is worth more than the same amount in the future. This is both because of earnings that could potentially be made using the money during the intervening time and because of inflation. The discount rate element of the net present value (NPV) formula is a way to account for this. Companies may often have different ways of identifying the discount rate. In this principle; the SHIPLYS project applies PV to investigate the cash flows during the whole life of a ship. The NPV formula is presented as following:

$$NPV=\sum_{t=1}^{T}\frac{C_t}{(1+r)^t}-C_0$$

where:

- C_t OpEx: net cash inflow during the period t
- C_0 CapEx: total initial investment costs
- r discount rate, and
- t number of time periods (years).

A positive net present value indicates that the projected earnings generated by a project or investment (in present dollars) exceeds the anticipated costs. Generally, an investment with a positive NPV will be a profitable one and one with a negative NPV will result in a net loss. This concept is the basis for the Net Present Value Rule, which dictates that the only investments that should be made are those with positive NPV values.

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6.1 Cost of Design (A1241)

Life cycle assessment approach provides information throughout the products "life", from design phase until scrapping and discharge.

The costs that contribute to the LCCA estimations are mainly related to the development/purchase of software and databases, personnel/man-hours costs and R&D costs. However, the phase of design is very important in ship's life cycle since very important decisions for future energy efficiency and operational impact are made during this time.

Additionally, during the conception and design phase of a ship, information, knowledge and documents are created and ideally filed within a product data management system. This can be system related data sheets, specifications, manuals, calibrations, settings, manufacturer information [**Error! Reference source not found.**].

6.2 Cost of Construction/Retrofitting (A1242)

In the construction phase, there are three main parts to be considered: hull, machinery and accommodation. Several significant processes should be considered in hull construction: material transportation, cutting, bending, welding and assembling, and coating. There are also many different types of machineries: engine, boiler, ballast water treatment system and so on. For accommodation, superstructure should be well-considered especially on materials and assembling.

All databases should provide different technologies from both shipyard and literatures with the energy consumptions of technologies and emission released. With the price of energy, the costs of these processes can be obtained. For some processes, there are also materials input, such as welding. The material consumption and prices should be provided in the database as well.

Retrofitting:

Retrofitting is installing a modular system in an existing system, with the purpose to increase the system's efficiency. An old part will be replaced by a completely different new part; therefore the new part should replace the function with a higher efficiency. It is sometimes more efficient to keep the old installation instead of buying a whole new one. That has led to an increasing upcoming principle in the maritime sector; retrofit [**Error! Reference source not found.**].

Life cycle methodologies can be used as a tool to assist in the decision-making process for ship-owners and fleet managers, during the retrofit process and practical evaluation of ship retrofitting. A cost–benefit analysis carried out against the systems, shown in comparison with the environmental impact results, will produce a more accurately holistic assessment [9].

6.3 Cost of Operation (A1243)

Operation phase will use database from construction phase to conduct LCA. The most significant results from this phase are operation cost, emission released and risk assessment. For operation cost, the fuel costs is the most important one as all the energy and electricity are supplied by consuming fuel in engines and generators. The engines and generators have been selected in the database for construction phase. With the fuel consumption, the emission, like CO_2 and SOx, can be derived according to selected fuel properties (Risk).

Hence, no database is necessary in this phase but the operation profile is essential to obtain the fuel consumption for a typical voyage.

6.4 Cost of Maintenance (A1244)

Different to operation phase, maintenance phase need several new database for evaluation. For ship hull, cleaning, re-coating (similar to coating database) and inspection and repairs techniques should be gathered to establish database because these processes are necessary maintenance for ship hull. For machinery, there are beyond many items to be inspected and repaired which results too many but insignificant database. In this project, assumptions are made to maintenance phase in order to reduce the redundant but unnecessary database. The assumptions are made on maintenance plans which indicate the times of maintenances in a ship lifetime. These assumptions could be referred to and based on manufactures and previous experiences.

Therefore database is not required in this phase and maintenance plans will be significantly important to maintenance evaluations.

6.5 Cost of Scrapping (A1245)

As scrapping is relative new in shipping industry, the technologies applied in scrapping should be considered based on processes. First of all, old ships for dismantling will be docked in the scrapping facilities so the docking technologies can be collected as a database. During dismantling, cutting and de-coating are another two important processes so database for both of them are necessary just like docking database. In this phase, cutting database is similar to construction phase.

7 Environmental Impact (A127)

Environmental impact assessment (EIA) is the assessment of the environmental consequences (positive or negative) of a project prior to the decision making. EIAs involved a technical evaluation intended to contribute to more objective decision making. For SHIPLYS project focusing on industrial products, environmental life cycle analysis is used for identifying and measuring the environmental impact of all activities associated with ship construction, operation, maintenance and dismantling.

The main objectives are to collect and analyse information on how LCA results are or could be interpreted including analysis of different indicators, normalisation and weighting systems and sensitivity of the results.

Normalisation is the calculation of the magnitude of the category indicator results relative to reference information, while weighting is a method in which the (normalised) indicator results for each impact category assessed are assigned to numerical factors according to their relative importance, multiplied by these factors and possibly aggregated.

Therefore different substances can be evaluated for their environmental based on same impact category. A flowchart of the principle is presented in the following figure. This figure sets Global Warming Potential as an example: with the fuel consumptions given from ship particulars, the emissions from fuel burnt (CO_2, CO and so on) can be derived. Therefore, the equivalent impact can be figured out with characterisation method.

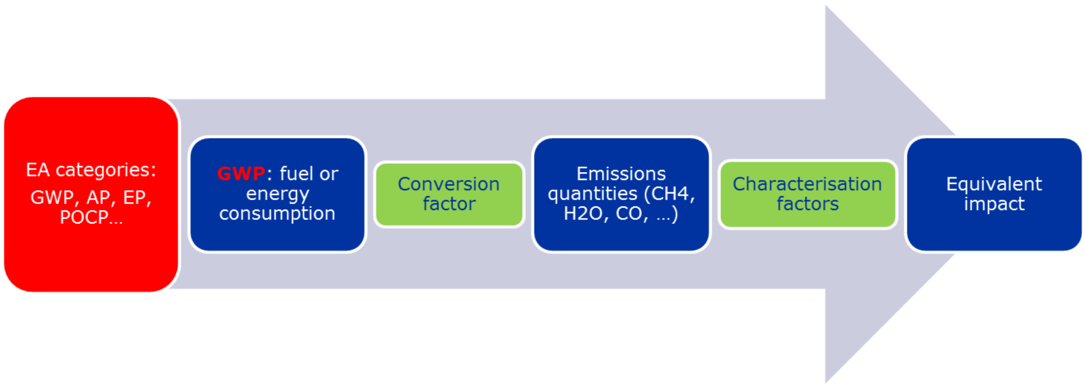

Figure 21: Flowchart of characterisation method principle

Characterisation factors and examples for different impact categories

Impact category **(Unit)**	**Characterisation factors**	**Examples**
Global warming potential (kg CO_2 eq.)	GWP100, CML 2001 **baseline** Version: January 2016.	**1 kg carbon dioxide = 1 kg CO_2 eq.** **1 kg methane = 28* kg CO_2 eq.** 1 kg dinitrogen oxide = 265 kg CO_2 eq.
Acidification potential (kg SO_2 eq.)	AP, CML 2001 **baseline** , Version: January 2016.	1 kg sulphur dioxide = 1 kg SO_2 eq. 1 kg ammonia = 1.6 kg SO_2 eq. 1 kg nitrogen dioxide = 0.5 kg SO_2 eq.
Eutrophication potential (kg PO_4^{3-} eq.)	EP, CML 2001 **baseline** (fate not included), Version: January 2016.	1 kg phosphate = 1 kg PO_4^{3-} eq. 1 kg ammonia = 0.35 kg kg PO_4^{3-} eq. 1 kg COD (to freshwater) = 0.022 kg kg PO_4^{3-} eq.
Photochemical oxidant creation potential (kg C_2H_4 eq.)	POCP, CML 2001 **baseline** (high NOx), Version: January 2016.	1 kg carbon monoxide = 0.027 kg C_2H_4 eq. 1 kg ethane = 0.123 kg C_2H_4 eq. 1 kg toluene = 0.637 kg C_2H_4 eq.

Meanwhile, International Maritime Organization (IMO) has introduced Energy Efficiency Operational Indicator (EEOI) as a monitoring tool for managing ship and fleet efficiency performance over time. The EEOI enables operators to measure the fuel efficiency of a ship in operation to indicate the ratio of CO_2 emission quantity and transportation works.

To combine EEOI concept with characterisation method, a LCA energy efficiency GWP score can be designed as the equation presented as below:

$$LCA_{effGWP} = \frac{\sum_i gGWP_i}{\sum_i (m_{cargo,i} \times D_i)}$$

where,

- D is the distance (nautical miles) corresponding to the cargo carried or work done;
- gGWP is the LCA CO2 inventory aggregate in grams comprising classification and characterisation of releases analogous to CO2;
- LCAeffGWP is the LCA energy efficiency GWP score in g CO2/tonne-nm;
- mcargo is cargo carried (tonnes) or work done (number of TEU or passengers) or gross tonnes for passenger ships;
- i is the index of summation. (Blanco, 2014)

Life Cycle Assessment (LCA) is a systematic way of examining the environmental impacts of a product throughout its life cycle, from raw materials extraction through the processing, transport, use and finally product disposal. LCA is sometimes called a “cradle to grave” assessment as it incorporates all stages of a ship’s life [**Error! Reference source not found.**].

LCA could be used also to assist companies to identify and assess opportunities to realize cost savings by making better design and more environmentally friendly products, more effective use of available resources and improving waste management systems, therefore, minimize energy consumption and environmental impacts holistically, across the entire life of the product. LCA analyses the entire life cycle of a product from raw materials extraction and acquisition, materials processing and manufacture, material transportation, product fabrication, transportation, distribution, operation, consumption, maintenance, repair and finally product disposal/ scrapping [**Error! Reference source not found.**].

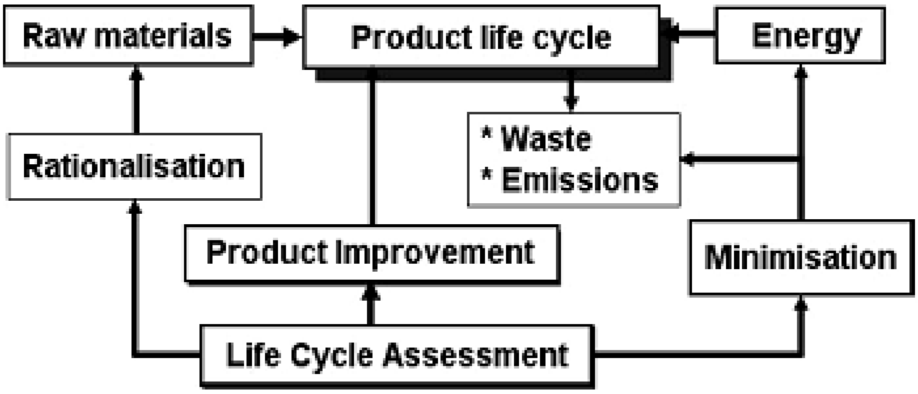

Figure 22: Main Concept of LCA

LCA can be used by the maritime industry to help the business actors to identify and to evaluate the opportunities for achieving significant savings in the output cost structure, with a better design and with a more efficient using of available resources, including a proper settlement of improved waste management systems [6]. The main objectives of the LCA approach are the minimization of energy consumption, the minimization of environmental impacts and the rationalization of material used.

In order for the SHIPLYS project to be capable to perform environmental assessment of the provided ship design scenarios, the developed LCA tool should be able to incorporate the global characteristics of the developed designs and quantify the environmental impact of each life cycle phase in a ship's life. To do so, a number of sub-activities of the Activity A127 - Environmental Impact, have been designed to meet with the requirements of the proposed LCA methodology.

These sub-activities are:

- A1271 – Environmental Impact of Construction
- A1272 – Environmental Impact of Operation
- A1273 – Environmental Impact of Maintenance
- A1274 – Environmental Impact of Retrofitting
- A1275 – Environmental Impact of Scrapping

The above sub-activities follow the life cycle of a ship and for each phase, the LCA methodology will evaluate its environmental impact. Additionally, a number of sub-sub-activities will be created in order to be able to estimate the environmental impact of each life cycle phase according to the impact categories and characterisation factors presented in the last Table (GWP, AP, EP and POCP).

In order for the ISO model to be implemented in the shipbuilding and shipping industry, there will be a need for closer cooperation and communication between the different parties involved in the different phases of the ship's life cycle (designers, construction yards, ship operators, maintenance and repair yards, supporters and suppliers, financial institutions, scrapping yards and waste handling and recycling companies, etc.). ISO model can be used to develop the industry standard for environmental performance evaluation within the maritime industry [7].

Finally, all life cycle phases should be considered as important, but with respect to different environmental impacts; global warming, acidification, eutrophication, smog and energy consumption for the operational phase; solid waste from the scrapping phase; local impacts like toxicity for humans and ecology for construction and maintenance [**Error! Reference source not found.**].

7.1 Environmental Impact of Construction (A1271)

Energy demands and emissions during the construction phase are used to evaluate the environmental impact of this phase in the life of a ship. The energy used in ship production could be divided into direct and indirect energies. The indirect energy used in the shipbuilding industry is used for the manufacture and production of the following main items: steel plates and sections, main and auxiliary engines, equipment, fittings, welding coils and electrodes, paints, etc. The direct energy required for ship construction is used for handling and transport (raw materials, fabricated sections and blocks), fabrication processes (cutting, forming, welding), assembly of steel plates and sections, construction of 2D and 3D blocks, erection and assembly of blocks on berth or in dock, outfitting operations, tests and trials. In all fusion welding processes, sufficient energy is required to produce local melting. During welding operations, welders are exposed to welding fumes. Welding current, arc voltage and welding speed are the most decisive variables affecting energy input to a welded joint.

Within shipping industry, the life cycle concept is often understood as the period from the time the ship is contracted until the time it is sold. Assessment of the economic life cycle focuses on the trading profit. The understanding of the life cycle within shipping is mainly restricted to the operational phase, which is in conflict with what is defined as the life cycle of a product according to the LCA-standard. For example steel enters the system life cycle of the ship in the construction phase. The environmental impact caused by steel parts depends on the raw material extraction, processes cutting and fitting of steel plates and profiles, mounting of plates to sections by welding, grinding, sand blasting and painting, and transportation of steel components and sections.

To further aim the implementation of the LCA methodology, the sub-sub-activities below are suggested, following the main impact categories used for evaluating environmental impact:

- A12711 - Global Warming Potential (GWP)
- A12712 - Acidification Potential (AP)
- A12713 - Eutrophication Potential (EP)
- A12714 - Photochemical Oxidant Creation Potential (POCP)

7.2 Environmental Impact of Operation (A1272)

Operational phase brings the highest contribution to the environmental impact over the life cycle of a ship, mainly due to fuel consumption. The energy demand and environmental impacts of ship operation are shown in the next figure.

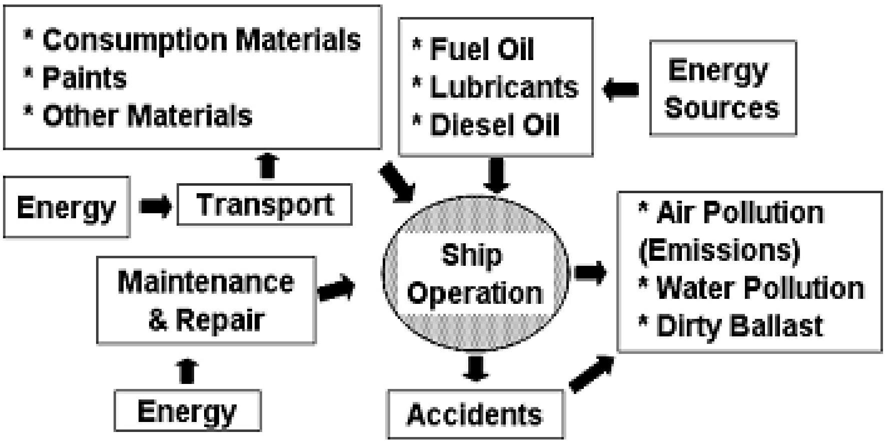

Figure 23: Energy and environment in ship operation

With regard to energy consumption, ships require less energy to carry a given tonnage of cargo over a given distance than all other means of transport. The environmental impacts of ship operation should be considered for both modes of operation at sea and in ports. The environmental impacts should be also considered for both conditions of normal ship operation and when a ship experiences major structural failures or an accident. The main causes of ship structural failures are aging, hull degradation, human error, accidents, etc. [**Error! Reference source not found.**].

Marine transport contributes to the world's NOx production. Minimization of the negative environmental impacts during sea operation require reduction of exhaust gas emissions (CO_2, NOx, SOx, particulate), sewage treatment, treatment of contamination of ballast water, handling/control of garbage by efficient stowage/incineration, reduction of the harmful impact on marine life induced by underwater coatings and antifouling paints, reduction of fouling at sea chests, etc.

As in the construction phase, the sub-sub-activities below are suggested, in order to aim the implementation of the LCA methodology based on the environmental characterisation factors:

- A12721 - Global Warming Potential (GWP)
- A12722 - Acidification Potential (AP)
- A12723 - Eutrophication Potential (EP)
- A12724 - Photochemical Oxidant Creation Potential (POCP)

7.3 Environmental Impact of Maintenance (A1273)

Maintenance cost includes all activities and efforts put forward in a period of time in the life of a ship, including planned maintenance, unscheduled maintenance, replacement and emergency repairs, in order to ensure the ship's operation in its original quality and function. Maintenance as well as scrapping phases contribute to the sustainability [**Error! Reference source not found.**].

Maintenance phase is usually considered as part of the operational life of a ship. However, construction, maintenance and scrapping are all included in the business of shipbuilding. As a result, the environmental impact of the maintenance procedures should be studied solely.

Environmental assessment of the maintenance phase could provide with solutions for reduced maintenance costs. ISO 14040 standards have already provided data input to ship design and improvement of maintenance routines. It has contributed to optimization of fuel consumption and bottom hull coating and to cost/environmental optimizations for the vessel taken under study [9**Error! Reference source not found.**].

In consistence with the ISO model used in the previous phases, sub-sub-activities are designed as follows:

- A12731 - Global Warming Potential (GWP)
- A12732 - Acidification Potential (AP)
- A12733 - Eutrophication Potential (EP)
- A12734 - Photochemical Oxidant Creation Potential (POCP)

7.4 Environmental Impact of Retrofitting (A1274)

As it has been mentioned, retrofitting procedures increase a system's efficiency by for example, reducing fuel consumption or increase a system's operational life. As a result, the environmental impact of ship's operation could be altered.

LCA methodology could be used as a tool applicable to shipboard and maritime industry operations, in order to estimate and compare environmental loads resulting from retrofitting procedures. A logical, realistic application of the LCA methodology could be used as a decision-making tool for ship-owners, during the environmental evaluation of different system alternatives, or similar retrofitting options [8].

The sub-sub-activities below are suggested, in order to follow the main impact categories used for evaluating environmental impact:

- A12741 - Global Warming Potential (GWP)
- A12742 - Acidification Potential (AP)
- A12743 - Eutrophication Potential (EP)
- A12744 - Photochemical Oxidant Creation Potential (POCP)

7.5 Environmental Impact of Scrapping (A1275)

Ship scrapping is becoming an important industry in several countries as the number of ships that has to go out of service is increasing significantly every year. For ship owners, the decision to scrap a ship, continue operation or convert to a different trade requires condition assessment and economic evaluation. Because of the increasing costs of acquiring a new ship, some ship owners have extended the life of some of their ships by upgrading either hull, machinery or both. Extending a ship's life is a positive attitude to protect our natural resources. The results of the condition assessment of hull and machinery should help ship-owners to take the right decision whether to up-grade and continue operation or to scrap the ship [9].

The energy demand and environmental releases of ship scrapping is shown in the figure below.

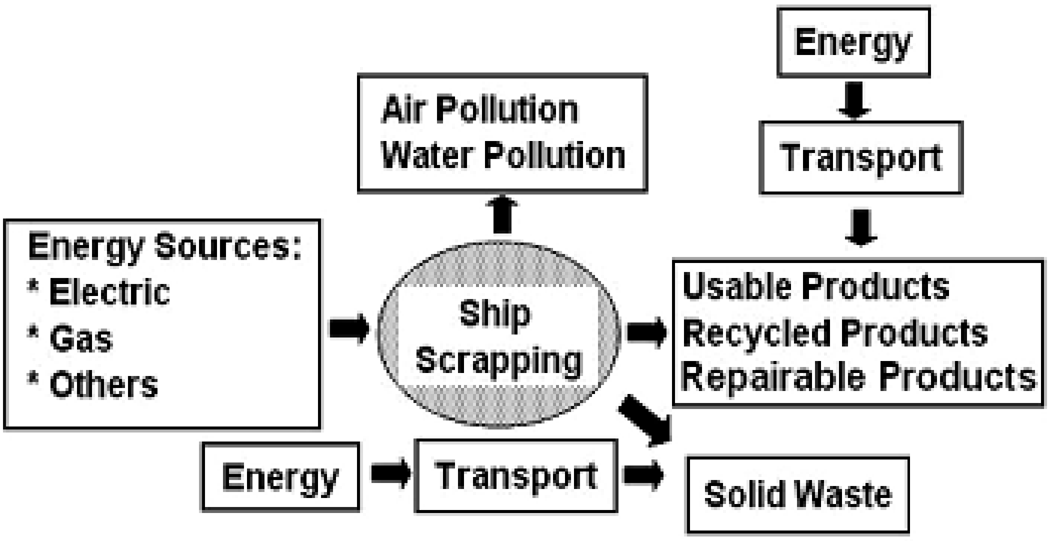

Figure 24: Energy and environment in ship scrapping stage

Ship scrapping products could be divided into:

- Usable materials, equipment, machinery, etc.
- Repairable engines, machinery, equipment, etc.
- Recycled materials, equipment, engines, etc.
- Waste

The outcome of ship scrapping includes:

- Ferrous materials: steel plates & sections, pipes stiffened panels, cast iron, cast steel, etc.
- Non-ferrous materials: copper, brass, bronze, aluminium, zinc, etc.
- Non-metallic materials
- Equipment: electric, navigation, electronic, communication, etc.
- Machinery: cranes, winches, motors, pumps, etc. – Engines: main and auxiliary

Environmental performance of ship scrapping could be improved by the development of a ship scrapping management system that aims at:

- Maximizing reuse, recover and repair of materials, fittings equipment, machinery, engines, etc.
- Minimizing wastes and recycled materials, machinery, equipment, engines, etc.
- Minimizing energy consumption and the negative environmental impacts.

However, the lack of information on scrapping activities throughout the world makes it difficult to measure total environmental impact. To gather sufficient information on these activities is a challenge. Another important challenge is to develop weighting models and specific environmental performance evaluation criteria for selected oceans areas [10].

In order to follow the main impact categories used for evaluating environmental impact, the sub-sub-activities below are suggested as part of the designed ISO model:

- A12751 - Global Warming Potential (GWP)
- A12752 - Acidification Potential (AP)
- A12753 - Eutrophication Potential (EP)
- A12754 - Photochemical Oxidant Creation Potential (POCP)

8 Risk estimation (A128)

Ship design and operation are predominantly governed by the ship owner's specification and applicable Regulations and Classification Rules. In fact, the owner's specification tends to cover the ship performance and minimize the capital and operational costs, the Regulations and Classification Rules cover the fundamental design requirements that include the safety, environmental and operational requirements.

The International Maritime Organisation (IMO) recognizes the importance of adopting the risk assessment procedures in their decision process by defining the Formal Safety Assessment, FSA (IMO, 2002, 2005, 2006a, 2013)) as a systematic methodology aimed at enhancing maritime safety, including the protection of life, health, maritime environment, cargo and ship integrity by using risk and cost-benefit assessments.

A concern about the poor management standards and the contribution of the human error and management shortcomings on marine casualties have motivated the introduction of the International Safety Management (ISM) code, which is directly related to personnel and crew competence and general operational aspects of shipping.

Another development is the creation of the Port State Control program with the objective of eliminating substandard ships from the waters. Addition, the maritime security is also an integral part of IMO's responsibilities.

There has been a tendency to adopt a goal-based approach (IMO, 2006b, 2015) to the Regulation in general, where the regulators do not prescribe technical solutions, but formulate the goals and functional requirements in a risk-based top down approach.

The FSA methodology is elaborated under the auspices of IMO, which is based on a Quantified Risk Analysis (Moan, 1994, Skjong et al., 2005, Sørensen, 2009) and provides widely application of QRA to marine transportation and is going to be employed here. It is a structured methodology, aimed at enhancing maritime safety, including protection of life, health, the maritime environment and property.

The FSA includes five steps, which are the commonly used in a risk analysis methodology, where Step 1 covers the hazard identification, Step 2 is the risk assessment, Step 3 performs the identification of risk control options, Step 4 is related to the cost– benefit assessment and Step 5 includes the recommendations for decision-making.

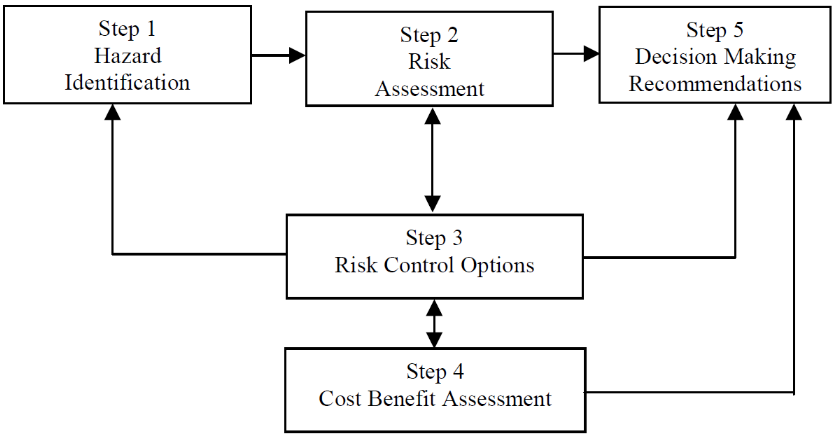

Figure 25: Formal safety assessment (IMO, 2013)

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APPENDIX: The Master Matrix

No	Functionality	Sub-functionality	Activity Diagram (for use in other worksheets)	Existing s/w or approach	Is an alternative s/w or approach that you would like to use?	To be developed within SHIPLYS	Required for SHIPLYS LCCA Module?	Required for SHIPLYS LCA Module?	Required for SHIPLYS Risk Module	SHIPLYS Scenario clearly showing application of the functionality S1 (Y/N)	SHIPLYS Scenario clearly showing application of the functionality S2 (Y/N)	SHIPLYS Scenario clearly showing application of the functionality S3 (Y/N)
A121	EVALUATE REQUEST & SCHEDULE BID	*NOT INCLUDED IN SHIPLYS TOOL*										
A122 (Lead by NTUA)	CREATE PRELIMINARY DESIGN	Create preliminary hull form	A1221	See A122 worksheet			N	N	Y	M	Y	Y (for large works of retrofitting and conversions)
		Create preliminary general arrangment	A1222	See A122 worksheet			N	N	M	M	Y	Y (for large works of retrofitting and conversions)
		Estimate hydrodynamics and power	A1223	See A122 worksheet	sub-contract CFD work		Y	Y	M	Y	Y	Y (for large works of retrofitting and conversions)
		Create preliminary structural design	A1224	See A122 worksheet			N	N	Y	N	Y	N
		Create preliminary machinery design	A1225	See A122 worksheet			N	N	N	Y	Y	N
		Create preliminary outfitting design	A1226	See A122 worksheet			N	N	N	M	Y	Y (for large works of retrofitting and conversions)
A123	DECIDE POST-SALES AND MAINTENANCE SUPPORT	*NOT INCLUDED IN SHIPLYS TOOL*										
A124 (Lead by AS2CON + SU)	CALCULATE COST OF SHIP	Cost of design	A1241			Y				N	Y	Y (for large works of retrofitting and conversions. These data should be included in SHIPLYS software)
		Cost of construction	A1242	In-house speadsheet/IST-tool		Y				Y	Y	Y
		Cost of operation	A1243	In-house speadsheet/IST-tool		Y				Y	Y	Y
		Cost of maintenance/retrofitting	A1244	In-house speadsheet/IST-tool		Y				Y	Y	Y
		Cost of scrapping	A1245			Y				Y	Y	Y
A125	PRESENT OFFER *(former A125)*	*NOT INCLUDED IN SHIPLYS TOOL*										
A126 (Lead by SOERMAR)	CREATE PRELIMINARY DESIGN FOR RETROFITTING PURPOSES	Create preliminary machinery and outfitting design via scanning three-dimensional	A1261	3D scanning Technology (FARO)	Y	N	N	N	N	N	N	Y (some of these data should be included in SHIPLYS software)
		Create preliminary machinery and outfitting design via two-dimensional drawings	A1262	2D model. - AUTOCAD	Y	N	N	N	N	N	N	Y (some of these data should be included in SHIPLYS software)
		Create preliminary machinery and outfitting design via three-dimensional drawings	A1263	3D model- AUTOCAD/SOLIDWORKS/ FORAN (FDEFIN, FSYSD, FPIPE, ISOM, FBUILDS, FDESIGN) /CAFÉ	Y	N	Y	N	N	N	N	Y (some of these data should be included in SHIPLYS software)
A127 (lead by SU)	ESTIMATION OF ENVIRONMENTAL IMPACT	Environmental impact of construction	A1271	In-house speadsheet/Gabi								
		Environmental impact of operation	A1272	In-house speadsheet/Gabi		Y				Y	Y	N
		Environmental impact of maintenance	A1273	In-house speadsheet/Gabi		Y				Y	Y	N
		Environmental impact of retrofitting	A1274	In-house speadsheet/Gabi								
		Environmental impact of scrapping	A1275	In-house speadsheet/Gabi								
A128 (Lead by IST)	ESTIMATION OF RISK	A-Identify hazard of new ship design	A1281	In-house speadsheet/software	N	Y	N	N	Y	N	Y	N
		B- Identify hazard of retrofitting design	A1282	In-house speadsheet/software	N	Y	N	N	Y	Y	N	Y
		C- Identify hazard of maintenance	A1283	In-house speadsheet/software	N	Y	N	N	Y	N	Y	Y
		D- Identify hazard of retrofitting construction	A1284	In-house speadsheet/software	N	Y	N	N	Y	N	N	Y
		Risk assessment: A, B, C and D	A1285	In-house speadsheet/software	N	Y	N	N	Y	Y(B)	Y(A and C)	Y(B and D)
		Estimate risk control options: A, B, C and D	A1286	In-house speadsheet/software	N	Y	N	N	Y	Y(B)	Y(A and C)	Y(B and D)
		Cost benefit assessment: A, B, C and D	A1287	In-house speadsheet/software	N	Y	N	N	Y	Y(B)	Y(A and C)	Y(B and D)
		Recommendation and decision: A, B, C and D	A1288	In-house speadsheet/software	N	Y	N	N	Y	Y(B)	Y(A and C)	Y(B and D)

* This sub-matrix is produced for the early design part only of SHIPLYS project, to breakdown the design activities into reasonable detailed level according to ISO10303 - A122. The activities are in line with the design flow chart provided by NTUA.
* The ISO10303 - A122 is used as a 'check-list', not all activities need to be carried out. Grey font are used for the activities that are not necessary, red fonts are used for new activities not included in the ISO standard.

Early/Preliminary Ship Design Activities (A122)	Sub/Detailed - Activities			Existing Software		Software to be developed (or under development)
				Priority	2nd choice	
A1221-Create preliminary hull form	A12211-Estimate main dimensions and parameters			CAFE, IST-tool	AVEVA, CADMATIC, CATIA MARINE, DELFTship,FORAN, MAXSURF, NAPA, PARAMARINE	
	A12212-Estimate form parameters			CAFE, IST-tool	AVEVA, CADMATIC, CATIA MARINE, DELFTship,FORAN, MAXSURF, NAPA, PARAMARINE	
	A12213-Do parametric variations			IST-tool	AVEVA, CADMATIC, CATIA MARINE, DELFTship,FORAN, MAXSURF, NAPA, PARAMARINE	
	A12214-Generate initial hull form definition	A122141-Generate initial fore- body definition		CAFE, IST-tool	AVEVA, CADMATIC, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, RHINO, SOLIDWORKS	
		A122142-Generate initial mid- body definition		CAFE, IST-tool	AVEVA, CADMATIC, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, RHINO, SOLIDWORKS	
		A122143-Generate initial aft- body definition		CAFE, IST-tool	AVEVA, CADMATIC, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, RHINO, SOLIDWORKS	
		A122144-Generate initial deck definition		CAFE, IST-tool	AVEVA, CADMATIC, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, RHINO, SOLIDWORKS	
		A122145-Calculate initial hydrostatic properties		CAFE, IST-tool	AVEVA, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, SESAM,	
A1222-Create preliminary general arrangements	A12221-Define compartments	A122211-Define compartment arrangement		CAFE, IST-tool, RSET	AVEVA, CADMATIC, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, RHINO, SHIPCONSTRUCTOR, SOLIDWORKS	
		A122212-Define non-structural bulkheads		CAFE, IST-tool, RSET	AVEVA, CADMATIC, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, RHINO, SHIPCONSTRUCTOR, SOLIDWORKS	
		A122213-Define compartment properties		CAFE, IST-tool, RSET	AVEVA, CADMATIC, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, RHINO, SHIPCONSTRUCTOR, SOLIDWORKS	
		A122214-Define space product structure		CAFE, IST-tool, RSET	AVEVA, CADMATIC, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, RHINO, SHIPCONSTRUCTOR, SOLIDWORKS	
	A12222-Calculate capacities	A122221-Calculate capacities, holds, bunker space		CAFE, IST-tool	AVEVA, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, SHIPCONSTRUCTOR	RSET
		A122222-Calculate underdeck space		CAFE, IST-tool	AVEVA, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, SHIPCONSTRUCTOR	RSET
		A122223-Calculate tonnage, freeboard		IST-tool	AVEVA, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS	RSET
	A12223-Estimate weight	A122231-Evaluate hull steel weights		CAFE, IST-tool	PIAS, SHIPCONSTRUCTOR, SHIPWEIGHT, AVEVA, CADMATIC, CATIA MARINE, FORAN, MAXSURF, NAPA, PARAMARINE	RSET
		A122232-Evaluate machinery weights		CAFE, IST-tool	AVEVA, CADMATIC, CATIA MARINE, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, SHIPCONSTRUCTOR, SHIPWEIGHT	RSET
		A122233-Evaluate weights of outfitting and accommodation		CAFE, IST-tool	AVEVA, CADMATIC, CATIA MARINE, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, SHIPCONSTRUCTOR, SHIPWEIGHT	RSET
		A122234-Calculate lightship weight		CAFE, IST-tool	AVEVA, CADMATIC, CATIA MARINE, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, SHIPCONSTRUCTOR, SHIPWEIGHT	RSET
	A12224-Calculate stability and trim	A122241-Define loading conditions		IST-tool	AVEVA, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, SESAM, VERISTAR	
		A122242-Check stability (intact, damage)		IST-tool	AVEVA, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS, SESAM, VERISTAR	
		A122243-Calculate trim		IST-tool	AVEVA, CATIA MARINE, DELFTship, FORAN, MAXSURF, NAPA, PARAMARINE, PIAS	
A1223-Estimate hydrodynamics and powering	A12231-Estimate resistance and powering	A122311-Predict resistance		IST-tool	AVEVA, FORAN, MAXSURF, NAPA, NAVCAD, PARAMARINE, PIAS, RAPID, SESAM, SHIPMO, SHIPX, STAR-CCM+	
		A122312-Predict propulsion data		IST-tool	AVEVA, FORAN, MAXSURF, NAPA, NAVCAD, PARAMARINE, PIAS, STAR-CCM+	
		A122313-Predict propeller performance	A1223131-Specify initial propeller characteristics	IST-tool	AVEVA, FORAN, NAVCAD (PROPCAD), PARAMARINE	
			A1223132-Create preliminary propeller arrangements		AVEVA, FORAN, NAVCAD (PROPCAD), PARAMARINE	
			A1223133-Create preliminary blades		NAVCAD (PROPCAD)	
			A1223134-Create preliminary propeller components		NAVCAD (PROPCAD)	
			A1223135-Estimate hydrodynamis and powering		AVEVA, FORAN, NAVCAD, PARAMARINE	
			A1223136-Validate initial propeller		AVEVA, FORAN, NAVCAD (PROPCAD), PARAMARINE	
		A122314-Predict brake power and service speed		IST-tool	AVEVA, FORAN, MAXSURF, NAPA, NAVCAD, PARAMARINE, PIAS, STAR-CCM+	
	A12232-Estimate sea-keeping			IST-tool, LR WAVELOAD FD	AVEVA, MAXSURF, NAPA, PARAMARINE, SHIPMO, SHIPX, STAR-CCM+, HYDROSTAR	
	A12233-Estimate manoeuvrability			IST-tool	AVEVA, FORAN, MAXSURF, NAPA, PARAMARINE, SHIPX, STAR-CCM+	
A1224-Create preliminary structure design	A12241-Calculate longitudinal strength			CAFE, LR RULESCALC, CSRS	AVEVA, CATIA MARINE, DELFTship, FORAN, MAESTRO, MAXSURF, NAPA, NAUTICUS HULL, PARAMARINE, PIAS, SESAM, SHIPLOAD, VERISTAR	
	A12242-Define midship section scantlings			CAFE, LR RULESCALC, CSRS	AVEVA, CATIA MARINE, FORAN, MAESTRO, MARS2000, MAXSURF, NAPA, NAUTICUS HULL, PARAMARINE, PIAS, SESAM, SHIPLOAD, VERISTAR	
	A12243-Define other transverse sections scantlings			CAFE, LR RULESCALC, CSRS	CATIA MARINE, FORAN, MAESTRO, MARS2000, MAXSURF, NAPA, NAUTICUS HULL, PARAMARINE, POSEIDON, SAFEHULL, SESAM, SHIPCONSTRUCTOR, VERISTAR	
	A12244-Carry out preliminary superstructures structural design			CAFE, LR RULESCALC, CSRS	CATIA MARINE, FORAN, MAESTRO, MAXSURF, NAPA, NAUTICUS HULL, PARAMARINE, POSEIDON, SAFEHULL, SESAM, SHIPCONSTRUCTOR, VERISTAR	
A1225-Create preliminary machinery design	A12251-Select main engine	A122511-Specify and select main engine			NAVCAD	
		A122512-Agree on main engine detail specification				
	A12252-Design transmission system	A122521-Select components			NAVCAD	
		A122522-Carry out transmission system analysis				
		A122523-Agree design				
	A12253-Select auxiliary equipment	A122531-Specify and select auxiliary equipment			NAVCAD	
		A122532-Agree on auxiliary detail specification				
	A12254-Design manoeuvring systems	A122541-Select components: 2			NAVCAD	
		A122542-Carry out manoeuvring system analysis				
		A122543-Agree design: 2				
	A12255-Select deck machinery	A122551-Specify and select deck machinery				
		A122552-Agree on detail specification of deck machinery				
A1226-Create preliminary outfitting design	A12261-Calculate Equipment Number					
	A12262-Generate equipment list			CAFE	CADMATIC, CATIA MARINE, FORAN, NAPA, SHIPCONSTRUCTOR	