LifeCycle and virtual prototyping requirements for ship Repair Projects

A. Porras and L. Herrera
Astilleros de Santander (ASTANDER), Astillero, Cantabria, Spain.

A. Carneros and J.I. Zanón
Fundación Centro Tecnológico SOERMAR, Madrid , Spain

ABSTRACT: Repair yards need new tools and paradigms to integrate the different design stages through more standardized information and to introduce a reliable modeling method for lifecycle analyses for retrofitting designs, supporting bid decisions and later lifecycle ship stages. It is crucial that the design tools and paradigms are improved to allow new designs and processes to minimize the total costs of refits. This paper focuses on specifying requirements for integration of rapid virtual prototyping and life cycle tools in the retrofitting design stage of a ship in order to provide insights into developing the optimal data structuring and user interfaces. With the target to support both ways it´s necessary : first the development of new design models which help the shipyard to assess the cost and time modeling for the retrofitting; and second the performance of LCCA, LCA and Risk analysis. The specified requirements will be outputs of the SHIPLYS project and will be used within SHIPLYS project to develop and integrate tools that allow increasing the efficiency, speed and reliability of retrofitting design processes.

1 ABBREVIATIONS AND ACRONYMS.

LCCA → Life Cycle Cost Analysis
LCA→ Life Cycle Assessment
SHIPLYS → Ship life cycle software solutions
LCIA→ Life Cycle Impact Assessment
M/E→ Main Engine.
A/E→ Auxiliary Engine.
ABS→ Exhaust Gas Boiler.
SME→ Small and medium-sized enterprises.
FMEA→ Failure Modes and Effect Analysis.
FTA→Fault Tree Analysis.
BIM→ Building Information Modeling
SECA→ Sulphur Emission Control Areas
RCO → Risk Control Options.

2 INTRODUCTION

The ship retrofit process is engineering process of the vessel, which in many cases could involve fundamental changes in the architecture, functionality or operation of the vessel, but the nature of repair and retrofitting projects differs substantially from long-term new building projects.

Bidding and preparation time is very short in comparison with new building project, and a lot of facts can only be determined on board the vessel or in close interaction with the ship operator.

The work specification is commonly provided by the ship operator. Along the same line, the ship operator is also often driving the engineering design activities in preparation for a repair or retrofitting project.

The main challenge for shipyards is to establish realistic estimates of work activities and their work volumes, and to develop an overall project schedule.

The dynamics of the repair and retrofitting process is complex. Typically, there are a large number of ad-hoc decisions that will have to be made as work progresses. The state of different systems is investigated during the course of the project, potentially revealing issues that were previously unforeseen. This creates a challenge, both in planning and logistics operations.

The scenario proposed in this report should support the development and validation of SHIPLYS for its application on the ship repair and retrofitting sector. It thoughout the provision of relevant information for a repair or a retrofit, in order to assess the cost and time modelling for the retrofitting and in order to be able to perform LCCA, LCA, Risk analysis and others

The scenario proposed will be firstly applied for assessing the retrofitting of a Ro-Ro Passenger vessel which has been equipped with an Exhaust Gas Cleaning System (SOx scrubber) in order to comply with MARPOL.

3 OBJECTIVES

The objective of this scenario is to help in the development of Virtual modeling tools to enable improved Retrofitting/ Conversion, particularly in SME shipyards, and to enable the optimal Retrofitting/ Conversion with life cycle cost assessment (LCCA), environmental assessment and risk assessment.

This scenario is aiming at satisfying the objectives of the SHIPLYS project, as follows:

- Demonstrate the effectiveness of the SHIPLYS integrated modelling and lifecycle approach.
- Develop a Virtual Prototyping system to incorporate LCCA, environmental and risk assessment criteria, for fast and cost effective evaluation of alternatives.
- Carry out concept-stage design 3D CAD modeling with the detail required for product construction at the shipyard, and use these to establish a data set suitable to determine work load, processes, resource needs and build a more complete analysis model.
- Be able to keep the bid-stage technical information and pass it through into the detailed design stages.
- Introduce a reliable modeling method for lifecycle analyses (costs, environmental, risk) for designs both at the early design stage (supporting bid decisions) and at later stages for detailed design.
- Assess the through life impact of changes at various stages in order to arrive at optimum configurations.

The framework will be organized in four tasks.

Figure 1 focuses on the holistic assessment and optimization through the SHIPLYS tools of a retrofitting recently addressed by the shipyard related to the installation of Scrubbers in existing ship ROPAX to reduce funnel emissions and to protect the environment.

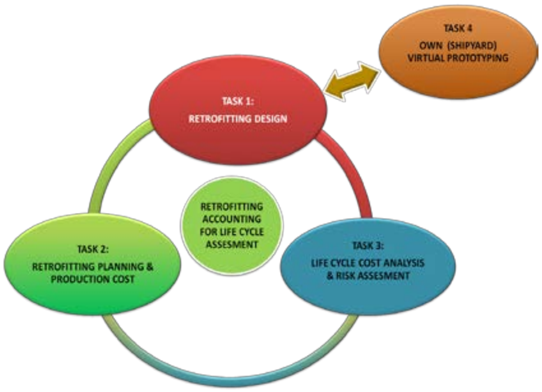

Figure 1 Schematic organization of RETROFFITING Scenario

The scenario will use technologies embedded in existing software applications. Those will be integrated with software able to perform LCCA (Life Cycle Cost Analysis) and Risk assessment from the conceptual ship retrofitting stage.

4 STUDY CASE FOR THE RETROFITTING SCENARIO PROPOSED

4.1 *Background*

The marine Industry is now facing the challenges of adopting new technologies and/or operational practices to comply with stricter international, national and local regulations introduced to reduce air emissions from ships. [1]

Although the scenario could be adapted to any ship types and works, the first study proposed for the developing of Scenario focuses on the holistic assessment and optimization (through the SHIPLYS tools) of some retrofitting activities recently addressed by ASTANDER which are related to the installation of scrubbers in existing ROPAX ferries to cut funnel emissions and to protect the environment.

As these ferries regularly operate in SECA areas and in order to comply with the newly updated MARPOL VI Regulation, an extensive program to update the fleet has been performed, based on maintaining the use of the cost-effective heavy fuel oil, and, consequently, installing scrubbers.

A typical example of retrofitting works related to scrubber are:

- Removal of the existing exhaust systems and replacement of the silencers by the new scrubbers.
- Installation of the new seven scrubbers (four for the M/E and three for the A/E).
- Rerouting of the existing pipe network in the casing.
- Installation of new pump rooms.
- Installation of the new exhausts and water system piping.
- Fabrication and mounting of new enlarged funnel.
- Installation of new electrical systems, control systems, insulation, structural modifications and other auxiliary jobs.

Due to the limited space available in the casings and the important interference of piping and structural systems, the tight delivery time was achieved by means of a correct planning and strategy of the removal/mounting process.

One of the requirements of the repair yard is to have a virtual prototyping tools with the aim of to decrease the risk of exist interferences and works that

[1] ABS Exhaust gas scrubber systems advisory.

not had been planned. It would be necessary to have a tool that provide 2D and 3D models similar to you can see in the follow figures (figure 2 and 3), which will be used with the aim of allow to increase the efficiency, speed and reliability of retrofitting design and carry out the quickly bid.

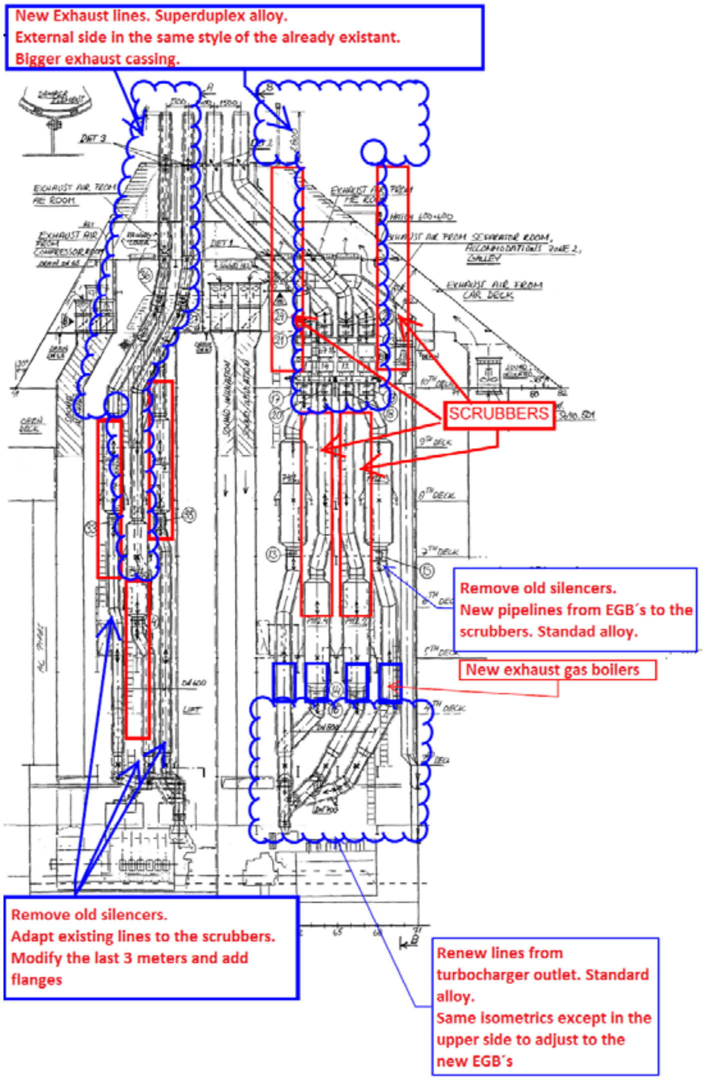

Figure 2 - 2D model retrofitting

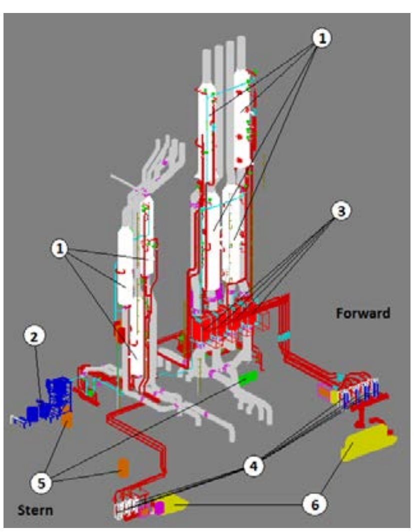

Figure 3 - 3D model retrofitting

4.2 *RETROFITTING Scenario: development and needs*

4.2.1 *Positioning of the Scenario and flow chart*

In the Shiplys project, the retrofitting Scenario is positioned at stage B` (Retrofitting planning. Design and Production) within the schematic view of life cycle model showed in Figure 4 specially adapted to the life cycle stages of marine installations and vessels.

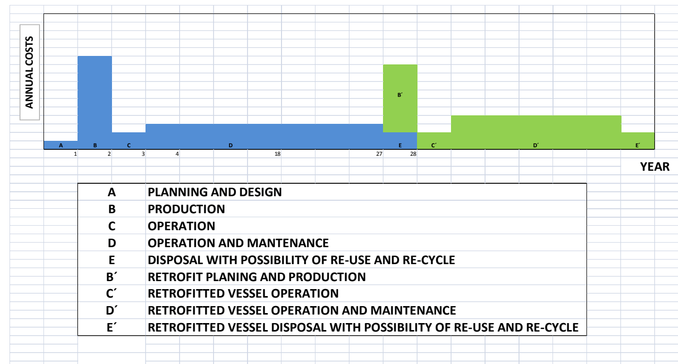

Figure 4 Schematic view of Life Cycle Cost model over the lifetime of marine structure [1]

With the aim of analyze the retrofitting scenario, hereunder is introduced a flowchart where you can visualize the various tasks that the SHIPLYS software should be able to deal with. Each particular box corresponds to a different module of the software. Additionally, the various required databases are also presented in the follow flowcharts.

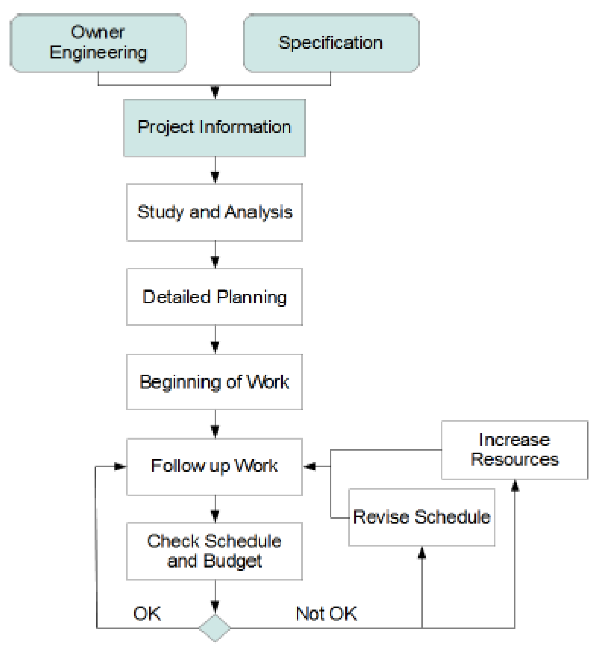

Figure 5: Ship retrofitting flowchart [2]

4.2.2 *Database and decision support tools to underpin SHIPLYS RETROFITTING Scenario*

The trend in naval architecture and ship design is to convert all data of a specific vessel in digital archives structured in many categories using the digital format that is appropriate to develop modeling and simulations of the components of the vessel at different scale and with different physics.

The scenario proposed will cover measures to take by the SME shipyard, since the introduction of a list of materials and equipment needed to perform the retrofitting until the required to perform different reparation's actions, all of them with the aim of obtain "inputs" related of management and planning, with the goal of have a database as complete as possible with direct effect in increasingly knowledge about these matters (Life Cycle of the ship), being all it could be extrapolated to other Retrofitting and New Constructions or Recycling.

4.2.3 *Organization of RETROFITTING Scenario*

As Figure 1 schematically shows, the scenario will be organized in four tasks related to retrofitting design (Task 1), Retrofitting planning and production cost (Task 2), LCCA and Risk Assessment (Task 3) and 3D virtual prototyping (Task 4).

5 COST AND PRODUCTION PLANNING AND LCCA

For completing successfully a project it should be managed properly, considering costs and schedule, based on agreements and technical specifications.

5.1 *Methodology for optimization purpose*

5.1.1 *Value Engineering / Value Analysis*

According to the definition adopted by SAVE International, "the value methodology is a systematic process used by a multidisciplinary team to improve the value of a project through the analysis of its functions". Under this context value can be defined as "the relationship between performance of a project, product, or process and the cost of obtaining it."(California Department of Transportation 2007).

Higher value can be obtained by improving the performance and/or reducing the costs. Cost reduction may be achieved "by identifying alternate ways to reliably accomplish a function that meets the performance expectations of the customer" (SAVE International 2007). Though cost reductions are a frequent outcome of Value Methodology (VM) [3] studies it should be noted that this tool is targeted at improving value and, therefore, "it is also common for a study to identify value improvements that may increase project cost" (Hammersley 2002). VM is based on a logical sequence of phases.

Within the context of the SHIPLYS project, phases of interest are the creative and the Evaluation phase.

The objective of the creative phase will be to produce potential alternatives for the retrofitting. In order to allow the generation of the biggest number of alternatives, one or several creative thinking techniques are normally used within this phase. One of most commonly used techniques within this phase is brainstorming, which is based on the free discussion of the problem under analysis.

The purpose of the Evaluation Phase is to pinpoint the most promising alternatives within the wide range of ideas that was generated in the creative phase.

The ideas shall be evaluated in the light of the defined criteria for the problem under consideration in order to produce a ranked list of alternatives.

Depending on the number of alternatives and criteria to be considered the execution of this task can be complex and time-consuming and therefore structured decision making methodologies should be employed.

5.1.2 *Process simulation.*

Simulation of planned production processes of a ship is used by several shipyards today, and may become a general and relevant part of production preparation planning activities. Since retrofitting projects are characterized by short planning periods and highly dynamic decision making processes, a powerful validation method like simulation has a promising potential for decision support.

5.2 *Life cycle cost analysis & Risk assessment*

Economic considerations have always been an integral part of engineering design and a force for refinement and sophistication of design methods.

As an example, the total cost of a scrubber system includes the initial cost of the scrubber, installation expenses, additional miscellaneous auxiliary equipment, off hire, ship modifications, ship operation, ship maintenance etc. Based on these factors, a comparison could be made to the life cycle cost of different solutions and alternatives. Shipyard main objective during this task is the valorization of the environmental impacts during ship retrofit, the improvement of safety in the operation and the minimization of the cost incurred during the ship retrofit.

5.2.1 *LCCA modelling process*

In the context of retrofitting scenario proposed, the LCCA should be applied as a means of assessing retrofitting cost or for evaluating retrofitting options.

It is suggested as reference the common European methodology for Life cycle costing in construction developed by Davis Langdon Management consulting 2007. [4]

It is important to note that this methodology is intended to be compatible with ISO 15686 Part 5 where the term "life cycle" differs from that used in the environmental standard, ISO 14040. The latter adopts a broad "cradle to grave" definition of life cycle, whereas the ISO 15686 definition can represent either "cradle to grave" or a shorter economic analysis timeframe driven by the specific client or projects needs.

5.2.2 *LCA*

LCA could aid in evaluating the overall environmental balance of the applied retrofit, by most commonly using quantitative analysis of products' and/or processes' effects in terms of consumed resources, and emitted or disposed substances, energy or radiation.

In order to properly distinguish from the reference resources consumed and emissions emitted by a specific ship, from the resources and emissions consumed and emitted by a retrofit measure applied, a baseline LCA model should be procured in the absence of an existing one for the existing vessel.

The baseline model to be developed would normally take into consideration the most common operations of the vessel, extrapolating these to an assumed lifetime, e.g. 25 years. The operational profile of the ship, as well as its consumption parameters, and additional information from the building phase to the assumed end-of-life scenario, prove significant to develop the ship's life cycle model.

Once the LCA baseline scenario of a specific ship is developed, the potential environmental impacts produced by the ship's operational profile can be calculated, accounting for the environmental history of the ship, as well as being able to extrapolate to potential future impacts. Any difference within the most common behavior of the operation profile, e.g. change to low-sulphur fuel, can now be assessed against the previously calculated baseline model. Additionally, the above comparison may offer the end-user the flexibility of adjusting relevant operational inputs regarding original systems or applied retrofits, in order to improve the calculated future environmental scores of the assessed system(s).

The procedure of gathering the data relating to the processes or systems under assertion, and additionally the modeling of the life cycle, pertains to the Inventory Analysis phase of the LCA. The following phase is termed Impact Assessment, and it is where the environmental inputs and outputs, i.e. resources and emissions flows, which have been collected and reported in the inventory, are now translated into impact indicator results for potential impact assessment related to human health, natural environment, and resource depletion. "The results of LCIA [Life Cycle Impact Assessment] should be seen as environmentally relevant impact potential indicators, rather than predictions of actual environmental effects."

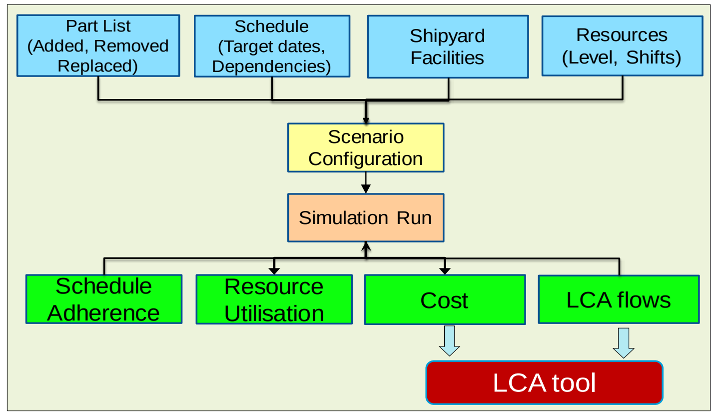

Figure 6 Shipyard production LCA workflow [5]

5.3 *Risk assessment as a life cycle process*

Risk assessment adopts an integrated and holistic approach that includes risk analysis in the design process.

Cost-effectiveness of safety-enhancing design features or measures is used as a basis to achieve optimum balance between costs and safety whilst reducing risks as low as reasonably practical.

This can be assisted, where appropriated, by comprehensive data and knowledge bases which relate to incident statistics, also design/operational measures applicable to risk prevention and mitigation.

Retrofitting system of a vessel can be analyzed using classical risk-analysis techniques, such as fault tree analysis (FTA) and failure modes and effect analysis (FMEA).

An operational procedure that is applied onboard can also be considered as a ship system and analyzed using the same techniques.

When considering implementing various safety-enhanced measures (risk control options – RCOs), their cost and benefits can be evaluated and checked using established criteria.

6 VIRTUAL PROTOTYPING

To be able to serve the ship retrofitting development process a product model is required including all the necessary information for the complete process.

Sometimes a detailed 3D model is delivered as technical documentation by the owner for the retrofit, but usually the traceability between the documentation provided by the ship-owner (Drawing, specifications, 3D model, etc..) and the reality ship do not match.

To avoid large deviations in terms of cost affecting in the cycle of repair, the shipyard need to perform its own 3D model based on data collection onboard which enables a quick design, procurement and planning phase.

6.1 *3D Model*

To support retrofitting works, the 3D vessel´s model to be built with SHIPLYS tools must include not only generalities about the ship, or individual models of different systems. It should contain models of every pipelines, cable lines, steel, and equipment.

Grouped by layers, but as a single whole thing, so there is almost no difference between model and real vessel. This will allow an easier planning of the installation or removal of the equipment, and will reduce non desired interactions among them.

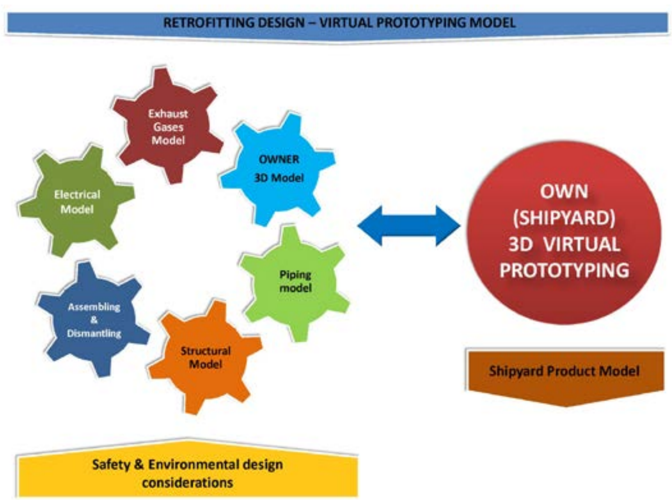

Figure 7 Virtual prototyping

7 CONCLUSIONS

ASTANDER and SOERMAR consider that a "BIM program" of the characteristics planned at SHIPLYS project could be useful for the transformation and repairs works in the shipyard if it accomplish the following requirements:

7.1 *Prototyping requirements*

- Generating a 3D product model at the early stage allows us to capture costs resulting from production in as much detail as those of material quantity.
- Carry out concept-stage design 3DCAD modeling with a reduced but sufficient number of main definition parameters, and use these to establish a data set suitable to determine work load, processes, resource needs build a more complete analysis model
- Integrate the different design stages through more standardized information.
- Introduce a reliable modeling method for lifecycle analyses (costs, environmental, risk) for designs at the early design stage (supporting bid decisions) and later stages for detailed design.
- To deal with the ripple-through of lifecycle effects if design changes are made before final design
- A further use of this modeling capability with sufficient knowledge base is to be able to produce their own unique 'style' of ship and asset designs, and to extrapolate for Virtual Prototyping.

7.2 *General requirements*

- BUDGET estimation based on the complete quantification of the needed materials and labor hours.
- Building on the detailed engineering provided by the owner (or not), the program should display a complete quantification of the needed materials and dimensional.
- This would include raw materials (plates, profiles, pipes, cables, etc.) as well as complete hardware (pumps, engines, scrubbers, etc.).
- As a budget consists not only in materials, but also in labor hours. Introducing the quantity of shipyard personal grouped by sectors, and considering the different works to complete (not only type, but also clearance), an estimation of the number of workers of each sector needed per operation should be provided by the program. The consequence of this is adequate planning of the works. In addition, labor hours could easily be calculated
- Allow to optimize the use of shipyard´s own machinery and times.
- The program should include a model of the shipyard, with it is dry-dock (or tier), as well as its means (cranes, ashore connections etc.). With this an adequate coordination of the means of dry-dock (or tier) could be planned.
- It allows "high" detailed engineering.
- The vessel´s model made with SHIPLYS must include not only generalities about the ship, or individual models of different systems. It should contain models of every pipelines, cable lines, steel, and equipment.
- Grouped by layers, but as a single whole thing, so there is almost no difference be-

tween model and real vessel. This will allow an easier planning of the installation or removal of the equipment, and will reduce non desired interactions among them.
- Allows determine the most adequate dates for material and equipment reception.
- Once completed the needed material and equipment list, logistical planning of acquirement and fabrication would be easier. Definition of the most adequate dates for material and equipment reception could be possible. This improves competitiveness of shipyards (Just in Time).

ASTANDER and SOERMAR recognize that the SHIPLYS overall objectives are wider than indicated above, but request solutions than at least allow them to Increase production efficiency, reduced energy consumption, environmental impacts and production costs in the shipyards.

The scenario proposed has the advantage of be based on real retrofitting carried out in the shipyard.

Lot information is already available and could be useful to develop a Virtual Prototyping system to incorporate LCCA, environmental and risk assessment criteria, for fast and cost effective evaluation of alternatives.

To end, we would like to highlight that the scenario proposed is building on the detailed engineering provided by the owner. It is true that there are solutions other than scrubbers to control the emission in SECA area, but it is not objective of this scenario to assess them.

The scenarios proposed should be used in developing Virtual modeling tools to enable improved Retrofitting/ Conversion, particularly in SME shipyards, and to enable the optimal Retrofitting/ Conversion with life cycle cost assessment (LCCA), environmental assessment and risk assessment.

8 REFERENCES

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