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D2.1: SmartShip requirements analysis, scenarios and KPIs definition

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Authors List

Leading Author				
First Name		Last Name	Beneficiary	Contact e-mail
Ioannis		Kontopoulos	HUA	kontopoulos@hua.gr
Co-Author(s)				
#	First Name	Last Name	Beneficiary	Contact e-mail
1	Panagiotis-Antonios	Varelas	DANAOS	drc@danaos.com
2	Konstantinos	Tserpes	HUA	tserpes@hua.gr
3	Antonios	Makris	HUA	amakris@hua.gr
4	Vlatka	Katusic	ENPC	v.katusiccuentas@pontsbschool.com
5	Hernan	Ruiz	ENPC	h.ruizocampo@pontsbschool.com

Reviewers List

Reviewers			
First Name	Last Name	Beneficiary	Contact e-mail
Marinos	Tsantekidis	TUBS	tsantekidis@ida.ing.tu-bs.de
Marcos	Bonazountas	EPS	bonazountas@epsilon.gr

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Executive Summary

This deliverable contains Scenarios and Requirements Elicitation and Analysis for each scenario, along with the KPIs for the SmartShip project, funded by the Horizon 2020 Programme under Grant Agreement No 823916.

This document is of importance to the project implementation since it describes specific type of Requirements essential for the design and development of the SmartShip framework. The deliverable describes use cases of the framework, actors who will interact with the system and their role . For each use case, user requirements are defined along with the methodology and the procedures with which requirements will be tracked and prioritized .This deliverable identifies marine market needs in energy efficiency, emissions control, vessel surveillance and how SmartShip contributes to the aforementioned fields.

The Requirements Elicitation and Analysis ensures that needs and requirements of the maritime industry are fulfilled, drive the project processes as directly linked to the project vision. Requirements will continue being investigated to ensure that objectives and innovation of the project are valid and act as guideline to project goals.

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List of Acronyms and Abbreviations

Term	Description
H2020	Horizon 2020 Programme
IoT	Internet of Things
AIS	Automatic Identification System
IMO	International Maritime Organization
EMSA	European Maritime Safety Agency
GPS	Global Positioning System
DSS	Decision Support System
RPM	Revolutions Per Minute
SOLAS	International Convention for the Safety of Life at Sea
ISM	International Safety Management
KPI	Key Performance Indicator
TCE	Time Charter Equivelent
ECDIS	Electronic Chart Display and Information Systems
GIS	Geographical Information Science
IFO	Intermediate Fuel Oil
PM	Particular Matter
GHG	Green House Gas
LCA	Location Condition and Availability
FOC	Fuel Operational Comsumption
LCPA	Life Cycle Performance Analysis

Partners Short Name	
DANAOS	DANAOS SHIPPING COMPANY LIMITED
ITML	INFORMATION TECHNOLOGY FOR MARKET LEADERSHIP
EPS	EPSILON MALTA LIMITED
ENPC	ECOLE NATIONALE DES PONTS ET CHAUSSEES
BLS	BLUESOFT SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA
TUBS	TECHNISCHE UNIVERSITAET BRAUNSCHWEIG
HUA	HAROKOPIO UNIVERSITY OF ATHENS

1. Introduction

Today's organisations need to act upon real-time events and take decisions to support their resource management and capitalize on opportunities. To this end, a system that copes with such decisions is of utmost importance. Therefore, requirements must be formed and analysed that fulfil organisations' and market's needs.

SmartShip aims to provide a complete framework which will take advantage of all possible available technologies and methodologies in order to provide complete and applicable energy efficiency management.

Taking into account SmartShip objectives and specifically, **Objective 5**: "To offer a holistic framework for energy efficiency and emissions control in maritime through the implementation and validation of new tools (**Objective 3**) and the integration with the existing ones (**Objective 2**), for optimizing the efficiency of daily operations (e.g. via weather routing optimization, trim optimization, real-time optimal navigational adjustment, vessel's performance under voyage scenarios and ship settings and real-time detection of complex events) the project aims at building skills and tools that will allow the augmentation of the functionality of existing maritime information systems towards the optimization of vessel fuel consumption and emission generation.

Below, the objectives of the SmartShip project are briefly described:

Objective 1. To accurately describe and identify marine market needs in energy efficiency and emissions control in parallel with end-users' requirements, towards the definition of accurate, industry–driven case scenarios.

Objective 2. To foster knowledge exchange between academic and non-academic experts in the fields of IoT, Data Analytics, decision support and optimization in terms of energy efficiency and emissions control in maritime.

Objective 3. To design and develop a Data Analytics tool and offer a Decision Support Tool that will (i) compile data from existing sensing devices in vessels; (ii) manage the operation of the whole IoT environment, and (iii) run optimization algorithms to provide suggestions related to the operations of the ship engines.

Objective 4. To investigate potentials of exploiting (i) existing infrastructure in ships (e.g. sensing devices and networks) and (ii) the technologies investigated and developed in Objective 2, in order to enhance the implementation of Circular Economy in the maritime field, in terms of management of engines' components.

Objective 5. To offer a holistic framework for energy efficiency and emissions control in maritime through the implementation and validation of new tools (Objective 3) and the integration with the existing ones (Objective 2), for optimizing the efficiency of daily operations (e.g. via weather routing optimization, trim optimization, real-time optimal navigational adjustment, vessel's performance under voyage scenarios and ship settings and real-time detection of complex events.

Objective 6. To demonstrate system effectiveness based on real-life use cases towards the reinforcement of the European Maritime Industry.

Objective 7. To develop new long-lasting research collaborations, achieve transfer of knowledge between participating organizations, and foster improved research and innovation potential through the development of training material towards long-term sustainability and exploitation.

1.1 Purpose of the deliverable

One SmartShip objectives is to describe in detail and identify the marine market needs in terms of energy efficiency and emissions control taking into account end users' requirements, in order to define accurately industry-driven case scenarios.

To this end, the purpose of requirements analysis, scenarios and KPIs definition (D2.1 of the SmartShip project) and its scope, is to report final set of scenarios and user requirements that will define system functionalities to be addressed by the SmartShip framework. The objective of D2.1 is to provide requirements from both, the maritime field and the technology field, essential for the design and development of the SmartShip framework. The deliverable provides details on specifications and requirements per case scenario, whist KPIs and goals are set to ensure that the objectives of Smarship are met.

During the course of the project, technologies and requirements related to SmartShip will continue being investigated, to ensure that the objectives of the project are valid and development fulfil the identified goals and requirements.

1.2 Structure of the deliverable

This deliverable contains the **Requirements Analysis**, **Scenarios and KPIs** definitions for SmartShip and the various specifications and requirements addressed during the lifetime of the project. The rest of the document is organized as follows:

- **Section 2** describes the methodology by which the requirements were formed and be tracked and prioritized in the future. Specifically, it acts as guideline that ensures requirements and goals are met, market needs are fulfilled, and technologies used are valid.
- **Section 3** identifies the Scenarios and the use cases of SmartShip and ensures full alignmemt with its objectives.
- **Section 4** describes project requirements for each identified scenario that SmartShip will tackle during its lifetime. For each scenario, specific user requirements are described that will later be translated into system funtionalites.
- **Section 5** incorporates concepts and principles of the Circular Economy in vessel management and monitoring.
- **Section 6** identifies entities and actors who interact with the SmartShip framework and specifies each entity's role on the project's platform.
- **Section 7** describes the Key Performance Indicators (KPIs) that will ensure achievement of goals and objectives, and
- **Section 8** concludes this deliverable.

1.3 Relation to other deliverables

This deliverable lays the foundation for further development of SmartShip. Use cases presented in this document set the "core topics" of research between academic and non-academic partners and the objective of interdisciplinary collaboration between researchers with maritime and technology background. Use case definition in SmartShip are bundled with Circular Economy principles and are translated into functional requirements for SmartShip framework components. Use case scenarios and KPIs set the scene for SmartShip piloting and validation.
Schematically input of D2.1 to other deliverables is displayed in Table 1 below:

WP	DELIVERABLE	INPUT
3	D3.1. SmartShip Circular Economy-based functional architecture	User Requirements are aligned with the Circular Economy principles to be validated against the Circular Economy concepts.
4	D4.1. IoT tools, technologies and data analytics module	User Reguirements define the actual design and development requirements of the IoT-based data analytics module
5	D5.1. Decision support module and multi-layer optimization tools and technologies	User Requirements set the objectives to be met by the SmartShip decision support module.
6	D6.2. Report on final pilot design and implementation	Use cases scenarios set the base for the pilot execution, and KPIs for the validation of the integrated Smartship framework design and implementation

Table 1. Input of D2.1 to other deliverables and WPs in the SmartShip Project

2. Methodology

This section describes the methodology to come-up with the final list of the SmartShip scenarios and requirements. In addition, it describes the way that each requirement is tracked and prioritized to ensure requirements are valid and do not deviate from project objectives and vision: “SmartShip capitalises on available COTS technologies and delivers an ICT and IoT-enabled holistic cloud-based maritime performance and monitoring system, for the entire lifecycle of a ship, aimed to optimise energy efficiency, emissions reduction and fuel consumption, whist introducing Circular Economy concepts in the maritime field”.

Weather routing optimization and route monitoring are of interest to maritime stakeholders. Several approaches have been developed to address the aforementioned issues. A review describing the state-of-the-art methods can be found in [1]. Many techniques create a graph of the maritime lanes and deliver shortest paths based on current weather conditions in real-time [2]. Other techniques focus on mathematical modelling of weather conditions loinked to speed and wave height and the ship’s speed and fuel consumption as the route’s safety to infer the best route [3]. Other focus on modelling the maritime traffic to detect patterns and routes [4], [5], [6], [7].

Pequirements are derived from key questions, which the state-of-the-art approaches try to address, that arise from the needs of shipping and needs to be answered for the maritime industry when resource management and energy efficiency is of utmost importance. Some questions are :

1. Which route will minimize risks of damage to crew, vessel and cargo?
2. How can we arrive at a fixed time or just in time, to achieve required ETA?

3. How can we sail the optimal route at minimal cost?
4. Is there a way to reduce costs and increase reusability of vessel engines' components?
5. Are concepts of Circular Economy related to the aforementioned questions?

In particular, the requirements elicitation and refinement phase capitalized on :

i. The project scenarios and use cases, as documented in Section 3 and described in Section 4.
ii. The envisioned SmartShip framework; specifically, the pilot scenarios and use cases.
iii. The feedback from interviews, and face-to-face meetings between interested parties, stakeholders, end users, and maritime authorities.
iv. The feedback from meetings with consortium partners and partner involved in the maritime sector.
v. Participation in workshops of EU Research and Innovation Maritime Projects.

The above include:

a. Requirements validation: Do use cases and requirements answer needs of the maritime industry regarding resource management, energy efficiency and emissions' control? More specifically, which of them have been met or not and why?
b. Requirements verification: Have we phrased requirements well? Are there any too generic/ not-relevant gaps in the requirements that should be further specified/eliminated/added?
c. Identification of possible adjustments in the scenarios, technologies and components.

During the lifetime of the project, requirements are tracked by using the same procedures followed in the elicitation / refinement phase, ensuring that needs of the industry and state-of-the-art are fully aligned.

3. Scenarios and Use Cases

3.1 Use case 1: Weather Routing Optimization

The navigational Officer on board plots a voyage plan further to be approved by the master so to safely navigate the ship from port of departure to the designated port of arrival. From Berth to Berth voyage planning and execution must meet the objectives of safety of life at sea (crew safety), safety and efficiency of navigation, and protection of the marine environment [8] In this context, meteorological and oceanographic factors are critical for safe passage. The IMO recognizes that weather routing must be available to shipping in the form of recommended "optimum routes" for individual crossings of the oceans. Practice of weather routing has proved of benefit to ship operations and safety as well as to their crews and cargoes.

This use case refers to the design and representation of the *best-fit weather routing advice* to the master on-board taking into account weather information along the plotted voyage plan and adapted to vessel individual characteristics and cargo specifications. Weather optimal routing is a multi-variable decision support mechanism against a bundle of objectives consisting of on-schedule arrival (passage time), charter party clauses compliance (fuel consumption, speed, allowance variations), fuel savings and energy efficiency, and cost savings and TCE[1] earnings maximization. Optimal routing advice is considering one or multiple objectives assigning weighting factors to each variable in consideration so to draft a best-fit route scenario for the Master's reference. This use case will be a built-in exercise on top of an existing tool used by DANAOS Shipping for weather routing optimization, developed under the framework of ORISMA [9] a company legacy of applied research for shipping operation efficiency.

[1] Time charter equivalent (TCE) is a shipping industry measure used to calculate the average daily revenue performance of a vessel

SmartShip capitalizes on existing tool and enhance functionalities embedding external reference in routing formulation by elaborating on statistical analysis of AIS data. The data will be used for normalization and benchmarking of given route advice against global trajectories patterns and traffic volume analysis. Furthermore, will take consideration of navigational restrictions, navigation warnings, notice to marines, bathymetric data, clearance limitations and other factors thus leveraging on capabilities of digital navigational systems on-board such as ECDIS[2]. In doing so, navigation officers on-board will be in a better position to assess route advice and the associated (to the designed) pathway risk factors.

To validate the use case, SmartShip will perform pilot testing by applying new built-in functionalities in real voyage planning scenarios for DANAOS ships. Applied optimal routing will be generated in long distance trajectories to scale up spatial reference, complexity of factors in considerations and alternative pathway options having at the same time reference to a significant volume of external (global scale) and internal (company scale) historical data.

3.2 Use case 2: Route monitoring

This use case liaises with the first one and addresses the continuous readjustments of routing advice along voyage execution. By default, the progress of the vessel in accordance with the voyage and passage plan is closely and continuously monitored, while any changes made to the plan are clearly marked and recorded [8].

Under the scope of continuous monitoring, the weather routing optimization tool generates a dynamic tuning of route advice to the master based on actual conditions and new weather forecast. A set of gridded weather data (Wind speed direction, Currents' speed and direction, waves/ swell / combined Significant Wave Height (SWH)/direction/period) sent in spatial resolution of 0,1-0.5 degrees (mostly in 0,25 degrees) and temporal resolution of three hours, updating routing advice to the master either following the same weight factor in objective definition (e.g. prioritize fuel consumption reduction), or different weight factor (e.g. set importance to an earlier time of arrival to the port of destination).

Weather routing advice is essential for safe and effective passage plotting but it is recognized that the final decision regarding the ship's navigation rests always with the master [10]. Therefore, routing advice adjusts not only to weather updates but to actual deviation from the initial route baseline driven from the master navigation decisions along the voyage.

In the Route monitoring use case, SmartShip will extend capabilities of DANAOS weather routing tool applied in DANAOS fleet by triggering an alerting system to generate warnings to the captain for performance deviation against predefined indicators due to his actual navigation decision deployment, or /and possible claims for under-performance. Alerts will be driven from a continuous risk assessment of master routing decisions which stem from statistical records of historical voyage performance based on AIS data for similar routes aligned with similar weather conditions (external reference) as well as analysis of own fleet voyage performance database (internal reference).

Through the same mechanism, there will be offered a recording of the conditions under which the deviation occurred such as the current state of the sea, unexpected bad weather conditions or due to an unexpected vessel behaviour, forming a root cause justification for any possible voyage under-performance and reducing false warnings to the master. At the same time SmartShip will generate a dynamic voyage performance comparison between actual route, driven by the master's decision, and the system's route advice reference, both fed with real weather data and assessed against actual voyage conditions.

[2] An Electronic Chart Display and Information System (ECDIS) is a computer-based navigation system that complies with IMO regulations and can be used as an alternative to paper navigation charts

At the end of the voyage, a full "Voyage Performance Evaluation Report" is generated to offer a more detailed look at the actual performance or non-performance of the vessel. This report will look at several factors, including the *charter party terms*, the actual speed and consumption, whether the vessel was in ballast or in a laden condition and the actual wind, sea, swell and ocean currents encountered. SmartShip will generate a vis a vis performance report between actual route followed by the master and route advice designed by the system. This will allow improvements in algorithmic-based route deployment, if, at the end, the master's decision outperforms route advice, and at the same time evaluate, indirectly, the master's skills either in positive (master's route plotting better than system's) or negative terms (system's route plotting better than master's). Validation of this use case will be performed in the same optimal route planning scenarios as in the first use case.

3.3 Use case 3: Condition based (Predictive) Maintenance

In shipping nowadays there is a shift of attention from corrective and preventive maintenance based on predefined and scheduled job orders to safeguard vessel sea-worthiness and retain machinery components integrity, to condition-based or/and performance-based maintenance. Condition-Based Maintenance (CBM) refers to a maintenance strategy that monitors the actual condition of an asset to decide what maintenance needs to be done. CBM dictates that maintenance should only be performed when certain indicators show signs of decreasing performance or upcoming failure [11]. It consists of three main steps: data acquisition, data processing and maintenance decision-making. Diagnostics and prognostics are two important aspects of a CBM program [11].

This use case will capitalize on the technology-driven fleet performance monitoring framework of DANAOS. The Company handles operational efficiency optimization as a continuous descriptive analysis of historical information (hindsight) to come up with insights and assessment of the reasoning behind what happened in the past (diagnostic analytics). The reason is to find a pattern of prediction of what will happen in the future (predictive analytics) and plan the right strategy to make it happen or prevent it from not happening (prescriptive analytics). The Company has developed an intelligence platform (DANAOS fleet performance monitoring platform) to retrieve data from different sources capitalizing on internet of things philosophy (IoT) while performing artificial intelligence (AI) and machine learning techniques.

For the above, data acquisition components are capturing real-time data from engine / propulsion monitoring sensors (main engine data, auxiliary engines data, generator engine data etc.), measurement instruments (e.g. flowmeters), navigational equipment (positioning systems, weather monitoring systems) and other gauges on board DANAOS vessels. Streaming real-time data is stored in a master server on board and synchronized with an offshore database back in the office for further analysis. DATA is validated against operational data (vessel telegraphs, reports etc.) and combined with historical reference (fleet database) to retrieve meaningful information. Time-series analysis is visualized to decision makers in tabular format, in charts and piecharts within an interactive front-end environment. SmartShip contribution to the system will be three-fold:

1. In configuration of algorithms and also in neural network training [12]; the backbone of historical data analysis and the core computation behind functional definition for predictive analysis.
2. In retrieving of information and data handling from other sources to maximize asset performance monitoring.
3. In the identification of events, patterns recognition and error detection aiming at on-time failure prediction and efficient asset error fixing management so to optimize vessel performance and minimize life-cycle cost embedding concept of Circular Economy in asset management evolution.

For validation of this use case DANAOS will offer fleet historical datasets to allow the configuration of SmartShip algorithms and the training of neural networks. SmartShip performance monitoring and assessment will be done on DANAOS vessels. Two candidate vessels of different age, particulars and active dates will be selected for individual assessment and two sister vessels of same age and active dates for performance comparison.

3.4 Use case 4: Visualization

Use case 4, refers to the efficient illustration and representation of the aforementioned use cases. The main concept is that alternative routes vessels must follow, the route deviations occurred and the weather conditions in each case must be presented to the officers on board the vessels in a user-friendly way.

To this end, the visual illustration platform will allow the entities described in Section 6 to explore the solution space in an intuitive visualization, see recommended and calculated routes as well as the consequences of taking each route in terms of estimated time of arrival (ETA), fuel consumption or other objectives and allow them to monitor voyage performance and re-plan their course based on the output of the weather routing optimization algorithm. Moreover, the visual illustration platform will work as an alerting system which will send notifications to the entities regarding the deviations or events of interest that occurred. Finally, the visual illustration platform will represent fleet performance monitoring in an interactive and user friendly manner.

The scope of this use case is to modernize and redefine the user interface and enhance the user experience of existing DANAOS tools at the same time with the introduction of new functionalities and features as explained in the previous use cases. For the validation of this Use case, the acceptance test will be performed to DANAOS end-users to score the visualization capabilities against several criteria namely interactivity, friendliness, clarity, usability, design and overall experience.

4. Requirements Elicitation and Analysis

Smarthsip aims to offer a holistic framework for energy efficiency and emissions control in maritime through the implementation and validation of new tools and the integration with the existing ones, for optimizing the efficiency of daily operations. The aforementioned objective can be achieved through algorithms that offer weather routing optimization, real-time optimal navigational adjustment, vessel’s performance under voyage scenarios and ship settings and real-time detection of complex events. Thus, SmartShip aims at building skills and tools that will allow the augmentation of the functionality of existing maritime information systems towards the optimization of vessel fuel consumption and emission generation.

The starting point is the identification and analysis of existing tools to identify the need and feasibility for extending them. The partner DANAOS, has developed weather routing and digital vessel performance monitoring tools based on the ORISMA [9] (Operation Research in Ship Management) suite of algorithms for managing maritime operations and providing added value to the maritime services. The Tool-kit employs algorithms for minimizing routing cost in terms of fuel consumption and routing time. It also tries to address the “optimal bunkering problem” in order to minimize fuel consumption from the starting berth port[3] to the next destination bunkering port. Moreover, the Tool-kit tries to address minimizatioin of the *idle time* whenever the next employment is not fixed but there are several possible employment destinations. Towards the need for improving and extending [9], several use cases have been identified in Section 3 to address the needs and objectives of SmartShip. The rest of this section describes in detail the requirements of each use case.

[3] a designated location in ports for mooring vessels that also help the loading or unloading of cargo or people from vessels

4.1 User Requirements for Weather Routing Optimization (Use case #1)

The objective of the first use case is to provide alternative routing options to the vessels and optimum routing advice to the master, in near real-time, considering the vessel's current location, its destination, the current conditions, and weather forecast. The criteria for suggesting an option are revolving around the fuel consumption minimization [13] given the "resistance" added by the en-route weather conditions.

However, apart from time, there are certain constraints that complicate the problem such as navigational obstacles, charter party clauses, and in some cases traffic. The key idea is that understanding past vessels behaviour through their routes can incorporate knowledge regarding perils, risk factors and opportunities that otherwise remain unseen. This is a multi-sensor approach, where a common pattern in a specific type of vessels in a specific time and place can play a governing role in the decision-making process. This can be seen either as a solution space filter (first get the options, then filter out those that do not fit in the past behaviour) or as an extra objective in the original multi-objective optimization problem. The patterns in their routes can be extracted through historic data analysis, especially AIS data of similar vessels [7], [6].

SmartShip will extend existing DANAOS weather routing system's functionalities satisfying the user requirements below:

- #1.1 Multi-variable routing optimization algorithmic analysis adding to existing considerations (weather conditions) new factors, based on information over navigational restrictions, notice to mariners, and other constraints.
- #1.2 Benchmarking and normalization of existing algorithmic-based weather routing optimization with common route patterns, based on AIS data analysis (external reference) and own fleet historical navigational/operational data (internal reference).

4.2 User Requirements for Route monitoring (Use case #2)

The second use case goes hand in hand with the first use case, and refers to the development of an *alerting system* that notifies the user when a vessel deviates from its predefined route objectives due to current voyage conditions and master decisions along vessel's course execution. The main concept behind route monitoring and route deviation is to generate warnings to the master for possible voyage under-performance based on analysis of both own fleet's and other vessels historical data aligned with similar weather conditions.

Under this scope, a reference maritime traffic model will be generated [14], [15]. This model will allow us to better estimate a voyage`s distance (port-to-port), fuel consumption and overall voyage performance based on predefined common routes vessels follow. Moreover, seasonality and vessel congestion will be taken into account to enhance the model`s accuracy and areas with narrow seaways (e.g. many islands such as the Aegean sea) will be studied which are of interest to the maritime sector. Other factors that may enhance the traffic model are the vessel's dimensions which may affect its route and the draught of the vessel which is an indication of whether the vessel is loaded or not.

Again for this use case SmartShip will work on top of the existing DANAOS weather routing system's functionalities satisfying the user requirements below:

#2.1 Ongoing monitoring of voyage performance.
#2.2 Alerting mechanism and warnings to the master for deviations and possible voyage under-performance.
#2.3 Risk assessment of master navigational decision along the route execution and cause analysis of any deviation from the system generated optimal route advice.
#2.4 Dynamic voyage performance comparison, triggered by user anytime along the voyage, between system route advice and master course plotting.

4.3 User Requirements for Condition-based (Predictive) Maintenance (Use case #3)

The objective of predictive maintenance is to help determine the overall condition of the vessel and her equipment to estimate when maintenance tasks should be performed. The aim is to reduce asset life-cycle costs by capitalizing on condition-based maintenance rather than planned based maintenance. The idea behind this use case is the prediction of equipment failures and degradations based on continuous vessel performance assessment and dynamic monitoring of the current state of the ship's equipment leading to an effective maintenance plan scheduling towards resource optimization.

The predictive maintenance will evaluate the condition of the vessel by elaborating on IoT and machine learning techniques. Data mining [16], data handling and data processing approaches will be studied in order to detect errors and schedule maintenance tasks before the vessel equipment's performance drops below a predefined threshold and on the other hand support, in a broader context, decision making in the operational management of the vessel. This use case is strongly linked to the Circular Economy concepts [17] which enables the reusability and remanufacturing of vessel's components [18], [19], thus prolonging asset lifetime, retain its value and promise tremendous cost savings in vessel's life-cycle maintenance.

In this Use case SmartShip will again contribute to the existing DANAOS fleet performance monitoring platform satisfying following user requirements:

#3.1 Real-time key machinery monitoring.
#3.2 User defined configuration of functions in data processing.
#3.3 Multi-index dataframe time-series generation and routine plotting for functional performance of vessel components.
#3.4 Alert mechanism for error/anomaly detection and failure prediction.
#3.5 Performance report of machinery/equipment for assistance in decision making for efficient maintenance plan and spare parts – consumables procurement plan.

4.4 User Requirements for visualization (Use case #4)

This use case applies to all other use cases, and refers to the enhancement of visual illustration of data delivered to user for better understanding of the information thus facilitating support of user in decision making.

In this Use case SmartShip will again contribute to the existing DANAOS front end data visualization satisfying following user requirements:

#4.1 Fully interactive environment.
#4.2 Intuitive menu.
#4.3 Friendly to user navigation.
#4.4 Representation of information in user defined and multi-format building Dashboard layouts.

5. The incorporation of Circular Economy principles in vessels management

In an era of dwindling resources, no maritime application can be considered complete without addressing sustainability. Here, we are convinced about the merits of the Circular Economy concept, as a development cycle reforming the current economic model of 'take-make-dispose'. The solution to be provided by SmartShip will be based on the innovative incorporation of the Circular Economy principles, designing out waste and reducing pollution, keeping products and materials in use, and regenerating natural systems [20]. In the maritime sector, these principles could be translated into the reduction of fuel consumption by energy-efficient operations, the improvement of engine performance optimization of ship and engine designs, the use of cleaner fuels, and the adoption of proper exhaust gas cleaning systems. The implementation of ship operation practices to reduce energy consumption is also of interest [21].

The pairing of Circular Economy and Smart ICT-enhanced maritime fleet management provides a fertile ground for innovation and value creation. The vision of SmartShip is the amalgamation of the ICT and maritime domains in an autonomous management system that will ensure ship's energy efficiency and emissions management in compliance with environmental regulations, thus enabling the contribution to - and integration of - the maritime domain into a Circular-by-design economy. The SmartShip project integrates the Circular Economy principles combining energy efficiency, fuel consumption, and emissions optimization with data related to the lifecycle of the overall management of engines' components (whose operation significantly affects optimization in the fields mentioned above).

Information creates value if it is used to modify future actions in beneficial ways. A modified action gives rise to new information, continuing the learning process. Thus, information can create value in a never-ending value loop. Getting information around the value loop will allow the SmartShip project to create value. The creation of value is a function of the "value drivers" (volume, velocity, variety, veracity, viability, variability, visualization). The value drivers will have different levels of importance based on the specific value loop in question [22].

Weather routing optimization and monitoring (Use case #1, #2)

In the mobility industry, maritime transport and mainly ships are responsible for a small fraction of the worldwide particle emissions. However, the most considerable portion of ship emissions is located along coastal shipping routes within 400 km from coastlines [23] [24] with high population density levels. Perspectives on the trade market indicate that the amount of goods transported by shipping may triple by 2050, leading to a corresponding increase in fuel consumption. This still represents a minor fraction of fossil fuel consumption, but a high increase of crude oil demand and emissions in high traffic density areas [21].

Consequently, ''the emissions from the maritime transport sector cannot be considered a negligible source of atmospheric pollutants in European coastal areas" [25]. Thus, shipping is permanently engaged in efforts to optimize fuel consumption. Reductions could be obtained through operational measures such as voyage optimization, lower speed, etc. [26].

The Second International Maritime Organization (IMO) Green House Gases (GHG) study, in 2009, identified the potential for further improvements in energy efficiency, through technical- and design-based measures that can achieve reductions in fuel consumption and resulting CO_2 emissions on a capacity basis (tonne-mile) [27].

The energy-efficient operations approach allows a reliable and straightforward way to reduce overall emissions from ships. The underlying principle of this approach consists in finding optimal operational practices that explicitly take into account the fuel costs and the environmental prescriptions while preserving the overall transport velocity of goods required by the markets. One of the most relevant parameters to assess this benefit is the so-called Fuel Operational Consumption (FOC) that is the actual fuel consumption per travelled route.

Among the most important ways to improve the FOC index, there are the improvement of ship routing, also accounting for weather conditions, and the so-called slow steaming. The adoption of an optimal weather routing system that integrates GIS platforms and ships autopilot systems can allow operating under optimal weather conditions reducing fuel consumption and proportionally cutting all exhaust gas emissions.

Slow steaming operation is mainly related to the functioning of the logistic chain: by minimizing berth time and defining just-in-time loading/unloading practices, it is possible to reduce ship velocity with limited effects on the overall transport velocity of goods. Reducing ship velocity should theoretically cut more than 50% of the fuel consumption. The ICCT (2011) estimated a fuel-saving from 15% to 19% for a 10% speed reduction and 36–39% for 20% speed reduction [21].

Condition-based (predictive) maintenance (CBM) (Use case #3)

CBM refers to a maintenance strategy that monitors the actual condition of an asset to decide what maintenance needs to be done. To this purpose, SmartShip will investigate potentials of exploiting the existing infrastructure in ships (e.g. sensing devices and networks) taking into consideration existing sensing devices applied in several parts within a vessel, focusing on engines' operation to enhance the implementation of Circular Economy, in terms of management of engines' components.

The ability to monitor and manage sensing devices makes it possible to bring data-driven decision-making to improve the maintenance strategy and optimize energy efficiency, emissions control, and fuel consumption. IoT profoundly changes the way value is created in a SmartShip environment, as the information generated by a connected asset becomes a critical component of value creation.

Through intelligent assets delivering information concerning their location (3D), condition or availability (LCA), it is possible to capture value in new ways throughout an asset's use cycle [22]. An ICT-enhanced infrastructure can facilitate this by collating knowledge on asset locations, conditions, quality, and performance in real-time and over time.

Reuse and remanufacturing strategies and operations that extend the lifetime of products have a crucial role to play in the transition to a Circular Economy. As part of the activities to achieve objective four of the SmartShip project, a detailed inventory could be used to recycle, recover, reuse and remanufacture the components to a higher quality than is currently possible [33]. In the matter of product life extension, several essential stakeholders emerge comprising the shipping industry and actors associated directly with it, such as shipyards, suppliers, equipment manufacturers, and shipbrokers [34].

6. Actors and Roles

SmartShip use cases involves users in different layers of decision making and authority as well as access control with the tools in consideration. Actors of the SmartShip framework cast across several departments of a typical shipping management company, represented in this project by DANAOS shipping.

There is also interaction between users ashore (office personnel) and users on board (crew).
Table 2 below displays maritime actors engagment in each use case making a distinction between first level access to the tool and second level access. Users in the first level have direct control with the tool and high authority in decision making while those in the second level have indirect control and supportive role in decision making. Interaction between first and second level users is also described in Table 2.

No	Use Case	Tool	Users with first level Access Control	Users with second level Access Control	Interaction between users
1	Weather Routing Optimization / Route Monitoring	DANAOS Weather routing system	Master, Navigation officers	Operation Department in the office	For both use cases the operation department ashore feeds the system with a new weather forecast and other useful operational information for safe navigation. The operation department also sends routing advice to the Master and Navigation officer on-board. The navigation officer takes into consideration the route advice and plots the route plan. The final decision and approval for vessel

					course and any deviation rests with the Master.
2	Condition based Maintenance	DANAOS fleet performance monitoring platform	Technical Manager in the office, owner , Financial manager	Technical operator (fleet manager), Procurement manager in the office	Data retrieved from vessel is processed by the technical department ashore. The technical operator (fleet manager), who is responsible for the vessel, has a first understanding of the vessel's condition by evaluating information from sensors while suggesting any corrective action in case of anomaly detection. The technical manager has the final decision on maintenance strategy, mitigation action for error handling and full technical administration of the whole fleet. At the same time, the financial officer has full visibility for asset depreciation and along with the owner of the vessel current condition and value of the asset itself. The supply department and procurement manager play a supportive role for any purchase and delivery of spare parts to replace machinery components in case of failure detection.
3	Visualization	DANAOS Weather routing system **plus** DANAOS fleet performance monitoring platform	Same users as in both cases above	Same users as in both cases above	SmartShip Visualization use case delivers improvements in user interaction with both tools. Consequently, users, roles as well as interaction between users are the same.

Table 2: Actors, Roles and Interaction of users in each user case

7. KPIs

The definition of Key Performance Indicators (KPIs) should both serve the validation of the SmartShip Use Cases as explicitly described in Sections 3 and 4 and measure the effectiveness of the SmartShip project against the objectives that should be met. In other words, SmartShip will justify the success delivery of an added value proposition to existing technology infrastructure for decision making support towards energy efficiency in shipping operations while at the same time foster knowledge exchange between academic and non-academic experts both in technology and maritime terms as well as introducing the concept of Circular Economy in traditional fleet management. SmartShip KPIs (Table 3.) definition and design is based on the S.M.A.R.T. criteria (Specific, Measurable, Achievable, Relevant and Time phased) [35]

No	Topic	KPI	Applied Use Case	Measurement Validation
1.	Enhance environmental performance in shipping operation	Assessment of Results in Voyage performance in terms of fuel consumption and emission control compliance due to SmartShip routing advice	#1,#2	At least 5% enhancement in environmental performance due to SmartShip routing scenarios against existing algorithmic-based routing advices
2.	Value added proposition to existing tools	Improvements in performance % of the existing weather routing optimization tool	#1,#2	At least 5% improvement in accuracy of routing advice and voyage performance evaluation due to SmartShip build-in functionalities
3.	Value added proposition to existing tools	Improvement in results of the existing vessel performance monitoring tool	#3	At least 5% enhancement in anomaly detection and failure prediction of vessel machinery components due to SmartShip build-in functionalities
4.	Value added proposition to existing tools	Improvement in user friendliness and experience	#4	User acceptance validation test by DANAOS staff
5.	Circular Economy Concept	Introduction of Circular Economy criteria in maritime operations	#3	At least 5% improvement in Engine fatigue treatment and performance monitoring to prolong asset lifetime and retain value.
6.	Knowledge transferability between academic and non-academic experts	Whitepapers & publications in professional journals	ALL	At least 2 technical papers or 4 papers in international conferences or journals introducing achievements and new approaches as applied in SmartShip's use cases
7.	Enhance the uptake of Circular Economy in the maritime sector	Performance of a Gap and LCPA analysis	#1,#2,#3	The identification at least two improvements from

				the current business models used.
8.	Through Circular Economy monitoring of energy-efficient operations performance	Monitoring Energy efficient operations performance	#2	Identify at least a 5% improvement on the Fuel Operational Consumption (FOC) model
9.	Circular economy	Reuse and remanufacturing strategies and operations	#3	Development of at least 1 reuse and remanufacturing Database of materials for engine components
10.	Circular Economy	Collaboration to foster an extended lifetime of products	#3	At least 1 contact with stakeholders on the product life supply chain

Table 3. SmartShip Key Performance Indicators

8. Conclusions

The deliverable describes the use case scenarios to be tackled during the SmartShip project. Each scenario description is a detailed definition and analysis of the Requirements. Furthermore, requirements are fully aligned with the marine market and technology needs.

A methodology by which the aforementioned needs are met and the requirements are conformed is also described. Entities that interact with the SmartShip framework are identified and analysed and the concepts of circular economy are incorporated to the use cases.

The constant evaluation and analysis of the requirements (mostly via LCPA analyses) will act as a key factor which will enable SmartShip to always work in parallel with the needs of the entities and the stakeholders involved in the maritime sector. Applied KPIs will be normalised from 0-1, and be units free to multiple reasons in oprimizations exercises.

Under this scope, SmartShip project is addressing a set of maritime requirements and at the same time is listing a number of key performance indicators targeting to foster a discussion between different disciplines (maritime and technology) as well as between academic and non – academic community that will support a less polluting and more energy efficient shipping operation which embraces values of Circular Economy.

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