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Project Acronym:	**SmartShip**
Project Full Title:	**A data analytics, decision support and circular economy – based multi-layer optimization platform towards a holistic energy efficiency, fuel consumption and emissions management of vessels**
Project Duration:	**60 months (01/04/2019 – 31/03/2024)**

D6.2 Report on final pilot design and implementation

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1. Executive Summary

The SmartShip framework is a comprehensive system designed to enhance maritime operations through the integration of various components. It is built around the following main elements: IoT (Internet of Things), data storage, weather-routing tool, predictive maintenance tool, and user visualization. These components work together to collect and process data from vessels, optimize voyage routing, and improve fleet maintenance.

The development of SmartShip followed agile principles, particularly the SCRUM framework, emphasizing collaboration, transparency, and flexibility. The release plan involved two iterations, integrating data analytics and decision support modules, followed by validation, and testing by end-users (evaluation team) in two pilot rounds. The first lasted between M42 and M45 following the release of the 1st integrated SmartShip system and the second lasted between M55 and M60 following the release of the second and final version.

The evaluation team that was comprised of users from DANAOS Shipping, judged the validity and usability of SmartShip framework per use case both qualitatively against defined attributes with the use of relevant questionnaires and quantitatively running validation scenarios against prescribed KPIs.

End-users confirm that SmartShip system satisfies functional and non-functional requirements recorded at the beginning of the project in D2.1. At the same time, they offer their recommendations for continuous improvements of the SmartShip system supporting an incremental change towards a market ready digital service to be provided in the future to the industry through a comprehensive and solid business model.

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List of Acronyms and Abbreviations

Term	Description
API	Application Programming Interface
CE	Circular Economy
COTS	Commercial off-the-shelf
DSS	Decision Support System
EU	European Union
IoT	Internet of Things
KPI	Key Performance Indicator
ML	Machine Learning
MS	Microsoft
QnA	Questions and Answers
RnD	Research and Development
UAT	User Acceptance Test
UI	User Interface
UX	User eXperience

2. Introduction

2.1 Scope and objectives of the deliverable

The scope of this deliverable is to describe the design and execution of the two pilot testing rounds associated with each iterated version of the SmartShip system. The pilot testing is performed by end-users with the objective to validate the system's functionalities against the defined functional and non-functional requirements. The deliverable is presenting the overall evaluation results for each pilot round and delivers suggestions for continuous improvements to be incrementally implemented in the next versions of the SmartShip system.

2.2 Structure of the deliverable

The deliverable is broken down in **three (3**) main sections
The **first section** is dedicated to the description of the pilots' planning and design. The **next section** is describing the execution of the pilot testing in two phases following the delivery of the iterated versions of SmartShip system. The **last section** delivers the results of the system's evaluation by the end-users in both pilot rounds and the satisfaction level of the defined KPIs while concluding with the users' recommendation for future developments.

2.3 Relation to Other Tasks and Deliverables

D6.2 is strongly related to **D6.1**.which describes the deployment of services and functionalities implemented in an integrated system. **D6.2** presents the design and implementation of the pilot testing of the integrated framework. The deliverable makes also reference to **D2.1** in which the SmartShip use cases and KPIs were defined and to **D3.1** in which the architecture of the integrated framework has been designed.

3. Overview of SMARTSHIP system

The SmartShip system main objective was to offer a multi-layer optimization in the fields of fuel consumption, energy efficiency and emissions control management, in full respect to the implementation of the requirements of maritime sector regulations while taking into account applications of circular economy concepts in the maritime. SmartShip is capitalising on available COTS technologies and specifically builds on top of the existing DANAOS infrastructure for fleet performance monitoring, data analytics and optimization algorithms for voyage planning.

SmartShip system is a holistic re-configuration of the existing DANAOS system and provides extended advanced add-in services offering added value to the shipping company's digital governance

SmartShip framework consists of the following main components: (1) IoT, (2) Data storing, (3) Weather-routing tool, (4) Predictive-maintenance tool, and (5) User visualization. The detailed description of the components may be found in D4.1 and D5.1. and the respective description of the intergrated platform (coming in two versions) could be found in D6.1 accordingly.

IoT, focuses on tools, communication protocols, and network topology for collecting data from various sources on vessels. Data sources are either onboard or onshore, while communication between these sources is established using two methods, based either on (a) a centralized cloud repository, or (b) a synchronization application.

Data storing exposes data collected from IoT systems located on the vessels.

The **weather-routing** and the **predictive-maintenance** tool involve the application of data insight, data analytics (see D4.1), DSS and optimization (see D5.1) techniques to assess optimal decisions in the field of voyage routing and fleet maintenance correspondingly.

User visualization complements the SmartShip framework as an efficient and interactive means of demonstrating data, solutions, and recommendations that supports decision-making, best-practices adoption and strategy implementation.

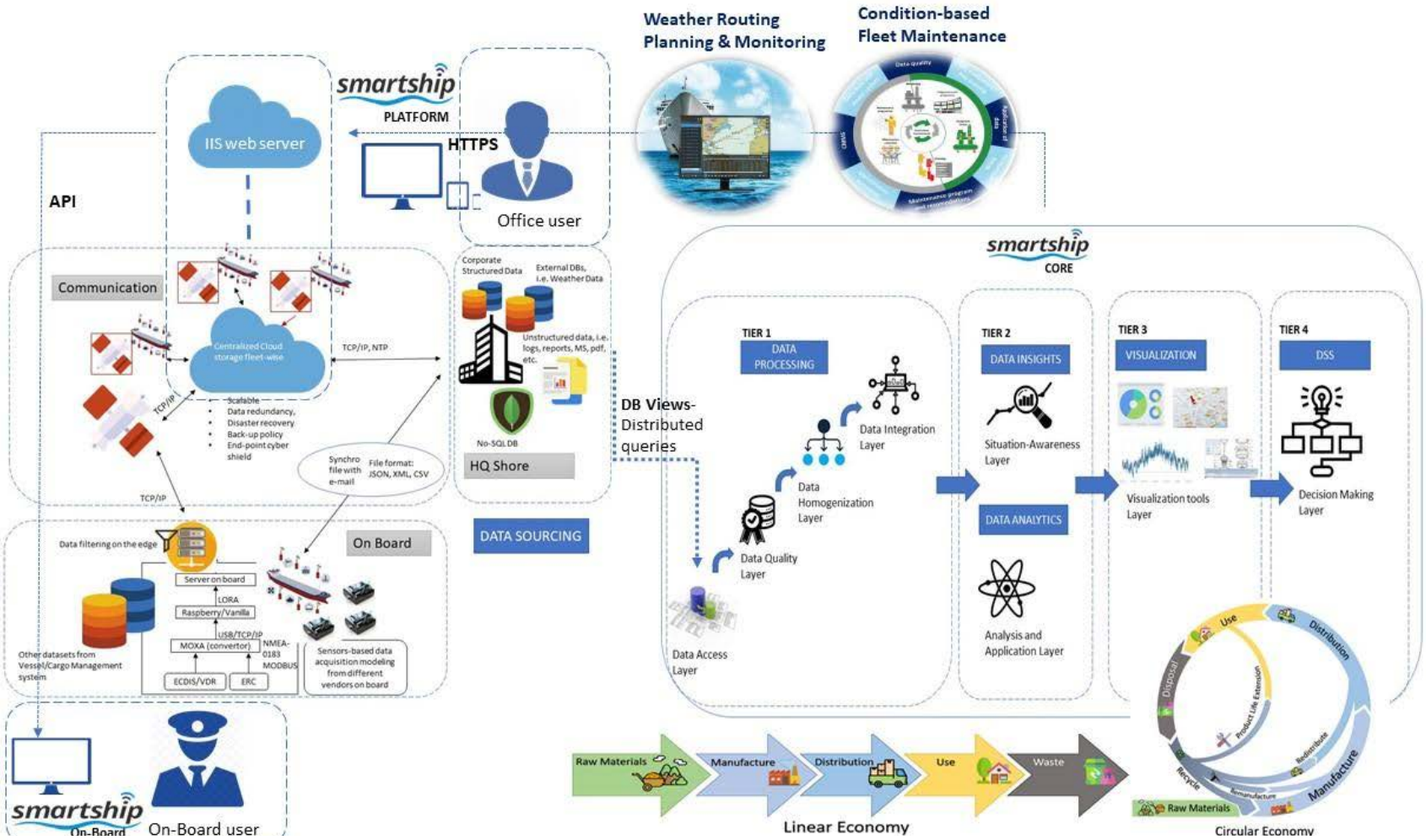


Figure 1. SmartShip Integrated Framework

4. Pilot Deployment Design

4.1 Pilot Overall Framework

In this section, the overall design of the testing and validation phases of the SmartShip framework is described concerning the two iterated versions of the integrated system. The project management approach and methodology for the deployment of the pilot rounds, the structure of the assigned evaluation team, the validation scenarios for each use case and the supportive documents for the execution of the SmartShip pilots are thoroughly presented in the following paragraphs.

4.1.1 Agile Pilot release plan

The Development of SmartShip followed the principles and practices of an agile framework. Specifically, the SCRUM framework was adopted, which provides a structured and iterative approach to project management that emphasizes collaboration, transparency, and flexibility. A more detailed description of the applied SCRUM framework may be found in Section 5 of D5.1. In terms of Scrum roles, rather than assigning them to specific individuals, they were assigned to the seconded staff of the project partners who were responsible for their respective roles but open to collaboration. Scrum events like sprint planning, sprint retrospective, and sprint review were conducted during consortium meetings, with progress documented in deliverable stages. Priorities were based on the proposal, and work progress was collectively accepted, with the tech leader having veto power.

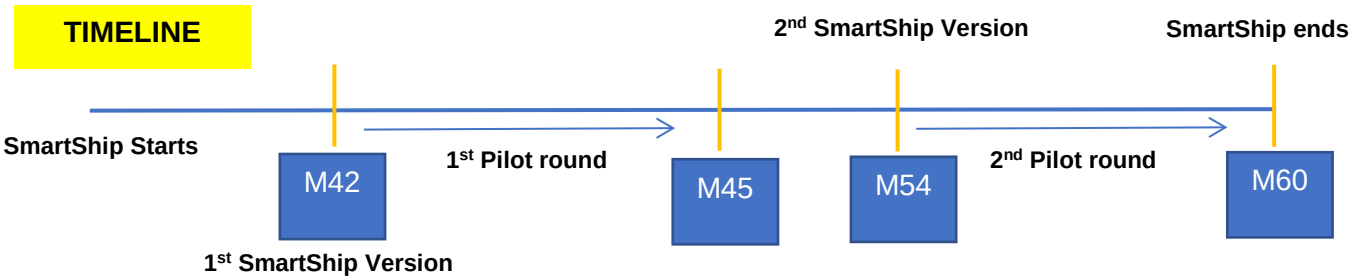
The release plan of the integrated framework consisted of two rounds of iteration. The first iteration integrated the initial versions of Data analytics Module (see D4.1 section 5) and the Decision support and optimization module (see D5.1) into a first integrated system following a backlog of user stories based on the user requirements as listed in D2.1. The first integrated version delivered in M42. The version tested by DANAOS users (see section 4.1.2) in the first pilot round that will be thoroughly presented in the current deliverable. Users' feedback triggered refinements to the initial version and directed the release of the second and final version in M54 of the project's timeline. The second version was subject to validation by the same assigned users. Overall results will be presented in the current deliverable (D6.2).

Pilot release plan was also designed under the principles of agile and scrum methodology. Allocated seconded staff from partners with deep understanding of the SmartShip features and the use cases' business logic played the crucial role of the "product owner" who, by definition in the SCRUM methodology, defines user stories and creates a product backlog. The Product Owner is the primary point of contact with the end users of the system in order to identify user requirements and trace the materialization of these requirements by the development team. In this principle, a solid and continuous communication link between the seconded staff working as product owner(s) for SmartShip system and the reviewers was designed in both pilot rounds.

This communication link was materialized through the scheduling of regular meetings (physically or online) with the users in order to

I. Present the system's functionalities and guide the users through the systems' interface
II. Provide assistance to the users during their interaction with the system and respond to any query where necessary
III. Support troubleshooting for any raised technical issue
IV. Collect and record users' feedback and remarks after the release of each integrated version of SmartShip system in order to trigger improvements for the next version.

The first round of the pilot scheduled to last between M42 of the project timeline and M45 following the release of the first version of the integrated system. The second round of pilot scheduled from M55 until the end of the project following the release of the final integrated version of the system. A schematic of pilots' timeline is presented in a simplified figure below



4.1.2 DANAOS User's team: Focus Group

In D2.1, actors and roles have been identified by defining the main users (personas) that interacts with the existing DANAOS digital ecosystem in which the SmartShip framework works as an extension (See section 3). A breakdown and association of the users with the use cases and the existing tools along with a description of the interaction between them are defined in the Table 1 below copied from D2.1 for easy reference.

Table 1. Actors, roles and interaction with the existing DANAOS system

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.

Based on the definition of actors and roles an evaluation team has been set up consisting of key end-users and decision makers of DANAOS shipping to interact progressively with the iterated versions of Smartship integrated system and assess the tool. The evaluation team is playing the role of a focus group that by definition assists in the elicitation of opinions from stakeholders and subject matter experts about the benefit of a product, which in our case is the SmartShip holistic framework.

The dedicated focus group run the validation scenarios both in the first and the second pilot round to certify the satisfaction level of the system against the backlog of the users functional and non-functional requirements. The feedback of the focus group for the non-functional requirements has been collected with the utilization of dedicated questionnaires (see ANNEX B. Evaluation Questionnaire). On the other hand, selected and defined KPIs were the basis of validation for the functional requirements (See section 4.2)

The end-users from DANAOS shipping' staff who played the role of the focus group or in other words comprised the evaluation team for SmartShip system are displayed in the Table 2 below

Table 2. Reviewers of the SmartShip system for both pilot rounds

No	User	Description	Use Cases
1	Technical Manager	Long Experience in same position in maritime companies managing different vessel types. Main role to coordinate technical department of DANAOS shipping and secure the technical integrity and seaworthiness of DANAOS fleet	Condition based Maintenance, Visualization
2	RnD Manager	A marine engineer with a rich research background. Product owner and Responsible for the continuous improvement of DANAOS digital ecosystem that is the backbone and foundation of SMARTSHIP framework.	All
3	Captain	Captain on board with long navigational experience at the bridge of vessels of distinct type and class. The most experienced captain in the pool of DANAOS crew. Now holds a position in the operation department of the company responsible for the continuous training of the crew.	Weather routing optimization, Route monitoring, Visualization
4	Operation Manager	High-graded licensed mariner who worked as captain on board with long record at sea. Now holds the position of the operation manager in the company responsible to manage the ships from ashore and provide assistant to the captain	Weather routing optimization, Route monitoring, Visualization

		and the crew on-board. Routing plan advice and monitoring of the voyage are his top priorities.	
5	Fleet Manager	Experienced technical manager responsible for the maintenance and monitoring of a number of DANAOS vessels	Condition based Maintenance, Visualization

4.2 Requirements Traceability Matrix: Validation scenarios for each SmartShip Use Case

During the pilot design phase a requirements traceability Matrix was drafted by the seconded staff who played the role of the product owner in the agile methodology selected and followed for SmartShip deployment and testing (described in section 4.1.1). The matrix associates the functional and non-functional requirements, as drafted and elicited in D2.1, with the technical realization of relevant functionalities that are deployed on top of the existing framework and constitute the add-in SmartShip services. The requirements are defining the user stories in the project backlog whilst their translation to technical developments was scripted by the development team (as the principles of SCRUM methodology dictates). The Matrix further associates requirements with validation scenarios per use case that are designed as user acceptance tests (UAT) fully adjusted to the maturity and readiness of the SmartShip system in each released version. The UATs in the first version are designed to validate mainly the non-functional requirements of the system whilst in the second version includes all the requirements (functional and non-functional). The basis for the validation of the non-functional requirements is questionnaires filled in by the evaluation team. Functional requirements are satisfied against the designated KPIs. The Requirements Traceability Matrix aligned with the validation scenarios (UATs) and KPIs for each SmartShip version is presented in the Table 3 below

Table 3. Requirements Traceability Matrix and validation scenarios for both SmartShip integrated versions

Use Case #	Description	Functional User Requirements	Non-Functional Requirements	SmartShip functionality implementation	Validation Scenario (1st Round)	Validation Scenario (2nd round)	KPIs
1	Weather routing optimization	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. 2. Benchmarking and normalization of existing algorithmic-based weather	1. Fully interactive environment. 2. Intuitive menu. 3. Friendly to user navigation. 4. Accuracy of system results 5. No critical issues or/and bugs (critical issue is defined as a severe in nature system error that cause the service to crash, produce incorrect results or even expose sensitive information)	Design and implement an algorithm to plot a voyage recommendation to captain based on AIS-based trajectory clustering driven by a rich library of historical actual voyages (clustered in groups defined by a similarity in terms of route, vessel capacity and weather conditions). This routing optimization algorithm called in the system AISROUTING function and triggered by a relevant button in the landing set up screen of the system (Refer to screenshots in ANNEX A: Screenshots taken from the SmartShip system). AISROUTING is plotted both with and without weather inclusion and based on historical reference of past actual voyages and encloses by definition as inherited knowledge, all navigational constraints that should be taken into consideration for route plotting. In this way	Run a simple voyage plot in the system selecting two ports (origin and destination) and evaluate service against **ONLY** the non-functional requirements. Record bugs and issues whilst draft an evaluation report based on the given questionnaire template.	Run a complex voyage plot judging the accuracy of the algorithm in narrow seas and evaluate service against **both** functional and the non-functional requirements. Functional requirements will be validated against the defined KPIs (as set in D2.1 and copied in the next column).The non-functional will be validated qualitatively with the given evaluation	1. Reduction of fuel consumption (at least 5%) with the use of the new AISROUTING algorithm for route optimization against the conventional setting 2. Reduction of emissions (at least 5%) with the use of the new AISROUTING

		routing optimization with common route patterns, based on AIS data analysis (external reference) and own fleet historical navigational/operational data (internal reference).		the otherwise necessary addition of nautical digital charts is avoided The new routing AIS-based configuration works as an add-in service that is put in comparison with the conventional and existing algorithmic approach for route optimization against a list of performance attributes (Route length, avg. vessel speed, environmental performance indices, fuel consumption, etc.)		questionnaire Record bugs and issues whilst draft recommendations for future improvements.	3. Improvement of accuracy of the routing advise tool (at least 5%) with the use of the new AISROUTING algorithm for route optimization against the conventional setting
2	Route monitoring	1. Ongoing monitoring of voyage performance. 2. Alerting mechanism and warnings to the master for deviations and possible voyage under-performance. 3. Risk assessment of master navigational decision along the route execution and cause analysis of any deviation from the system generated optimal route advice.	1. Fully interactive environment. 2. Intuitive menu. 3. Friendly to user navigation. 4. Accuracy of system results 5. Richness and pluralism of available information (critical voyage data) 6. No critical issues or/and bugs (critical issue is defined as a severe in nature system error that cause the service to crash, produce incorrect results or even expose sensitive information)	Continuous monitoring of critical voyage conditions in near real time visualized in relevant graphs (time-series, comparison tables, scatter diagrams, etc.). Graphs portrayed next to the map where the route is displayed and continuous updated when the ship is crossing each designated waypoint of the route. (Refer to screenshots in ANNEX A: Screenshots taken from the SmartShip system). Voyage analytics dashboard based on actual recorded voyage data collected by sensors on-board or manually reported (marine noon-reports) and sent by the captain. Warnings and alerts for any deviation against users-defined voyage constraints and performance thresholds. (Refer to screenshots in ANNEX A:	An actual voyage of DANAOS vessel will be imported in the system. Monitor in real time the voyage of DANAOS vessel by comparing the advanced route advice for the respective voyage generated by the route optimization service (see Use	An actual voyage of DANAOS vessel will be imported in the system. Monitor in real time the voyage of DANAOS vessel by comparing the advanced route advice for the respective voyage generated by the route optimization service (see Use case #1) and the actual voyage decisions of the captain. Evaluate	1. Reduction of fuel consumption (at least 5%) with the use of the new AISROUTING algorithm for route optimization against the Captains' actual decision 2. Reduction of emissions (at least 5%) with the use of the new AISROUTING

		4. Dynamic voyage performance comparison, triggered by user anytime along the voyage, between system route advice and master course plotting.		Screenshots taken from the SmartShip system). Dynamic performance comparison of route defined by the system and actual route plotted by the captain. Portrayed on the same interactive map for route visualization	case #1) and the actual voyage decisions of the captain. Evaluate service against **ONLY** the non-functional requirements. Record bugs and issues whilst draft an evaluation report based on the given questionnaire template.	service against **both** functional and the non-functional requirements. Functional requirements will be validated against the defined KPIs (as set in D2.1 and copied in the next column).The non-functional will be validated qualitatively with the given evaluation questionnaire Record bugs and issues whilst draft recommendation for future improvements.	algorithm for route optimization against Captains' actual decision 3. Improvement of accuracy of the routing advise tool (at least 5%) with the use of the new AISROUTING algorithm for route optimization against Captains' actual decision
3	Condition-based (predictive) maintenance	1. Real-time key machinery monitoring. 2. User defined configuration of functions in data processing. 3. Multi-index data frame time-series generation and routine plotting for functional performance of vessel components.	1. Fully interactive environment. 2. Intuitive menu. 3. Friendly to user navigation. 4. Accuracy of system results 5. Richness and pluralism of available information (critical voyage data) 6. No critical issues or/and bugs (critical issue is defined as a severe in nature system error that cause the service to	Implementation of a comprehensive dashboard of data analytics correlating critical functional parameters of key machinery on-board. Data analytics are both user defined and product of predictive application of advanced Machine Learning models (ML algorithms). (Refer to screenshots in ANNEX A: Screenshots taken from the SmartShip system). Implementation of an intuitive user interface where user or data analyst could easily build up a predictive model by selecting key variables from a vast data	User will build-up and set up at least **one ML model** to predict the future trend of a critical variable for vessel performance (speed or fuel consumption), Users will populate a simple	User will build-up and set up at least **three ML models** to predict the future trend of critical variables for vessel performance. Users will train and populate model to identify anomalies and predict failure for a critical component on-	1. At least 5% enhancement in anomaly detection and failure prediction of vessel machinery components due to SmartShip build-in functionalities 2. Development of at least 1

		4. Alert mechanism for error/anomaly detection and failure prediction. 5. Performance report of machinery/equipment for assistance in decision making for efficient maintenance plan and spare parts – consumables procurement plan.	crash, produce incorrect results or even expose sensitive information)	library collected from sensors on-board. ML models are forecasting trends of vessels performance indicators (for example fuel consumption) and at the same time produce alerts for anomaly detection or failure prediction of a machine or equipment on-board in order to trigger a decision-making for repair or replacement of the component. (Refer to screenshots in ANNEX A: Screenshots taken from the SmartShip system). Continuous monitoring of critical voyage conditions in near real time visualized in relevant graphs (time-series, comparison tables, scatter diagrams, etc.). Graphs portrayed next to the map where the route is displayed and continuously updated when the ship is crossing each designated waypoint of the designed route (same as use case #2). (Refer to screenshots in ANNEX A: Screenshots taken from the SmartShip system). Creation of cohesive and comprehensive performance reports dedicated to the managers of the vessel to support the decision making process. (Refer to screenshots in ANNEX A: Screenshots taken from the SmartShip system).	performance report for one vessel based on time-series analysis of one critical performance factor (e.g. fuel consumption). Evaluate service against **ONLY** the non-functional requirements. Record bugs and issues whilst draft an evaluation report based on the given questionnaire template.	board (e.g. main engine). Users will retrieve a performance report for at least two vessels based on time-series analysis of one or more critical performance factors (e.g. fuel consumption). Evaluate service against **both** functional and the non-functional requirements. Functional requirements will be validated against the defined KPIs (as set in D2.1 and copied in the next column).The non-functional will be validated qualitatively with the given evaluation questionnaire Record bugs and issues whilst draft recommendations for future improvements.	reuse and remanufacturing Database of materials for engine components 3. At least 5% improvement in Engine fatigue treatment and performance monitoring to prolong asset lifetime and retain value.

4	Visualization		1. Fully interactive environment. 2. Intuitive menu. 3. Friendly to user navigation. 4. Accuracy of system results 5. Richness and pluralism of available information (critical voyage data) 6. No critical issues or/and bugs (critical issue is defined as a severe in nature system error that cause the service to crash, produce incorrect results or even expose sensitive information)	This use case is judging and evaluating interactivity, user-friendliness, clarity, usability, design, and the overall experience of the services materialized in the above functional use cases	Users will evaluate qualitatively the 1st version of the platform against the non-functional requirements, based on the given questionnaire template.	Users will evaluate 2nd and final version of the platform against the non-functional requirements.	Acceptance evaluation from DANAOS end-users in terms of interactivity, friendliness, clarity, usability, design and overall experience

4.3 Pilot Supportive documents

For a smooth pilot execution, a list of documents was prepared to support the deployment of both pilot rounds. The list of documents included

1. Descriptive manuals of the SmartShip services assisting the interaction of the users with the system
2. Questionnaires for the collection of user's feedback against the non-functional requirements (see ANNEX B. Evaluation Questionnaire)
3. User Acceptance scenarios document with an analytical step-by-step description of the validation stories. A high level presentation of the validation scenarios is presented in Table 3 above
4. An open registry for the users to constantly record remarks and suggestions for future improvements or dynamically configure their requirements.
5. Issue log to report bugs and critical errors of the system or record remarks during each pilot round execution. The issue log template is presented below

All documents were easily accessible online through the projects' dedicated repository in Google Drive

Table 4. Issue Log template

#	Issue	Description	Reported By	Status	Priority	Date Reported	Date Resolved	Resolution

5. Pilot Execution

5.1 1st Round of User's Evaluation (1st version of the SmartShip system)

The first pilot round was executed at the premises of DANAOS shipping according to the original timeplan. Started at M42 with a kick-off meeting which was conducted between the project team with the role and responsibility of the product owner (called product owner team), and the assigned evaluation team (end-users). The Kick-off was a full day event offered in a hybrid mode (both physical and online through MS teams). The agenda started with informative presentations about SmartShip project and concluded with a live demonstration of the integrated first version of the system. Following, a QnA session with questions and clarifications run. The session ended and all necessary supportive documents shared with the users.

The users interacted with the system at their own pace for 3 months. During the pilot round and along the process of user's interaction with the system a dedicated communication link working as a fishbowl window was opened providing constant direct communication between users and the product owner team. The pilot round finished on schedule around M45. The evaluation team competed and submitted to the project's repository the relevant questionnaires (see ANNEX B. Evaluation Questionnaire) for the evaluation of the first SmartShip version against non-functional requirements. The product owner team also collected the end user's suggestions for further inclusions and improvements towards the release of the second integrated version.

Pilot evaluation results and the summary of user's suggestions for further improvements to be assessed by the development team and implemented in the second version, are presented in Section 6.1.1

Issues Recorded

During the first pilot phase, there were no critical issues recorded by the users with the exception of the response time of the system when the route optimization service deployed (use case #1 and #2)
The issue reported in the designated issue log and mitigated by the development team.
The resolution progress tracked and monitored by the product owner team. Issue successfully resolved before the release of the second version

Table 5. Issues in the first pilot round

#	Issue	Description	Reported By	Status	Priority	Date Reported	Date Resolved	Resolution
1	Extreme Response time for route optimization	The time to call optimal routing through the AISROUTING service	All users	Closed	High	10/10/2022	13/01/2023	Scalability in system configuration. Utilize profiling, tracing, logging, benchmarking, and load testing tools to analyze system's response time. These tools help identify components or functions that slow down the system or consume excessive resources. The issue resolved with an increase in database and application server's memory (RAM)

5.2 2nd Round of User's Evaluation (2nd version of the SmartShip system)

The second pilot round engaged the same seconded staff playing the role of the product owner in the SCRUM methodology and the same end-users evaluation team. The pilot phase started at M55 following the release of the second and final integrated version. A kick off meeting was again scheduled and conducted between product owner and evaluation team at DANAOS shipping premises with the same communication configuration (virtual and physical). The agenda included a full live demonstration of the system pointing out all systemic differences and improvements related to the first initial system version. After the necessary questions and answers for further clarifications, the updated versions of the living supportive documents (see section 4.3) were provided to the users to support pilot execution and SmartShip overall evaluation.

Same to the first pilot round the end users interacted at their own pace with the system and were provided with the same open communication link in order to interact with the product owner team and seek support and assistance where needed. It is worth to mention that no critical bugs or issues recorded and the system responded very well to user's commands.

The pilot phase concluded at the end of project's timeline (M60). Similar to the first round the users completed the evaluation sheets for the non-functional requirements and delivered them to the project team. The product owner team collected the questionnaires and prepared a report with the pilot evaluation results along with the user's recommendations for future SmartShip system's releases.

Results and recommendations are presented in the current deliverable in section 6.1.2

6. Pilot Results

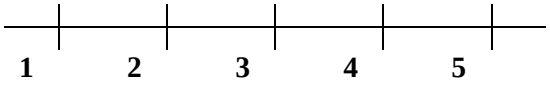
6.1 SmartShip System Evaluation

6.1.1 Results for the 1st version

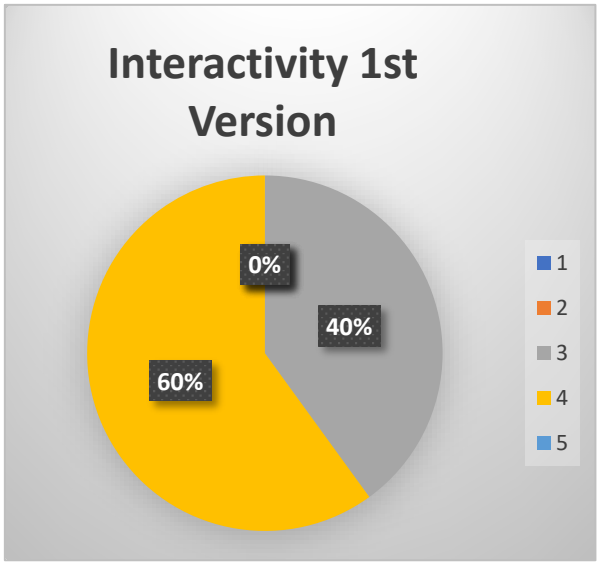
This section presents the results of the first pilot round performed by the designated evaluation team of DANAOS users (see Table 2). During this process, users followed the validation scenarios drafted for the 1st version and described in Table 3. In this first pilot phase, the evaluation team assessed only the non-functional requirements against qualitative attributes through relevant questionnaires. The requirements subject to evaluation are casting across all use cases but are directly associated with Use case #4 (visualization) which addresses all the UI and UX improvements materialized on top of the existing DANAOS infrastructure and embedded in the first integrated version of the SmartShip Platform

Overall results stemmed from the completed questionnaires and represented in graphs below. All qualitative attributes were scored by each individual user on a scale of one (minimum) to five (maximum).

(1-Very Low, 2-Low, 3-Medium, 4-High, 5-Very High)



In the following pie graphs, the share of each grade (1-5) per qualitative attribute is represented as aggregated by the provided responses of the reviewers



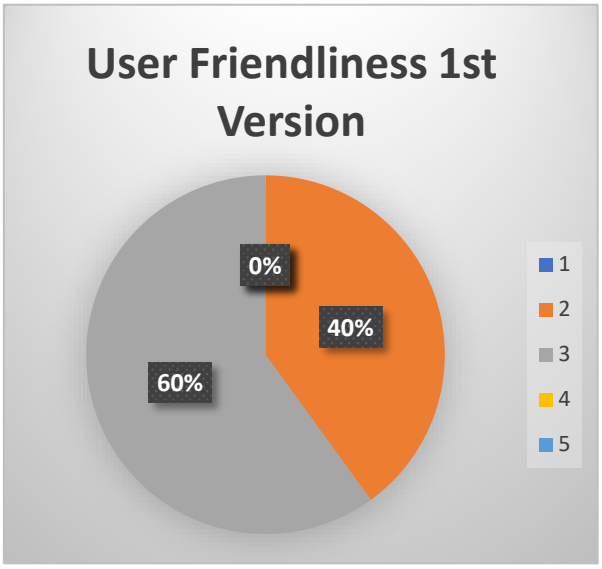


Figure 2. Evaluation results of non-functional attributes based on User's feedback (1st pilot round)

Even from the 1st version of SmartShip, users seem to appreciate the interactivity with the tools (graded with three by 60%). User-friendliness is quite moderate though. As far as data availability is concerned, the plurality and richness of available information is at a medium scale. Users witnessed some inconsistencies in the results generated by their interaction with the services of the 1st SmartShip version judging by the grade assigned to the "accuracy" attribute. Finally, the user's overall experience with the system is considered controversial ranging from low to high with equal shares between score three and four (40%).

The overview of the results shows an appreciation of the users towards the system's functionalities. On the other hand, the score given to most if not all the evaluation criteria signifies that there is plenty of room for significant improvements in order to enhance system's integrity and usefulness. Improvements are reflected in the suggestions recorded by the users and presented in the following consolidated list

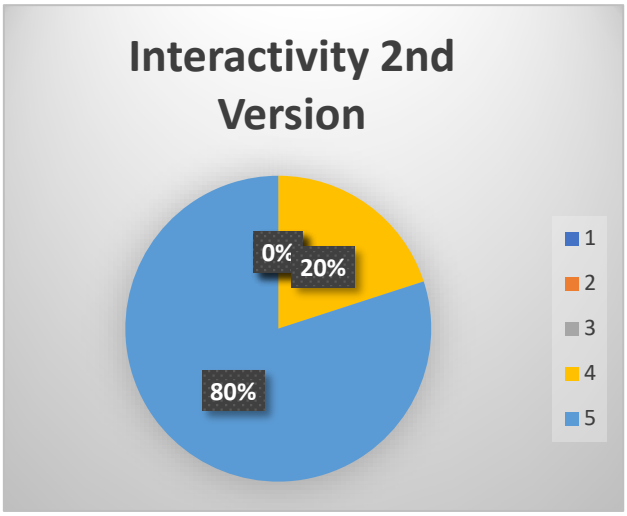
Table 6. User's recorded suggestions for improvements after the 1st round of system's evaluation

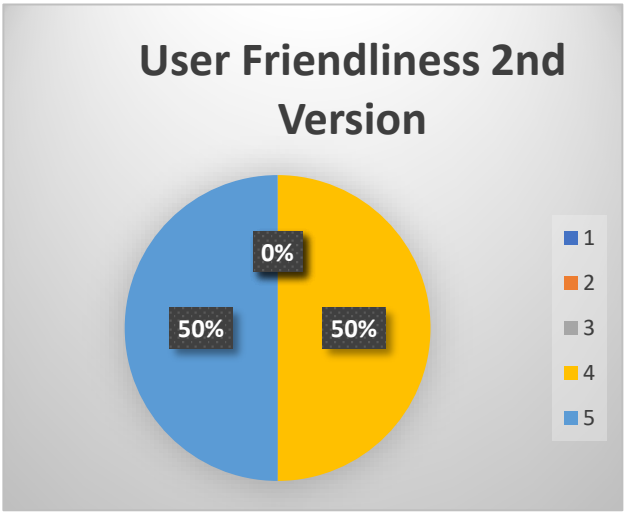
Applied Use Case (#)	Suggestion
#4	System should generate one dashboard with consolidated analytics in order to compare performance of all vessels in the fleet. Intuitive data representation format in one consolidated page for a quick review by the accountable manager
#1, #2, #4	Ability for the user to change format in the digital map for route representation
#2	User should have the option to populate multiple data representation graphs selecting from a list of available attributes in the first landing page of the system. This is crucial for the overall monitoring of the plotted voyage
#3	Ability to opt more raw data collected from sensors on board. Lack of availability of information for critical machinery has been noticed to some extent
#1, #2	User to have an option to manually configure the plotted route advice directly on the map by drag and drop (add or remove) new waypoints along the route (human in the loop of an automated process)
#1, #2	Weather data should be displayed on hover the interactive map in each waypoint

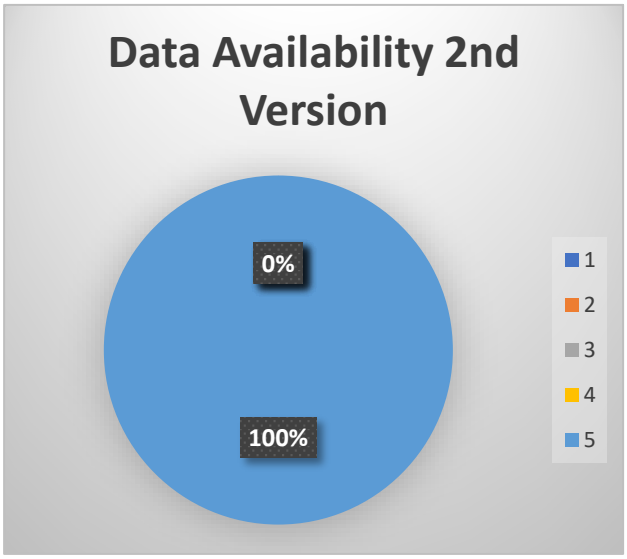
6.1.2 Results for the 2nd version

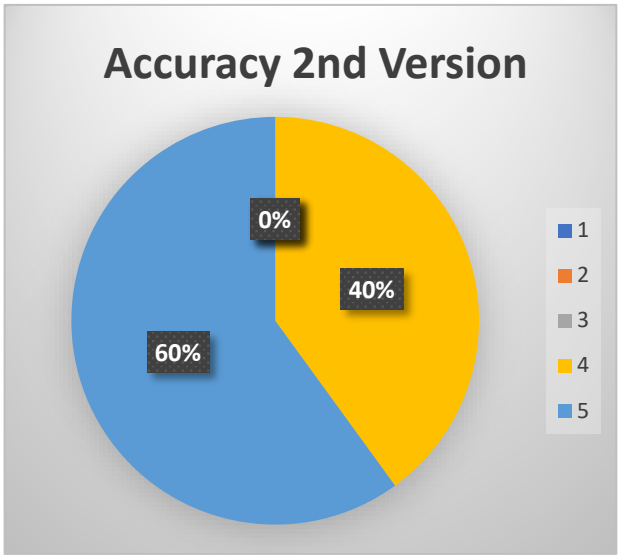
During the second pilot phase, the evaluation team run the defined validation scenarios (see Table 3) in order to assess SmartShip functionalities against the full list of requirements (both functional and non-functional). For the assessment of the non-functional requirements, the same methodology as to the first pilot round was followed. Same questionnaires templates was shared to the users in order to grade SmartShip updated and final version against the same qualitative attributes.

The results from the qualitative assessment are represented in the pie graphs below.
The quantitative validation of functional requirements per use case is reflected in the satisfaction of the associated KPIs as presented in Table 3. KPIs satisfaction results are represented in Table 7 in section 6.2









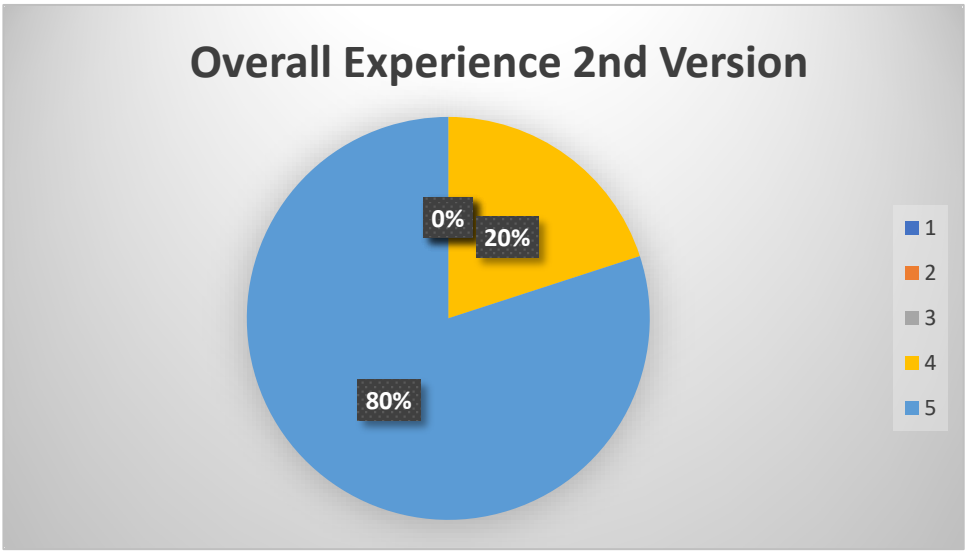


Figure 3. Evaluation results of non-functional attributes based on User's feedback (2nd pilot round)

Following the users' assessment, it is evident that both interactivity and user friendliness are significantly improved compared to the 1st version. Contrary to the 1st version, the evaluation team values positively the data availability provided in the system. The algorithmic functions of the digital services provide accurate results. It is worth noting that all system users expressed a positive overall experience from their interaction with the digital services per use case (the score with the greatest share is the maximum -5-, 80%). End-users are appraising the fact that all of their suggestions recorded in the 1st pilot round (see Table 6) are satisfied in full in this version.

The evaluation team has communicated through a related question in the questionnaires, their recommendations for further system upgrading. A list of recommendations stemming from the aggregated users' remarks are presented in section 6.3 and constitutes the foundation for levelling up the overall experience and usability of the SmartShip framework

6.2 SmartShip KPIs satisfaction

The following table constitutes a consolidated view of the SmartShip KPIs, as defined in D2.1, along with their link to the use cases. For each KPI a validation method is assigned. ***KPIs' review and validation indicate that the majority -if not all- have been satisfied. In particular, except KPI No. #3 which is partially accomplished, all the rest have been fully achieved. The high level of KPIs' satisfaction fully validates the accomplishment of the system's functional requirements per use case, following the depicted association in Table 3***. Some KPIs, such as No #6, #7, and #10, are not directly linked to the pilot testing and the evaluation of the end-users but rather are satisfied via other activities performed in the project. Activities that are associated with the demonstration and communication of SmartShip's outcomes to an external audience mostly, through workshops, publications and strategic collaborations.

Table 7. SmartShip KPIs validation

No (#)	Topic	KPI	Applied Use Case	Measurement Validation	Validation method	Result (KPI satisfaction)
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	Validation is based on the evaluation scenario drafted for the 2nd version of the SmartShip System. It is described in Table 3 and executed by the designated reviewers for Use case #1	**Fully**. The new AIS-based algorithm AISROUTING compared to the conventional algorithm for routing advice showed an **estimation** of fuel reduction around 7-8%
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	Validation is based on the evaluation scenario drafted for the 2nd version of the SmartShip System. It is described in Table 3 and executed by the designated reviewers for Use case #2	**Fully**. The new AIS-based algorithm AISROUTING compared to the conventional algorithm for routing advice showed an actual fuel reduction of 6% against the **actual** voyage plotted and executed by the captain on-board

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	Validation is based on the evaluation scenario drafted for the 2nd version of the SmartShip System. It is described in Table 3 and executed by the designated reviewers for Use case #3	**Partially.** ML models designed trained and run in SmartShip project identify and detect anomalies 3% more than the existing algorithmic configuration
4.	Value added proposition to existing tools	Improvement in user friendliness and experience	#4	User acceptance validation test by DANAOS staff	Relevant evaluation questionnaires shared with the users asking them to grade the SmartShip system against several qualitative attributes. See results for 1st and 2nd version (refer to section 6.1.1 and section 6.1.2 accordingly)	**Fully.** DANAOS users value very positively the overall experience of the SmartShip system. All non-functional requirements have been satisfied in full.
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.	Validation is based on the evaluation scenario drafted for the 2nd version of the SmartShip System. It is described in Table 3 and executed by the designated reviewers for Use case #3	**Fully.** ML models designed trained and run in SmartShip project and time series analysis driven from data captured by sensors on-board showed improvement in the monitoring of engine fatigue at least 10%
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	Validation is based on the publication of a policy brief, five papers in conferences and five papers in journals.	**Fully**: More than ten papers introducing achievements and new approaches as applied in SmartShip's use cases were published.
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.	Validation is based on the implementation of Exploitation Workshop, the development of a business canvas using the Dynamic Business Model (DBM) approach and mapping of the use cases to circular business model	**Fully.** Using of the Dynamic Business Model approach (DBM) to identify improvement to the offer of the Smaprtship platform for different customers and the mapping of circular strategies for the use cases 1, 2 and 3

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	Validation is based on the evaluation scenario drafted for the 2nd version of the SmartShip System. It is described in Table 3 and executed by the designated reviewers for Use case #2	**Fully (justified indirectly from the validation result of KPI #2).** The new AIS-based algorithm AISROUTING compared to the conventional algorithm for routing advice showed an actual fuel reduction of 6% against the **actual** voyage plotted and executed by the captain on-board
9.	Circular economy	Reuse and remanufacturing strategies and operations	#3	Development of at least 1 reuse and remanufacturing Database of materials for engine components	Validation is based on the evaluation scenario drafted for the 2nd version of the SmartShip System. It is described in Table 3 and executed by the designated reviewers for Use case # 3	**Fully.** Justified by the fully satisfied KPI #3,#5. The improvements in anomaly detection and monitoring of the performance of critical machinery on-board materialized the concept of predictive maintenance. The supply chain of spare parts has been normalized with the achievement of cost savings and lean management in the procurement of necessary components. As a positive cascade effect, the prediction of failures in vessel's machinery triggered the reusability of obsolete components stocked in the company's inventory before being expired or scrapped. Normalization and optimization of inventory management of the spare parts is a beneficial result of SmartShip project. A proven result by the execution of SmartShip use case #3 was the re-use of **5 components** from the stocked material that were utilized to fix

						identified issues in the auxiliary engines (AE) of one vessel.
10.	Circular Economy	Collaboration to foster an extended lifetime of products	#3	At least 1 contact with stakeholders on the product life supply chain	Validation is based on the Big Data Mobility collaboration generated through the Horizon Booster (HRB) services and the partnership with the HS4U project.	**Fully.** The collaboration with HRB generated five contacts with other project leaders related to big data namely, MASTER, SoBigData, Polluscope, i4Sea, and Glasseas. also the partnership with the HS4U project.

6.3 Recommendations for the future

In this last section, a consolidated list of DANAOS user's recommendations for future improvements is presented. The list is aggregating the registered suggestions of the users collected from their responses in the questionnaires after the conclusion of the second pilot round. The recommendations will be considered for the upgrading of the market readiness of the SmartShip framework. The intention is to implement the extra functionalities in the post-project era to strengthen the value proposition to the industry. The SmartShip business model will define the potential commercialization of this future version of the system

- ✓ Re-configure the route optimization model to take into account the new environmental indices that come into play (e.g. Fuel EU[1])
- ✓ An API should be developed and documented to open access to external services from third-party providers to enhance data/information availability (e.g. necessary external information for voyage planning like bunkering prices, port tariffs, etc.)
- ✓ Enhance the ML model repository by incorporating advanced algorithms addressing the same challenges (e.g. fuel consumption optimization) and compare with the existing configuration for better prediction accuracy.
- ✓ Enhance data points. Re-calibrate the IoT configuration on-board to augment the data requisition from on-board data sources. This is necessary to assess and monitor the performance of recently installed energy-saving devices or engines that burn alternative fuels.
- ✓ Make the system configuration scalable and move to cloud engineering. The existing setup is exploiting a data analysis engine hosted on a server on-premise (DANAOS office ashore). Cloud engineering will support streaming analytics of a data lake collected from the source (vessel) in near real-time
- ✓ In the long term, a re-configuration of the SmartShip framework to address the digital twin concept should be implemented. The Digital Twin concept allows the continuity of the interaction between the virtual and physical objects. In this context, the vessel is better monitored managed and controlled. Finally, this two-way interaction will eventually automate the decision process on-board.
- ✓ Seek for a certification of the system as a circular economy by design concept. The CE trademark will solidify the value of the SmartShip framework in the market

7. Conclusions

This report on pilot design and implementation concludes with the following key takeaway notes

- The testing of the two versions of SmartShip system was performed successfully in two consecutive pilot rounds with the assistance of appointed users from DANAOS shipping
- Users evaluated positively the final version of the SmartShip system against the non-functional qualitative attributes. All suggestions for improvements stemming from the first pilot round were embedded in the final version
- Defined KPIs of the system were fully satisfied validating the elicited functional and non-functional requirements of the SmartShip framework
- A list of recommendations has been drafted from the end-users to forge the next version of the SmartShip system after the end of the project

[1] https://www.dnv.com/maritime/insights/topics/fueleu-maritime/#:~:text=FuelEU%20Maritime%20sets%20requirements%20on,unit%20(gCO2e%2FMJ)

8. ANNEX A: Screenshots taken from the SmartShip system

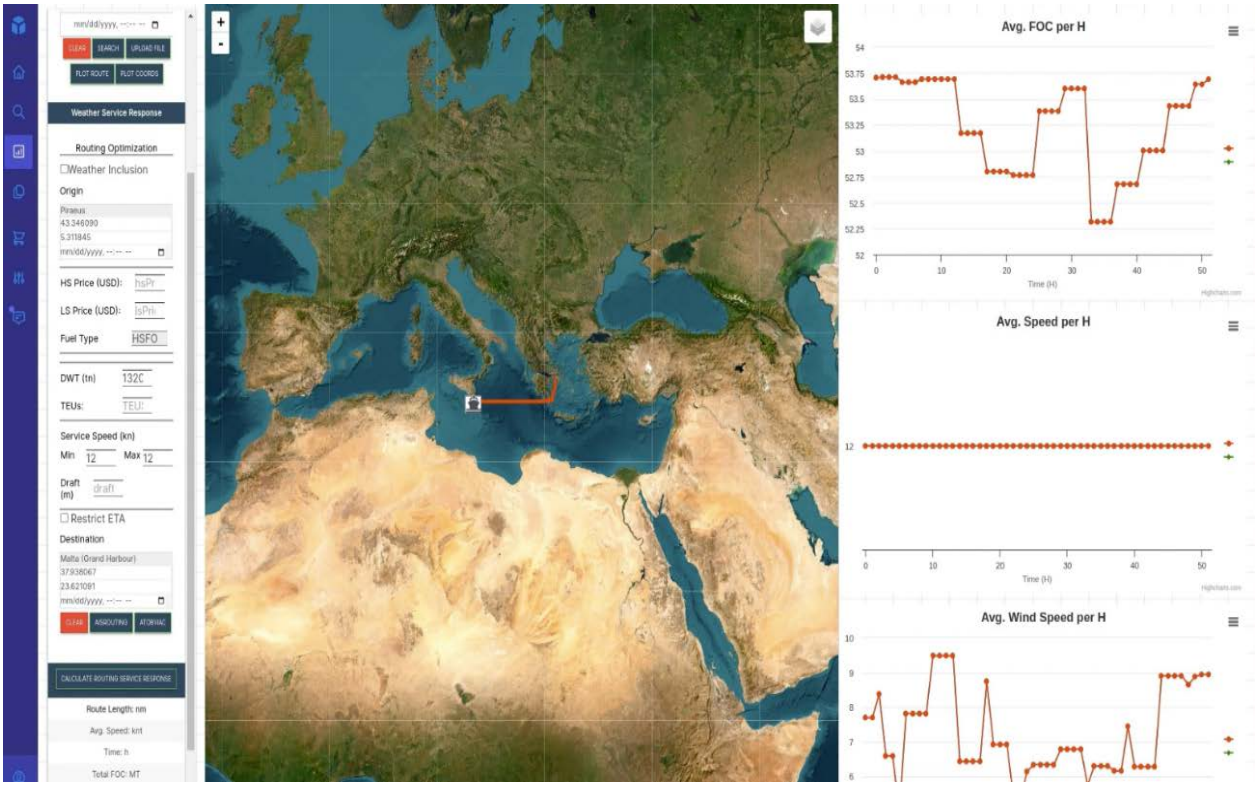


Figure 4. SmartShip route monitoring page

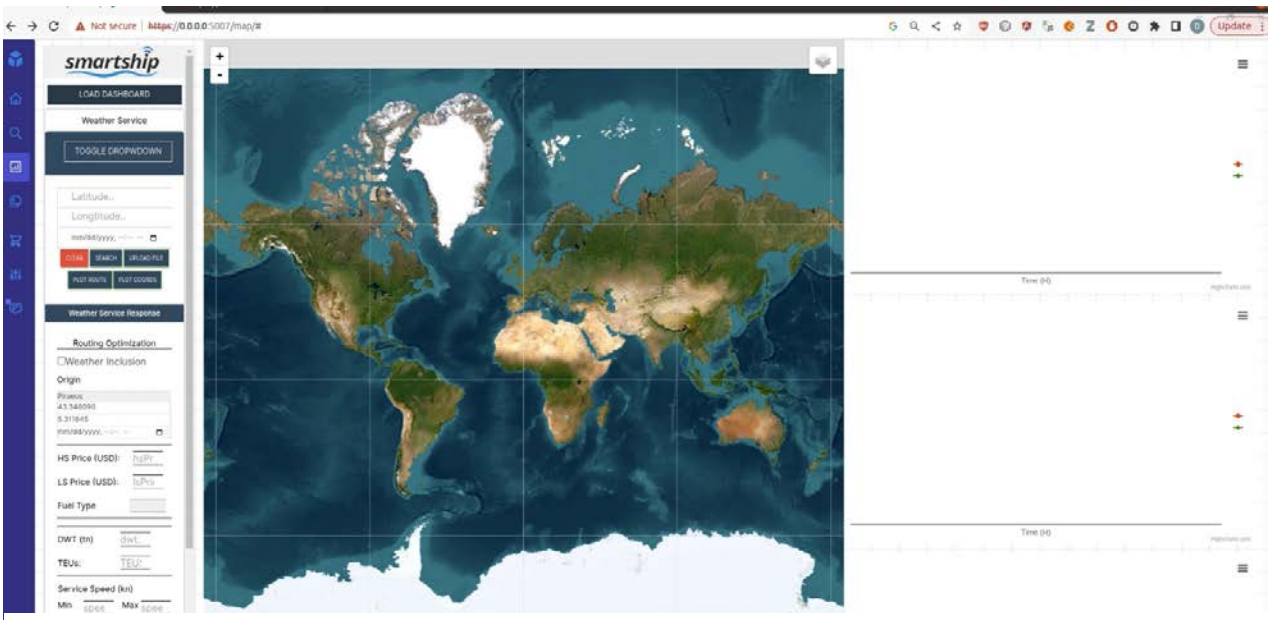


Figure 5. SmartShip system landing page

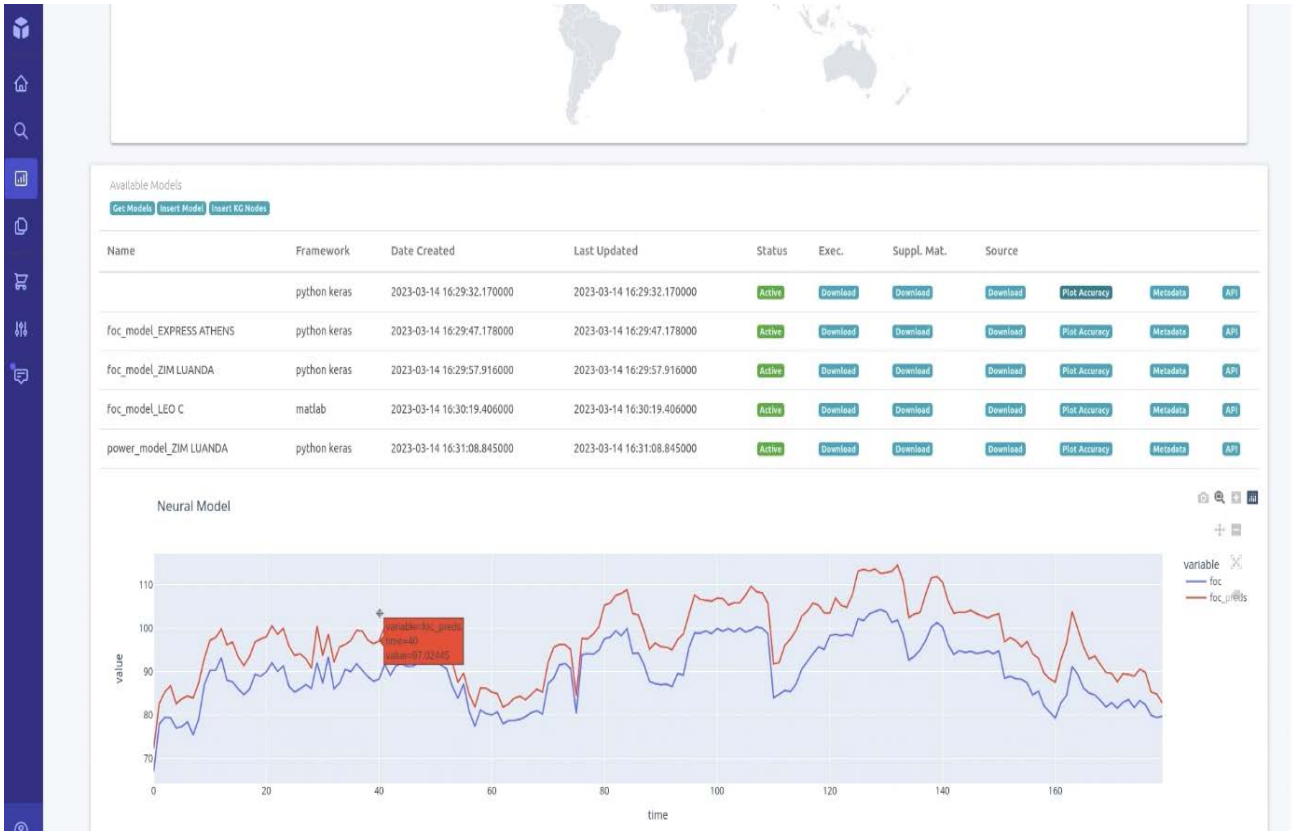


Figure 7. ML models repository

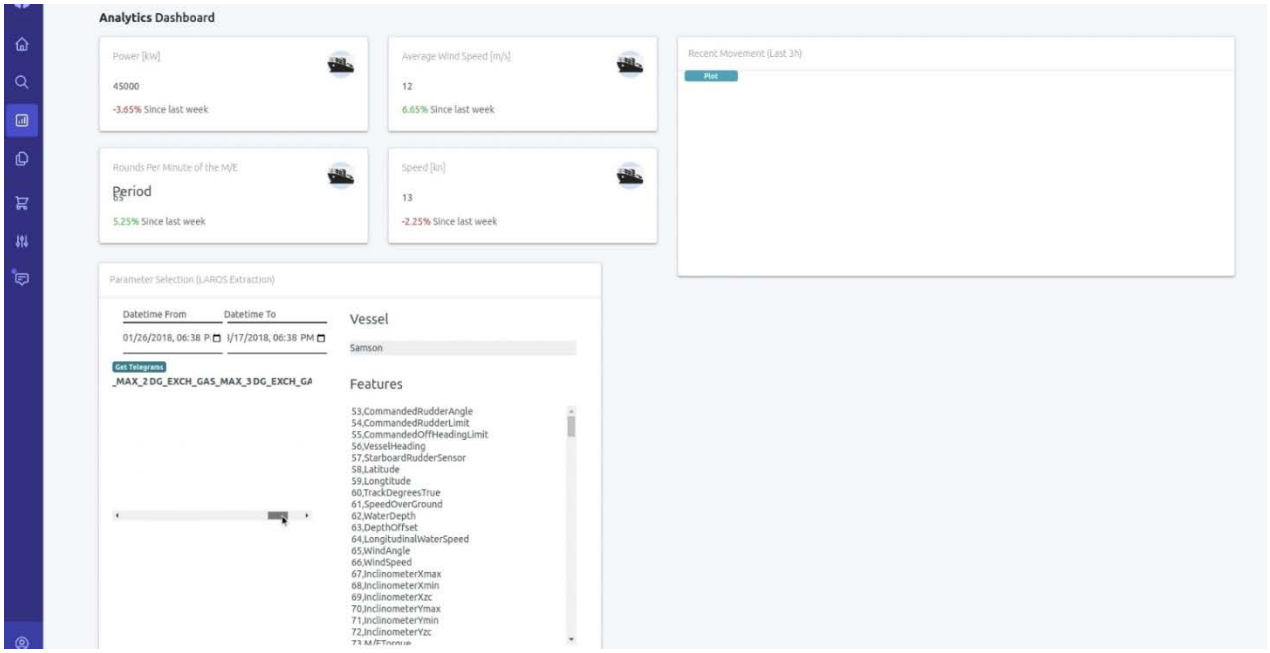


Figure 6. SmartShip data repository

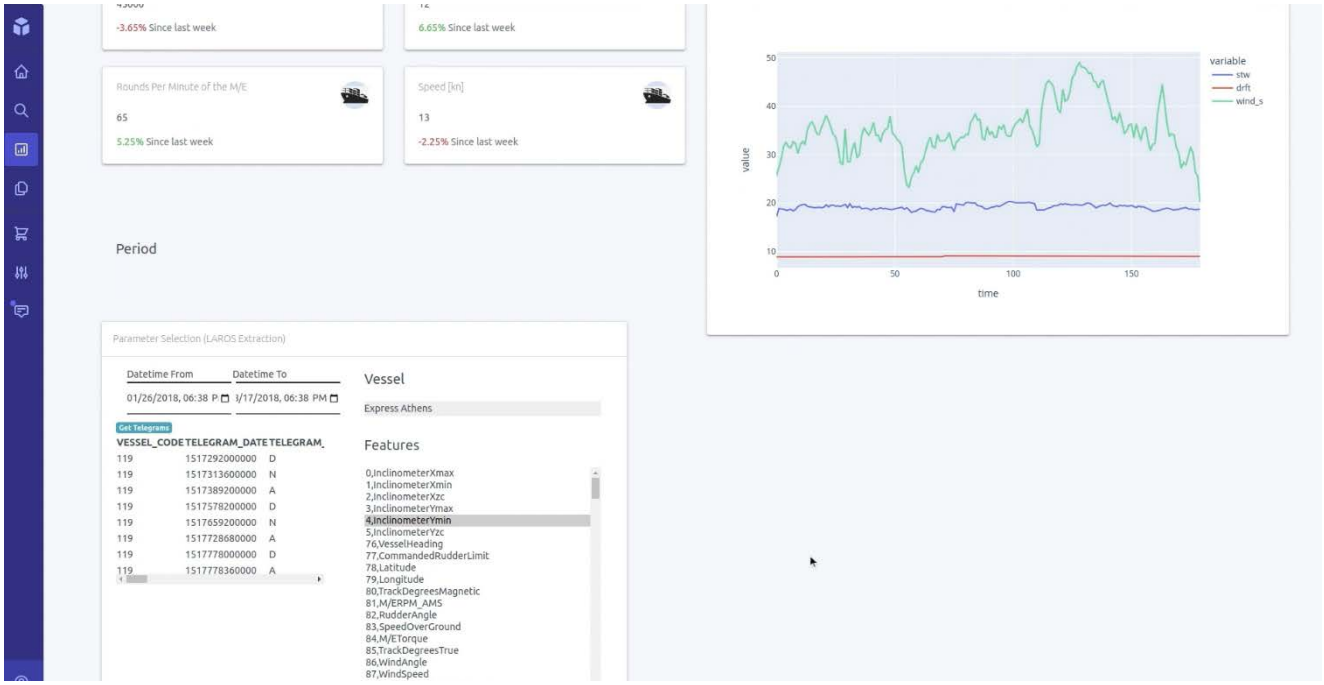


Figure 8. SmartShip advanced data analytics

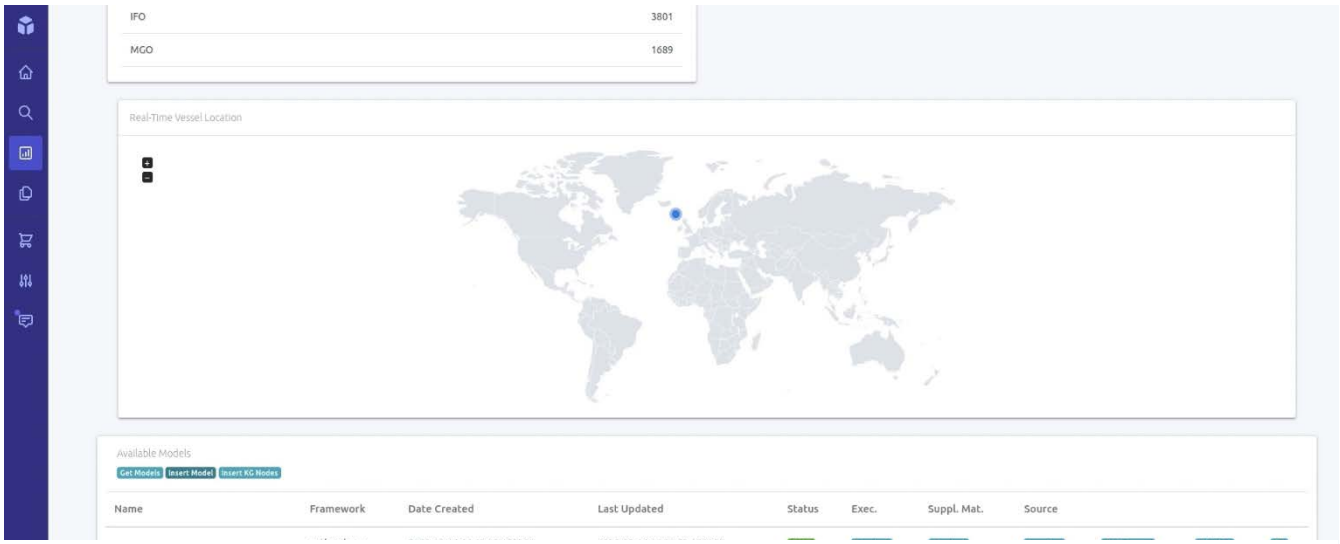


Figure 9. ML model configuration page

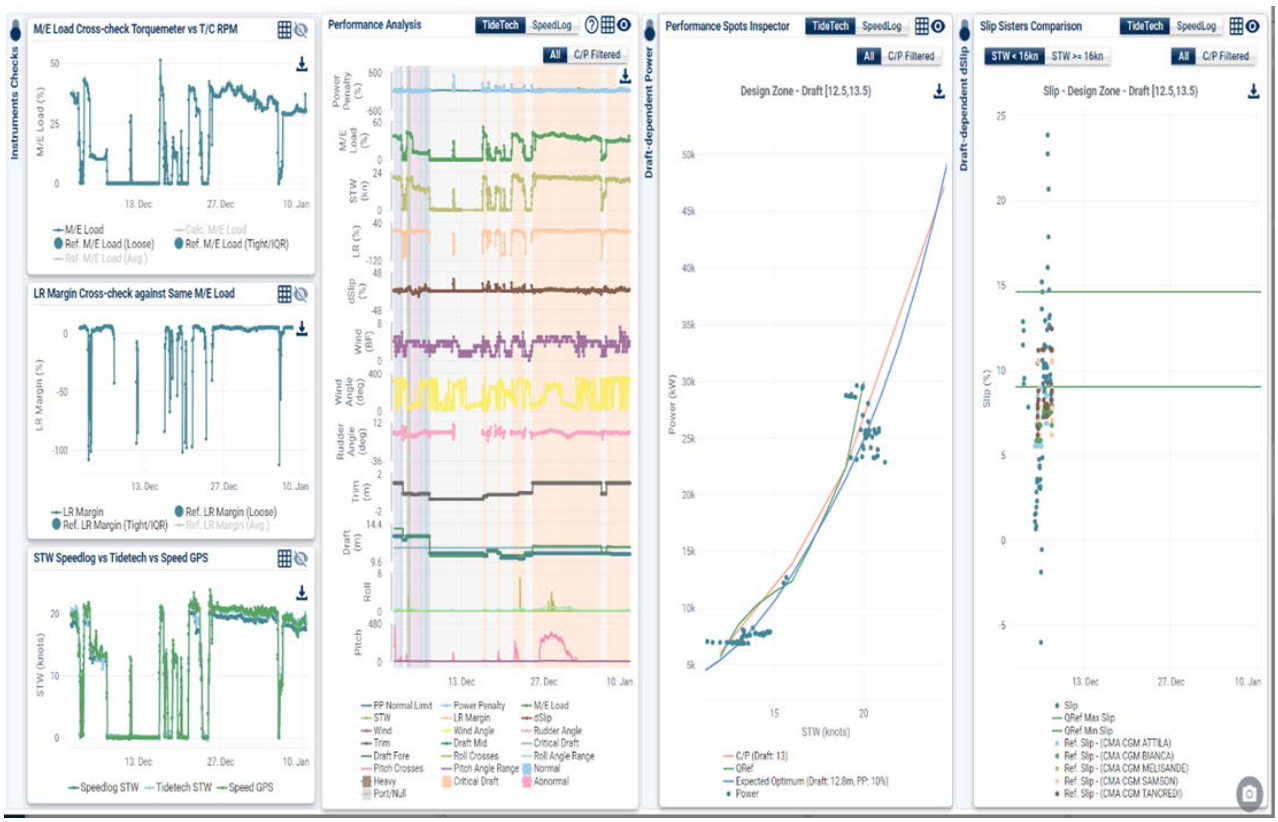


Figure 10. Reporting Dashboard for the whole DANAOS fleet

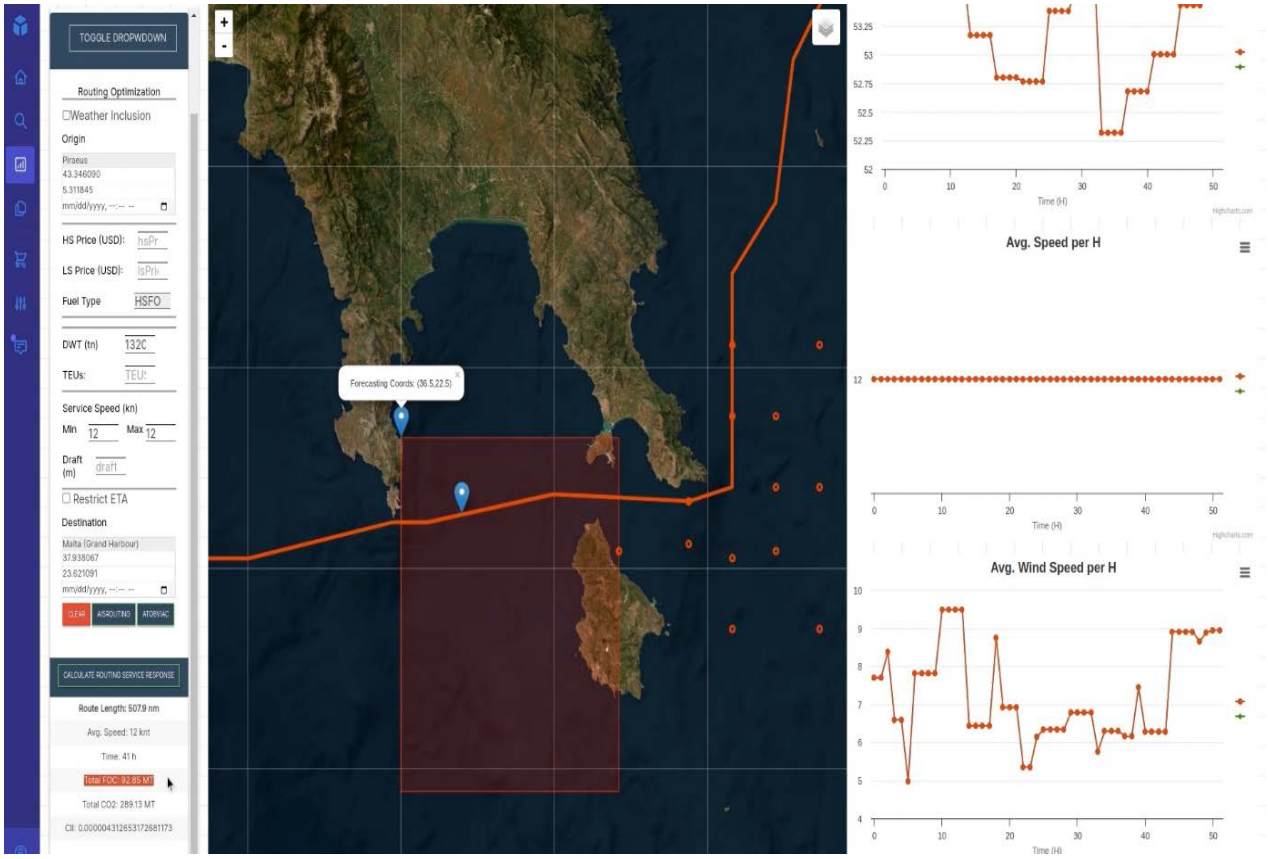


Figure 11. Voyage Performance monitoring

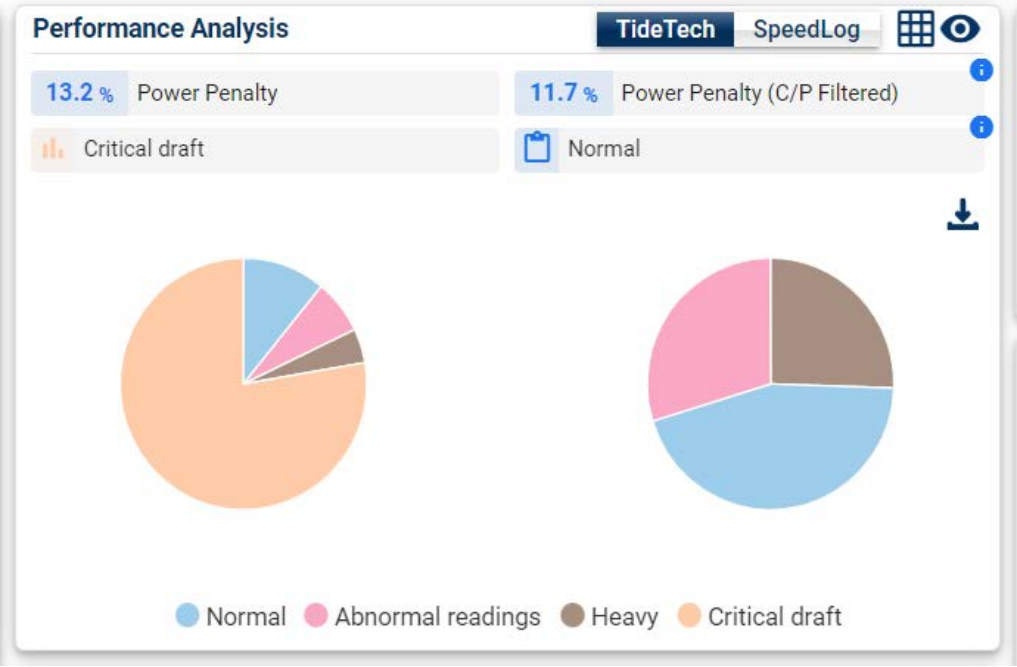


Figure 12. Performance analysis based on data recordings on vessel energy consumption. Anomaly detections of power readings trigger decision-making for corrective actions

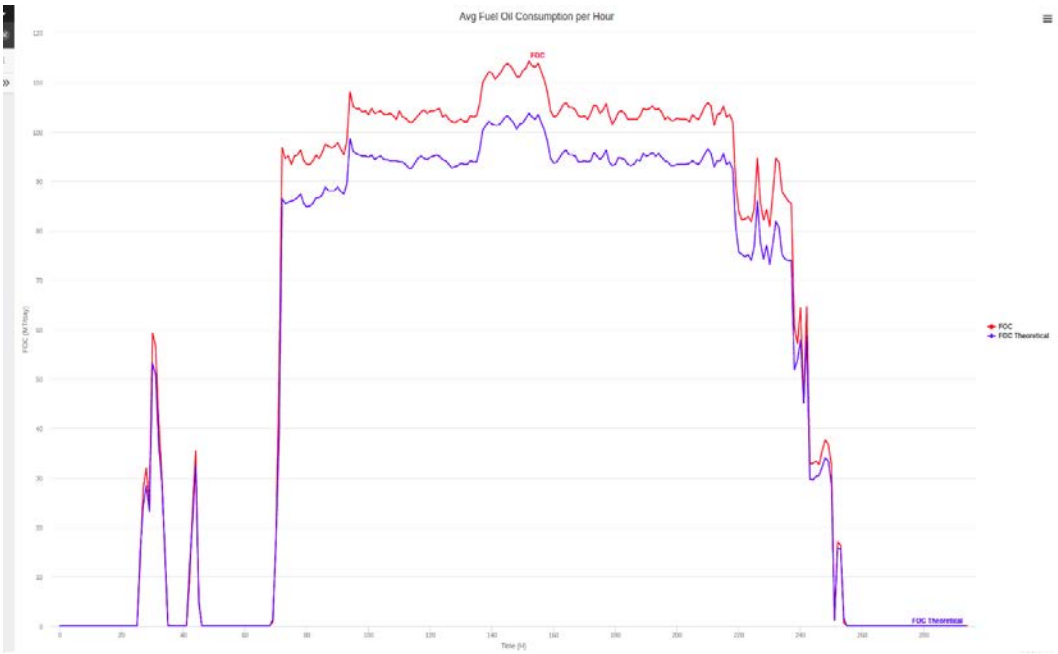


Figure 13. Report of fuel consumption deviations for a single voyage

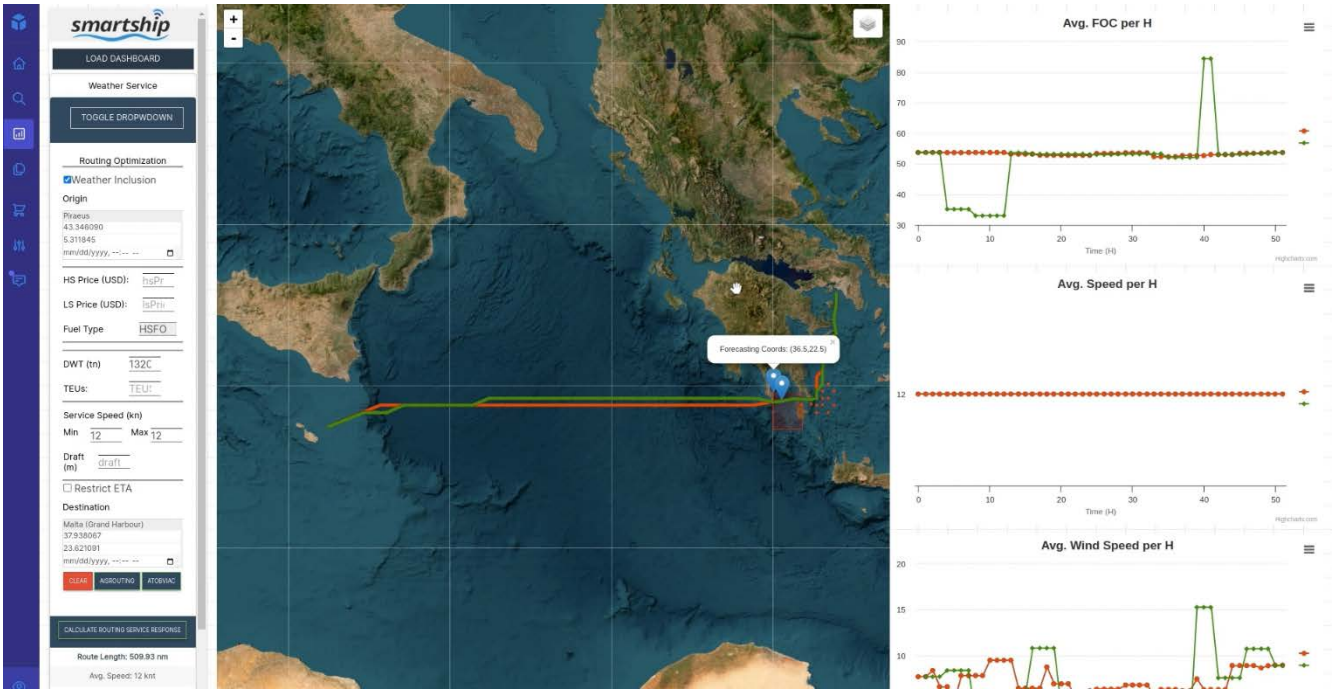


Figure 14. Performance Comparison of Smartship route advice against actual route plotted by the Captain on-board

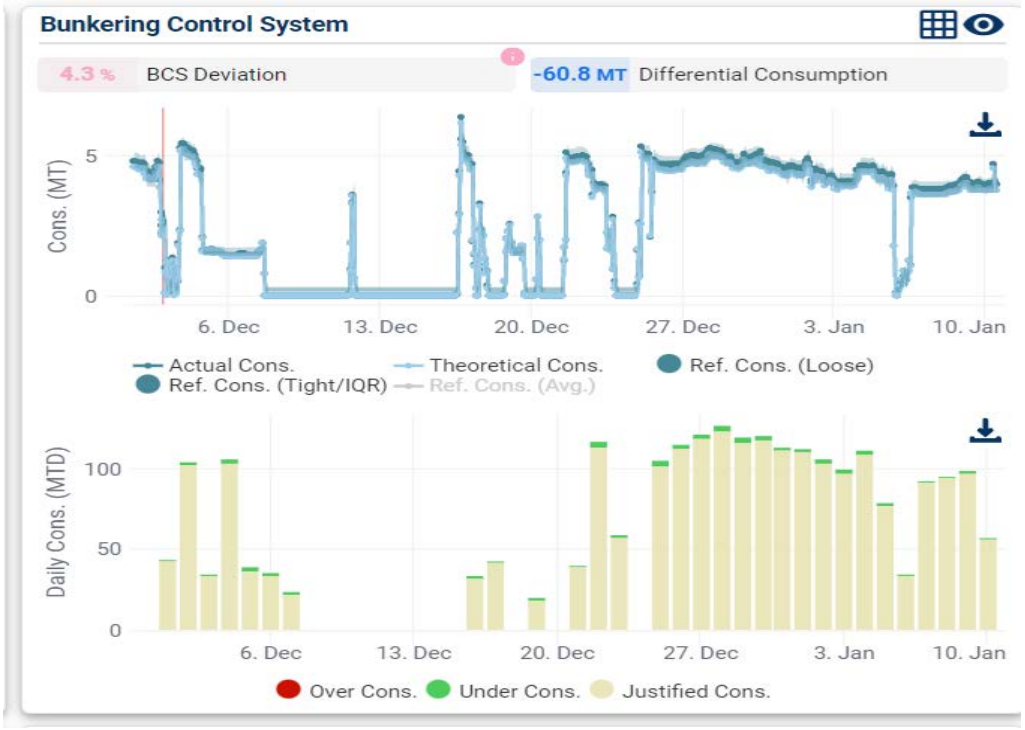


Figure 16. Monitor of daily fuel consumption of a vessel and presentation of recorded deviations from the expected baseline

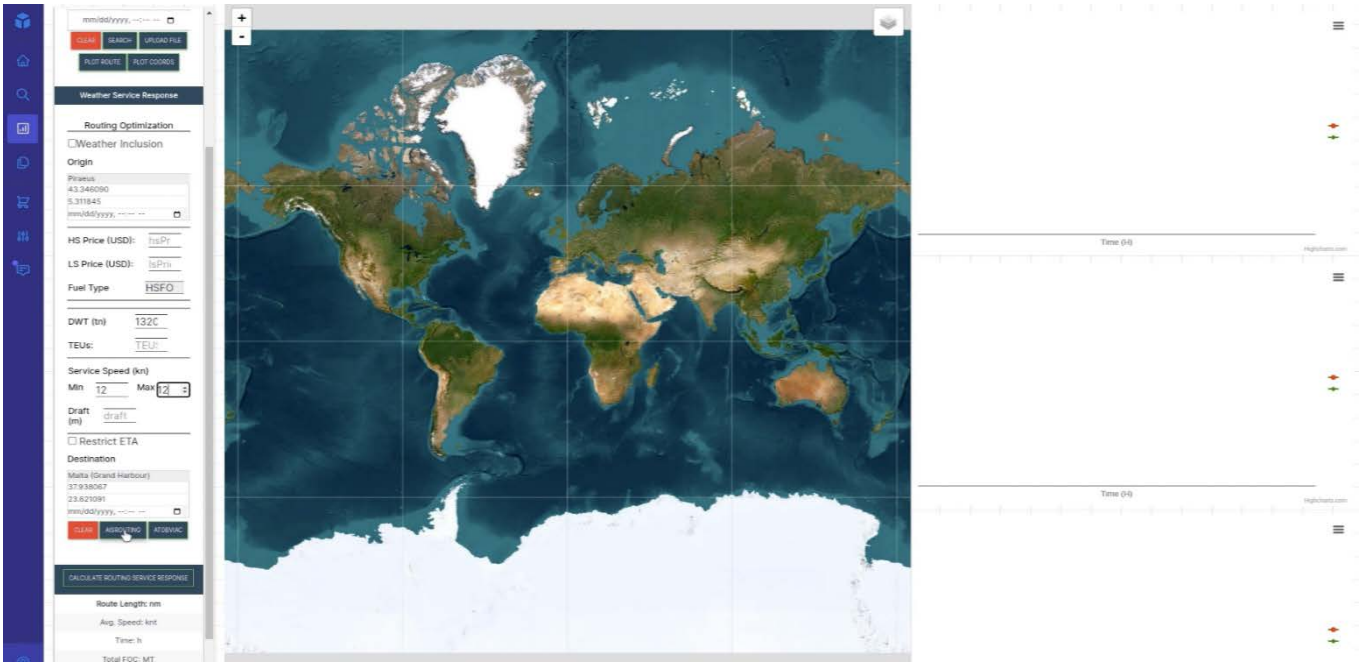


Figure 15. Activating AISROUTING service on the SmartShip landing page

9. ANNEX B. Evaluation Questionnaire

EVALUATION QUESTIONNAIRE

A data analytics, decision support and circular economy – based multi-layer optimization platform towards a holistic energy efficiency, fuel consumption and emissions management of vessels.

D6.2 Report on final pilot design and implementation

The SmartShip project has received funding from the European Union's Horizon 2020 research and Innovation programme under the Marie Skłodowska-Curie Grant Agreement No 823916

Description

SmartShip aims to offer a multi-layer optimization in the fields of fuel consumption, energy efficiency and emissions control management, in full respect to the implementation of the requirements of maritime sector regulations and taking into account applications of circular economy concepts in the maritime as well. Knowledge exchange between the partners that are already involved in the maritime sector, the ICT technology industry partners and the academia partners is one of the major **SmartShip**'s objectives and will be materialised through corresponding secondments during the whole project's timeplan. **SmartShip** will capitalise on available COTS technologies and will deliver an ICT & IoT-enabled holistic cloud-based maritime performance & 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.

Reviewer

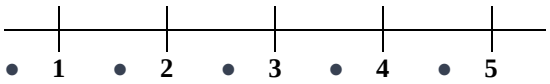
"Please tick the box next to your position"

Technical Manager	
RnD Manager	
Captain	
Operation Manager	
Fleet Manager	

Value attribute -1-: Interactivity

Please grade the interactivity and responsiveness of the integrated SmartShip system by assigning a score on a scale of 1 (minimum) to 5 (maximum).

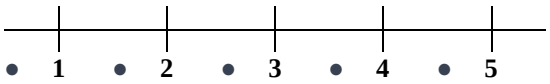
(1-Very Low, 2-Low, 3-Medium, 4-High, 5-Very High)



Value Attribute -2-: User Friendliness

Please grade the user friendliness of the integrated SmartShip system by assigning a score on a scale of 1 (minimum) to 5 (maximum).

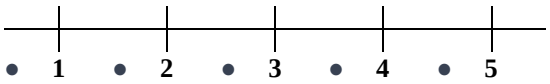
(1-Very Low, 2-Low, 3-Medium, 4-High, 5-Very High)



Value Attribute -3-: Richness of information and data

Please grade the availability of data offered by the integrated SmartShip system by assigning a score on a scale of 1 (minimum) to 5 (maximum).

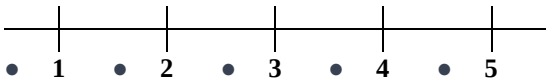
(1-Very Low, 2-Low, 3-Medium, 4-High, 5-Very High)



Value Attribute -4-: Accuracy of Results

Please grade the accuracy of results generated by the intergrated SmartShip services by assigning a score on a scale of 1 (minimum) to 5 (maximum).

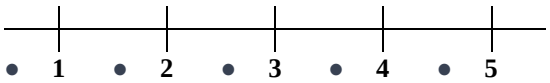
(1-Very Low, 2-Low, 3-Medium, 4-High, 5-Very High)



Value Attribute -5-: Overall Experience

Please grade the overall experience from your interaction with the integrated SmartShip system by assigning a score on a scale of 1 (minimum) to 5 (maximum).

(1-Very Low, 2-Low, 3-Medium, 4-High, 5-Very High)



Please share your comments and remarks

"Type free text HERE"

Please share any recommendations for future improvements

"Type free text HERE"