Decarbonization and Efficiency: the potential of digital fleet management

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Abstract. Never more so than during the Covid-19 pandemic, technology has shown its potential to avoid or minimise business disruption to the maritime industry. Digitalization is playing a key role in being resilient and efficient, while remotization is the new normality in everyday work. Being able to transfer such technologies to the shipping sector and use them to take data driven decisions, enhance regulatory compliance and monitor the asset life cycle can give to owners and shipping companies real advantages in overcoming the new challenges the business faces.

In the actual and near future, one of the major challenges that the marine sector must face is represented by the global decarbonization targets, which will impose strong changes to the whole shipping sector. Due to these ambitious targets, every shipping company will be forced to work on three main pillars: new fuels, new technologies, optimized operational measures.

Fleet performance management and digitalization play a key role in the optimization of the operational measures: monitoring efficiency, proving, and ensuring compliance with the upcoming regulations and optimizing reporting operations on board.

With the upcoming regulations, it will become even more important to always know how a vessel is performing, being capable of simulating the ship's behavior in different operational conditions and reduce the carbon footprint of a fleet by deploying the whole fleet in the most efficient way. When the vessels emissions need to be reduced as much as possible, the focus should be on how collect the information on board, ensure that the information is reliable and have tools to manage such data and enhance decision making.

This paper will explain the importance of data and how digital tools are starting to permeate the life of the shipping companies, helping both onboard and ashore personnel in enhancing operations: from electronic logbooks to live monitoring of scrubber systems, from collecting data on board to building the hydrodynamic digital twin of the vessel to be used in weather routing applications.

Keywords. Digital, operations, efficiency, decarbonization, sensors, data

1. Introduction

Since 2020, the pandemic has boosted an already existing situation where technology and digital were becoming an increasingly important part of the shipping sector. As an example, MEPC.314(74)[1] had introduced the concept of electronic record books that can be used instead of the paper version. However, the spread of the coronavirus accelerated digital transformation tremendously; it forced Companies and Classification Societies to find alternative ways to stay close to the asset, with remote inspections and other means to being closer to the vessel through data live streaming and remote monitoring.

The maritime sector has been under the spotlight for environmental regulations trying to assess and reduce the carbon footprint of the market for several years. In April 2018 the International Maritime Organization, IMO, adopted an initial strategy aimed at reducing total annual GHG emissions by at least 50% by 2050 compared to the 2008 level, IMO (2018)[2]. As part of the short-term measures of the strategy, IMO adopted resolution

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MEPC.328(76) in June 2021 introducing amendments to MARPOL Annex VI with new requirements for:

- Energy Efficiency Existing Ship Index (EEXI)
- Operational Carbon Intensity Indicator and CII rating

The new focus is now not only on how vessels are designed (EEDI, EEXI), but also on how vessels are operated (CII). This situation exploits the need of shipowners to continuously keep under control the vessel's energy efficiency and optimize the operations, being able to adopt correcting actions on time.
Digital is already playing a key role as it provides the tools to make informed decisions in marine business and vessels operations; in the following chapters information about data collection techniques and analysis together with digital tools will be provided.

2. Data collection

Even if the exponential advancement in data analytics techniques and machine learning algorithms of the last few years has made it easier to shipping companies to widen their analytical capabilities, no analysis can be performed and no decisions can be taken on unreliable or insufficiently detailed data; therefore on-board data collection and data pre-processing has a central role in the whole process.

2.1. Automatic data collection

Automatic data acquisition systems are typically composed of hardware and software modules, capable of acquiring data continuously from the ship navigation and automation systems or directly from sensors, capable of processing those data advising in real time personnel on board and ashore on performance optimization and/or safety issues.

RINA has developed a tool that foresees the installation of an industrial PC with Linux OS configured on the ship network, connected to ship navigation and automation systems or directly to sensors if required (high precision inclinometers, torque meters, flow meters, …).

As per **Figure 1.** the data collector acquires measurements at customizable sampling frequencies, it filters and processes the data and stores them in a database with a standard aggregation rate of 5 minutes. Then the data is live streamed to shoreside, where the information from all the vessels are visible in real-time, stored and made available for advanced analysis to the ashore operators.

The onboard system also performs data enrichment using external data sources, adding weather data from provisional models or information coming from crew manual inputs such as drafts, displacement, and any other kind of data not automatically available.

The signals from the navigation system are expected in NMEA standard - Serial line RS422, to the nearest LAN plug of ship network on the bridge.

- ZDA: Date and Time
- GGA: Geographic Position (or GLL)
- VTG: Track and ground speed
- HDT: Heading True
- VBW: Water Speed
- MWV: Wind Speed and Angle
- RTE, WPL: Route and waypoint from ECDIS

The required signals from the automation system are expected in NMEA or Modbus standard - Serial line RS422/485 directly to the industrial PC.

- Shaft(s) torque

- Shaft(s) RPM
- Shaft(s) power
- Propeller pitch (if CPP)
- Shaft generator(s) power (if available)
- Main Engine(s) Fuel Consumption
- Draft aft / Draft mid / Draft fore (if available)
- For each DG: status/power/fuel consumption
- Boiler status, Boiler fuel consumption (if available)
- Fuel in use/Temperature and specific gravity of fuel (if available)

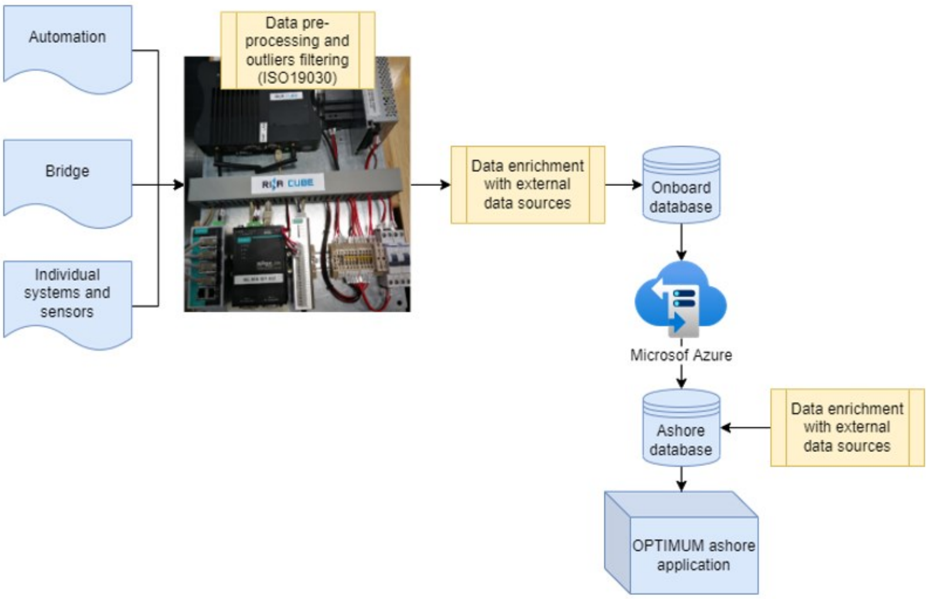


Figure 1. RINA CUBE OPTIMUM data acquisition process

2.2. Ensuring data quality

The data collector software pre-processes the data filtering and detecting outliers as per Annex I and Annex J of ISO 19030-2 (2016) [4], before each 5 min data point is created. This pre-processing activity is in any case not sufficient to ensure a high data quality.

The continuous sensors and data maintenance is responsibility of the shipping company and recognizing implausibility of the data usually creates a major procedural challenge for the operators; it is important to highlight that in case an anomaly is identified, the data records cannot be trusted and used for analysis until the issue with the sensor has been solved as often the error on the measured quantity is higher than the optimization potential.

To ensure data quality a process should be in place in the company to ensure prompt reaction and intervention:

- Definition of automatic alerts generated by the performance system
- Regular data analysis to spot data implausibility that the automatic alerting system may have missed
- Once the issue has been identified and confirmed also on vessel's side, quick onboard intervention planning for sensor's calibration or substitution

The ashore systems should provide proper tools to allow the operator to easily perform the first two points of the list.

3. Using data to monitor and optimize operations

3.1. Realtime monitoring

Realtime monitoring of vessels operations breaks barriers and enables the cooperation of several stakeholders at the same time; remote inspections from Class Society, remote support from a system provider, remote support of ashore personnel and continuous collaboration with the onboard team can be mixed to fit the specific needs.

For example, to handle complex systems that are meant to ensure compliance like scrubbers (example in **Figure 2.**), being able to monitor, assist the vessel and act on time is of paramount importance.

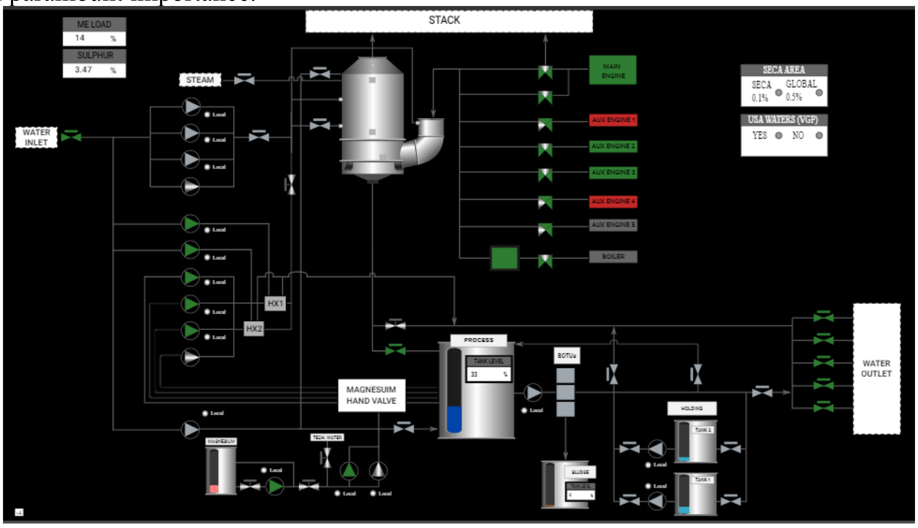
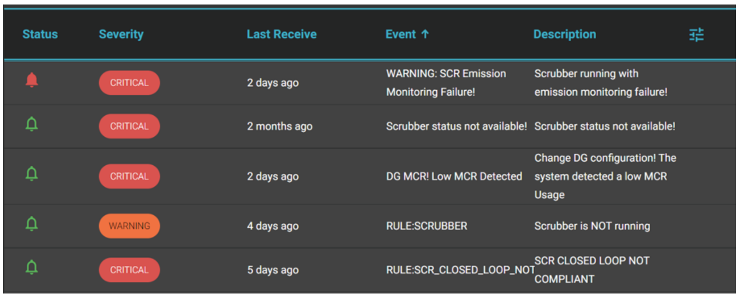


Figure 2. Remote monitoring of hybrid scrubber system

On the other side, performance monitoring increases transparency between ship and shore or between business partners and it becomes a key to unlock hidden energy saving potential. Transparency also affects and improves crew behavior, increasing their awareness and leading to better vessel operations and consequent fuel savings, Köpke and Catarino (2012) [3].

An important role in performance monitoring is covered by alerting capabilities that allow not only to detect missing data or data implausibility, but also to help both the ashore and the onboard operators to enhance efficient vessels operations and regulatory compliance.

Figure 3. shows some alerts that have been generated on a container vessel. When an alert is generated, the system sends emails both onboard and ashore, warning the users about critical situations.



Status	Severity	Last Receive	Event ↑	Description
	CRITICAL	2 days ago	WARNING: SCR Emission Monitoring Failure!	Scrubber running with emission monitoring failure!
	CRITICAL	2 months ago	Scrubber status not available!	Scrubber status not available!
	CRITICAL	2 days ago	DG MCR! Low MCR Detected	Change DG configuration! The system detected a low MCR Usage
	WARNING	4 days ago	RULE:SCRUBBER	Scrubber is NOT running
	CRITICAL	5 days ago	RULE:SCR_CLOSED_LOOP_NOT	SCR CLOSED LOOP NOT COMPLIANT

Figure 3. Generated alerts on a containership

The alerting system has proven great results in changing onboard habits, for example it was successfully implemented to monitor and correct inefficient Diesel Generators usage; in general, the crew tends to stay on the “safe side” keeping more than one DG running at low MCR, thus causing unjustified fuel consumption. The alert, that detects the number of DGs running and their MCR, has been implemented in two different company: one small ferry company after the full fleet was installed and one big containership company where number of vessels installed with the monitoring system was still growing.

Both situations have shown good results, in the first case the number of generated alerts decreased over time as visible in **Figure 4.**, while in the second case the number of alerts generated became stable over time even if the number of installations was growing as shown in **Figure 5**.

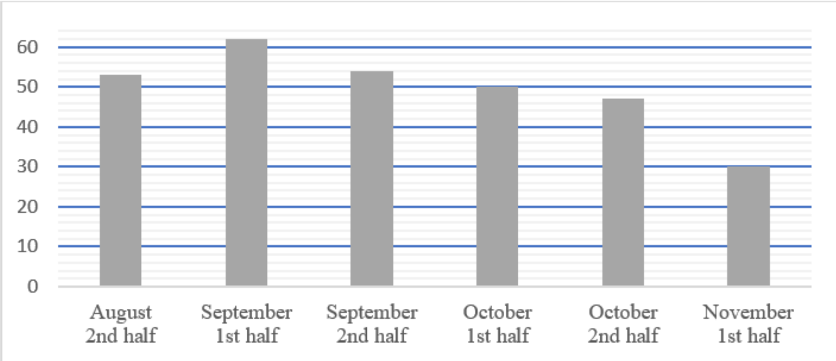


Figure 4. DG MCR usage alerts generation over time

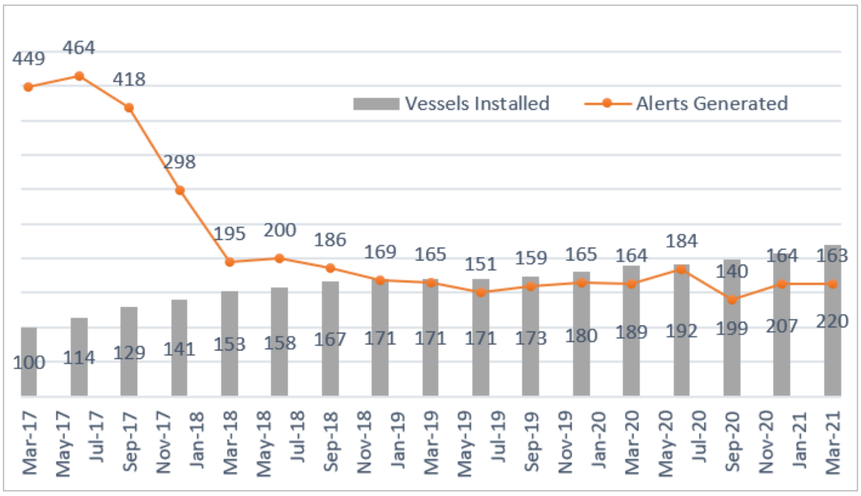


Figure 5. Vessels installed VS alerts generated

3.2. Noon reports or automatic data collection

Historically, noon reporting has been the mean of collecting data from the vessels, manual data input is the core of this methodology that foresees data aggregated daily, covering different vessel operations. On the other hand, onboard automatic data logging is implemented on more and more vessels every day.

Due to the change of market conditions and to new regulations vessel's operational profiles could change, for example after engine power limitation or speed reduction, and several vessels are found to be inefficient in the new sailing conditions.

In this case study, it will be described how RINA performed a performance analysis as a third party of a reblading intervention on a ferry, due to a new operational profile (speed reduction). The new operational speed range was 18-22kn, and the contractual conditions imposed to consider only wind states below 4 Beaufort scale.

A monitoring campaign on the vessel was carried out before (two months) and after (three months) the propeller installation to assess the increase in the propulsion efficiency in the contractual speed range. The long-term assessment is considered to be more reliable than the single point assessment based on speed-power seatrials, as it comes from the analysis of several voyages and is able to consider different sailing conditions, allowing to filter out data affected by excessive weather.

To collect the data, an automatic data acquisition system was installed, and, at the same time, the deck officers continued to manually report data inside the standard vessel noon reporting system. Among the other parameters, the following information were recorded for each voyage:

- Wave height [m] and direction of waves [deg]
- Absolute wind speed [kn] and direction [deg]
- Current speed [kn] and direction [deg]
- Displacement [t]
- Draft aft, midship and fore [m]
- Propulsive power [kW]
- Consumption per hour [kg/h]

As per **Figure 6.** to perform the analysis after the monitoring campaign the data has been duly pre-processed and filtered taking into considerations contractual conditions.

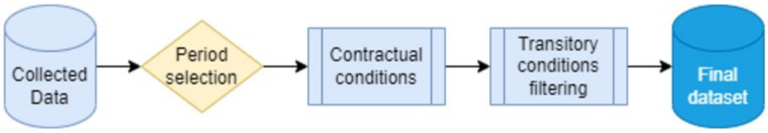


Figure 6. Data filtering process

As agreed in the contract, to reduce as much as possible any bias in the data, the points with reported weather conditions greater than Beaufort scale 4 (or Douglas scale greater than 2) were excluded from the analysis.

The measured shaft power has also been corrected based on the Admiralty Formula to refer the results to the same reference displacement (in a maximum displacement range of ±2%):

$$P_S = \frac{\Delta^{2/3} \cdot V^3}{K}$$

Where P_S is the shaft delivered power, Δ is the ship's displacement, V is the ship's speed and K is the Admiralty coefficient.

The improvement in propulsive performance of each ship before/after dry-dock intervention was calculated in percentage as:

$$\text{Propulsion\_Gain [\%]} = \mathbf{100} \cdot \left(\mathbf{1} - \frac{\boldsymbol{P_{S\_AFTER\_RB}}}{\boldsymbol{P_{S\_BEFORE\_RB}}}\right)$$

The data have then been plotted into SOG [kn] – Propulsive Power [kW] scatter diagrams with a cubic polyfit.

Figure 7. shows the results of the intervention on both datasets; the picture on the left represents the results obtained on data collected manually, while on the right the results on data automatically collected on board is presented.

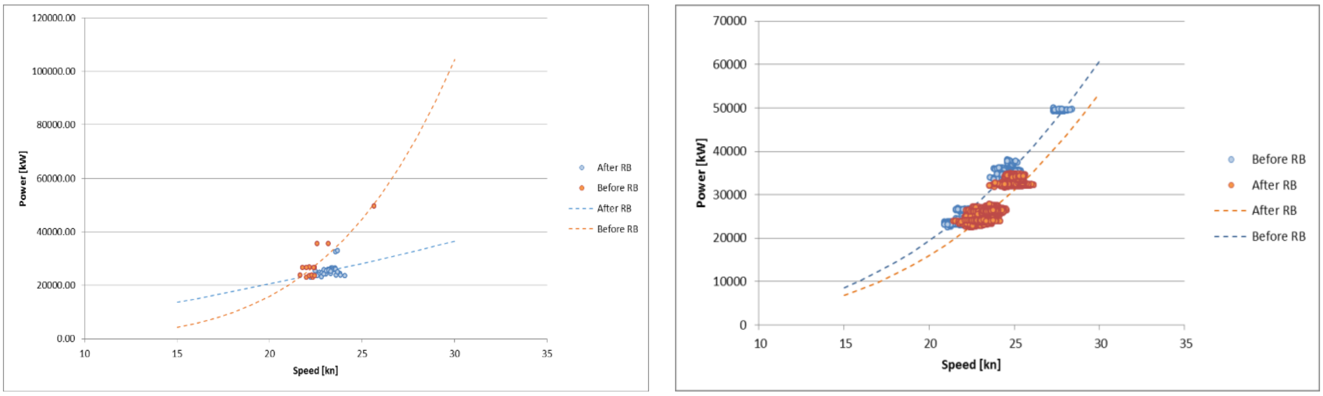


Figure 7. Noon reports VS automatic data acquisition results

As a result, with noon report data it was not possible to access the gain of the intervention, while on data collected automatically it was possible to certify an overall improvement in the hydrodynamic efficiency of about 17% in the speed range of 18-22 knots (as shown in **Table 1**.).

Speed [kn]	Propulsive Power Before [kW]	Propulsive Power After [kW]	Saving [%]
18	11727	14431	18.7%
19	13766	16805	18.1%
20	16028	19414	17.4%
21	18522	22270	16.8%
22	21261	25382	16.2%

Table 1. Before and after intervention propulsive power

The gains in terms of fuel consumption were not fully reflecting the power gain, as the intervention ensured a saving of about 11% in fuel consumption over the analyzed period.

4. Conclusion & Discussion

Different examples of how digital can help improve vessel's operations and performance monitoring have been presented in this paper. The case study has also shown how collecting data automatically and systematically allows to easily prove the effectiveness of retrofitting interventions in terms of energy efficiency. Having the opportunity to show in numbers the gain of an intervention has not only technical benefits as exposing such values publicly could also bring to the company benefits related to the social image of the company.

The paper proved the importance of digital in guiding human interventions, increasing crew awareness on efficient operations. It is important to remember that crew has limited time for voyage evaluation of optimization, furthermore energy efficiency is in general secondary to safety on board. For these reasons, onboard operators need to be assisted and supported by easy digital systems in operating the vessel in the most efficient way.

It is important to note that even if the benefits of implementing such systems have been widely proven, not all shipping companies have the correct mindset yet. We often find several barriers in the implementation of digital solutions: availability of sensors, bandwidth costs, concerns about cyber-attacks, lack of uniform technological standards throughout the industry, lack of human resources.

Those barriers are anyhow slowly falling in the market, mostly thanks to the reporting and monitoring regulations introduced by IMO and EU overtime, that stress to shipowners the importance of understanding and monitoring the carbon footprint of their vessels.

References

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