The Average Operational Profile of Large Yachts

Author: Water Revolution Foundation | 6 April, 2022

This research has been conducted in support of the development of the Yacht Environmental Transparency Index (YETI) by a Joint Industry Project (JIP) organised through Water Revolution Foundation. YETI is the result of an extensive collaboration between renowned shipyards, naval architecture studios and research institutes, and offers a systemic, data-driven approach to assess and compare the environmental performance of large yachts, and is the result of extensive collaboration between renowned shipyards, naval architecture studios, and research institutes. A shared motivation to educate on and visualize impacts and solutions has driven their efforts to develop this tool and formed the basis for the research presented below.

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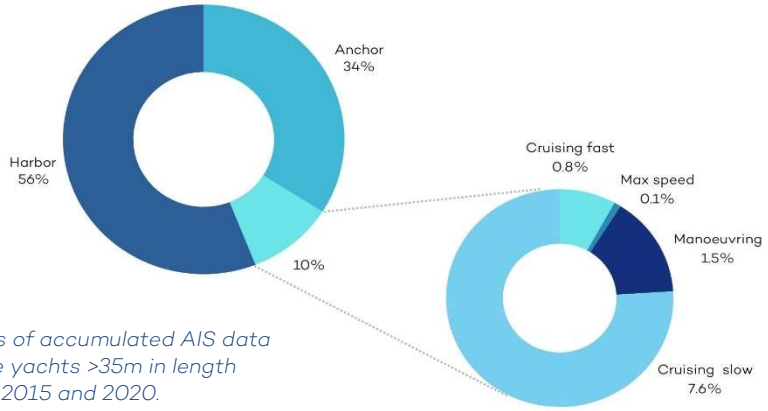
1. Abstract

Determining the average operational profile of large yachts was needed to define a benchmark profile for large yachts to be assessed on, using the Yacht Environmental Transparency Index (YETI) method. A set operational profile allows for yachts of various type, make and age to be compared, resulting in a comparison of naval architecture and installed systems, rather than owners' behaviour.

This YETI sub-study found that:

- Most yachts are designed for a top speed (hull speed, Fn approx. 0.34) that is rarely utilized, leading to overpowered vessels and engines that do not operate efficiently;
- Yachts move 10% of the time in a year;
- Yachts are stationary 90% of the time in a year, of which 56% in port, leaving 34% of time sitting at anchor;
- Advice: Design more closely to actual cruising speeds, ensuring safety and reliability while minimizing material usage, fuel consumption, and maintenance needs.

*Figure 1: Operational Profile of a Yacht**



**Based on 297 years of accumulated AIS data from 109 diverse yachts >35m in length between 2015 and 2020.*

2. Background

In March 2019, key industry players, including prominent shipyards and naval architects, convened in The Netherlands to launch a joint industry project aimed at developing the Yacht Environmental Transparency Index (YETI). Spearheaded by Feadship - De Voogt Naval Architects, this initiative sought to establish a standardized rating system for assessing the sustainability of superyacht designs, encouraging the industry to prioritize environmental considerations alongside economic ones. Water Revolution Foundation (WRF), an entity dedicated to reducing the superyacht industry's environmental footprint, played a facilitative role in this endeavor. YETI aims to provide for better decision making by clients, taking into account the unique operational characteristics of superyachts that traditional environmental impact assessments, such as EEDI, often overlook. The project emphasizes the importance of considering actual operational profiles, including sailing hours, but also when yachts are stationary only running the hotel function, to truly gauge and improve large yachts' environmental performance. To support this comprehensive assessment, three working groups were formed to address different facets of the project, with a call for extensive data collection on yacht operations to inform the index.

3. AIS Data

The initial YETI operational profiles were based on estimates of sailing, harbor, and anchoring times, plus a set cruising speed at 40% of the Maximum Continuous Rating (MCR), from which annual fuel consumption was calculated. This raised questions about the validity of these assumptions across a broader yacht spectrum. To address this, the YETI group utilized Automatic Identification System (AIS) data, initially analyzed by Feadship, a key YETI participant. Feadship's development of the 7Seas platform, which integrates AIS with meteorological data for comprehensive operational analysis, marks a pivotal advancement in understanding yacht behaviors.

AIS, an essential maritime navigation exchange system, mandated by the

International Maritime Organization (IMO) since 2004 for significant vessels, enables the electronic sharing of vessel information. This system, integrating GPS for precise tracking, facilitates the analysis of dynamic and static ship data.

Global AIS Data

YETI's research incorporated AIS data from 130 yachts, of different type, make and age, and spanning up to five years, to define operational modes like sailing, at harbor, or anchoring, based on movement speeds and geographical perimeters. This analysis provided detailed insights into yacht operations, including time allocations and speed patterns, visualized through charts and global mapping of yacht trajectories. This data, coupled with individual yacht identifiers like IMO and MMSI numbers, allowed for an aggregated and yet detailed examination of yacht operational profiles, laying the groundwork for further development and refinement of the average operational profile as benchmark for the YETI project.

The verification of AIS data, conducted with the Maritime Research Institute Netherlands (MARIN), identified several issues affecting data accuracy, including distortions from yard MMSI numbers used during builds and sea trials, the impact of maiden voyages, data ranges under one year, and significant data gaps. To address these, the analysis was refined by excluding yard MMSI data and maiden trips that did not reflect typical operational profiles, and by marking or removing data sets with substantial gaps or those under one year without 90% uptime. This meticulous data cleansing led to a refined set of AIS data for 109 yachts, encompassing 289 years of operational information. This dataset, reflecting a mix of yacht types and incorporating various yacht characteristics, forms the basis for further research into yacht usage and speed profiles.

4. Use of a yacht

The study aimed to answer three key questions about yachts' operational profiles: the distribution of moving versus stationary times, their typical speeds while moving, and the relationship between ship characteristics and operational times. It quantified Sailing

Time (ST), Anchor Time (AT), and Harbour Time (HT) as percentages of total uptime, easily convertible to annual hours for consistent analysis.

4.1 Sailing Time (ST)

The study found no direct link between a yacht's Sailing Time (ST) and its type, noting considerable variability in the data. On average, ST is around 10%, with a standard deviation of 5%, indicating wide differences in sailing habits. However, trends suggest that larger yachts tend to sail more, while those with higher cruise speeds (Fn-cruise) sail less. The reasons behind these observations are not immediately clear.

Figure 2: LOA vs. Sailing Time

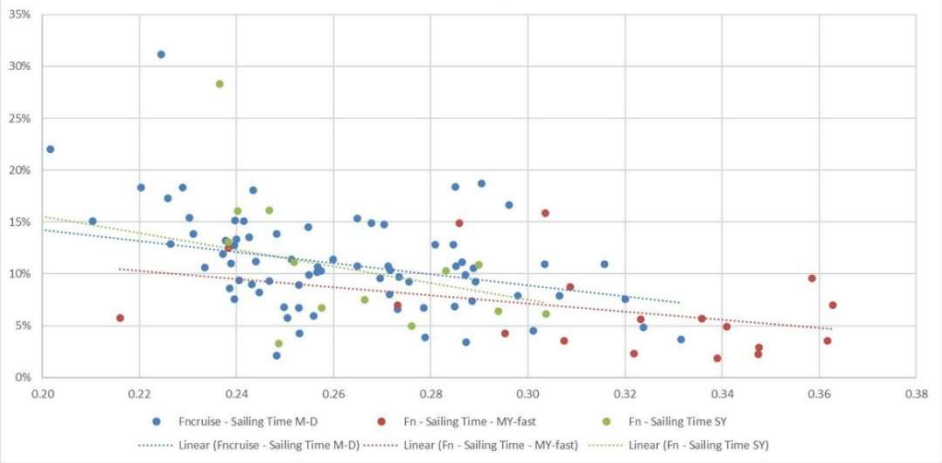
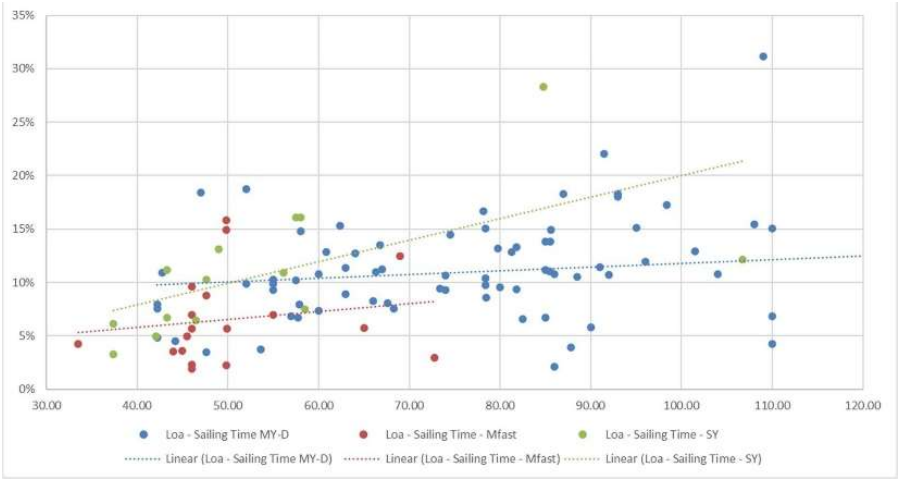


Figure 3: Fncruise vs. Sailing Time



The data indicates a wide range of sailing activity among yachts, from those that rarely sail to those that are highly active, potentially used for chartering. Since the intended use of a yacht, such as chartering, is often undecided at the design stage, it poses a challenge for predicting its operational profile. To address this, two methods for defining Sailing Time (ST) in the operational profile are proposed: either use the average ST of

10% or adopt the trendline from graphs showing ST in relation to cruise speed (Fn-cruise) or length overall (Loa).

4.2 Harbour Time (HT)

The analysis of Harbour Time (HT) reveals an average of 56% with a standard deviation of 18%, showing significant variability. No clear correlation is found between HT and the yacht's maximum Froude number (Fn-max), though there's a slight trend linking HT with both the cruising Froude number (Fn-cruise) and the yacht's overall length (Loa), despite considerable data scatter.

Figure 4: LOA vs. Harbour Time

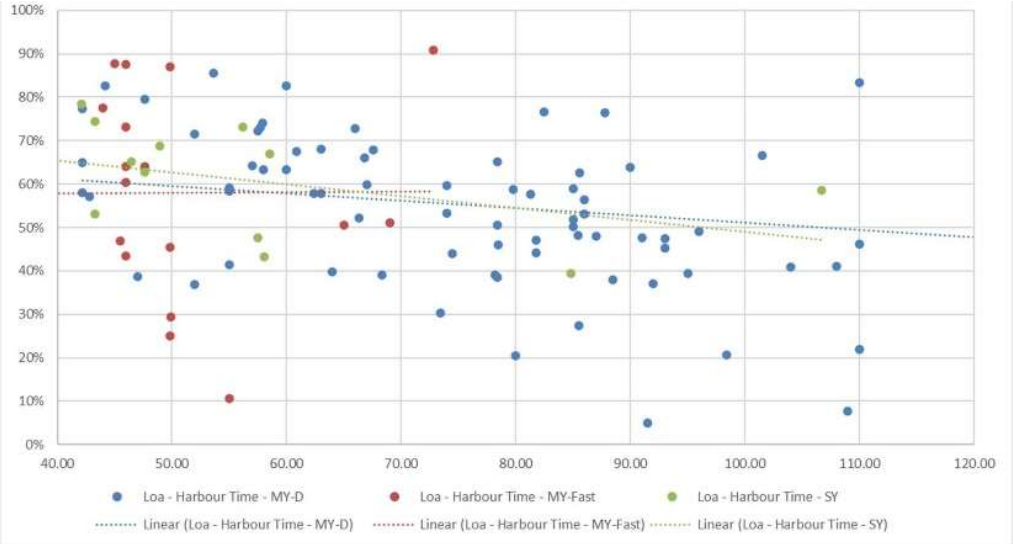


Figure 5: Fnmax vs. Harbour Time

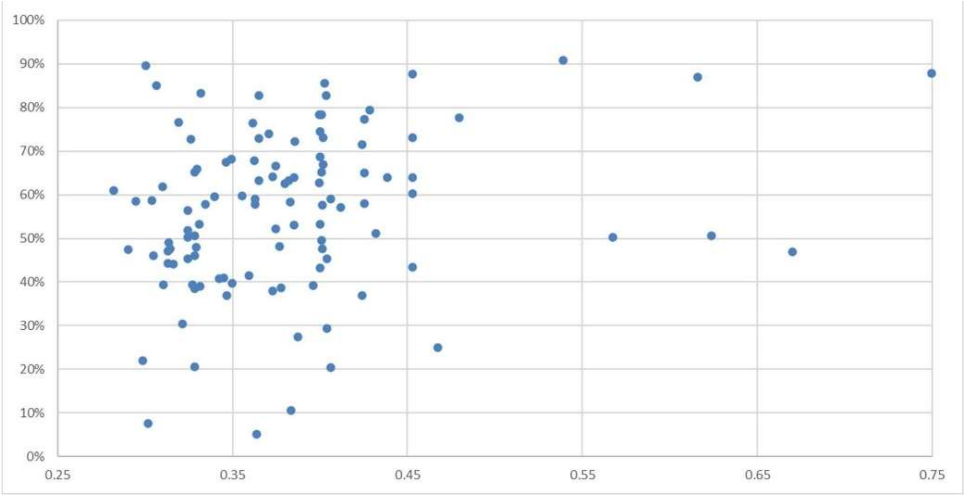
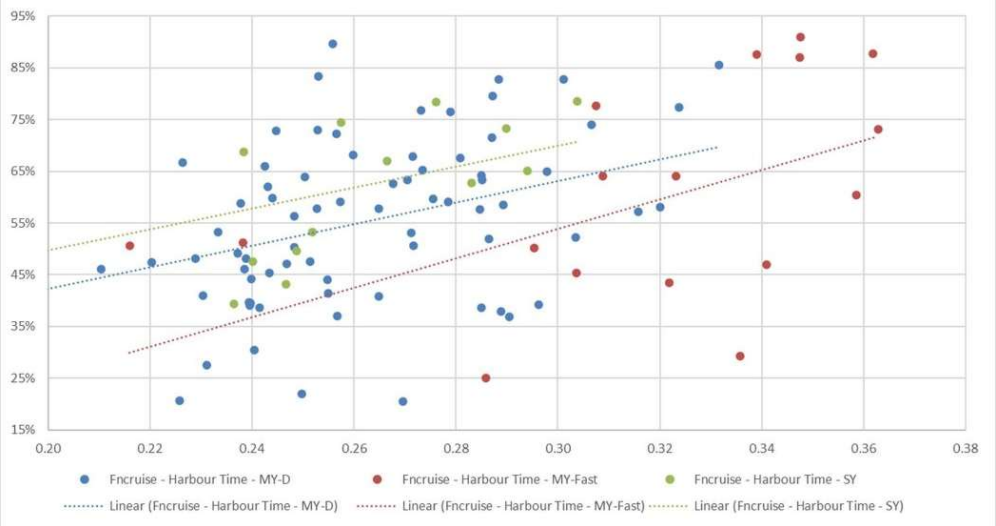


Figure 6: Fncruise vs. Harbour Time



To define HT in the operational profile, two approaches are suggested: either using the average HT of 56% or employing the trendline derived from HT's relationship with Fn-cruise or Loa.

4.3 Anchor Time (AT)

For Anchor Time (AT), the data doesn't show a clear trend, and attempting to define AT based on the cruising Froude number (Fn-cruise) or other variables poses a risk of the sum of AT, Harbour Time (HT), and Sailing Time (ST) exceeding 100%. Thus, the most practical approach is to calculate AT as the remainder: AT = 100% - (ST + HT).

4.4 Influence of yacht type

The study categorizes yachts into three types: displacement, sailing, and fast yachts, with speed evaluated using the Froude number (Fn), a crucial hydrodynamic metric for understanding a vessel's resistance and wave-making capabilities. Displacement yachts are typically slower, with a maximum Fn of 0.34, while fast yachts exceed an Fn of 0.43. The analysis notes potential correlations between yacht types and their operational usage, but limitations in data for sailing (14 yachts) and fast motor yachts (18 yachts) preclude definitive profiles for these categories.

$$\mathrm{Fr} = \frac{u}{\sqrt{gL}}$$

Despite observing some relationship between a yacht's cruise speed (Fn) and its usage, the variance is significant, and the dataset's breadth insufficient for conclusive analysis. Consequently, the Working Group opted to standardize the operational profile across all yacht types based on average usage rates—Sailing Time at 10%, Harbour Time at 56%,

and Anchor Time at 34%—acknowledging the data's scatter and gaps. This decision, made to accommodate the current data limitations, is open for future reassessment as more comprehensive data becomes available.

5. Conclusion

The study concludes that most yachts are designed for a top speed (hull speed, Fn approx. 0.34) that is rarely utilized, leading to overpowered vessels and engines that do not operate efficiently, resulting in increased maintenance and quicker overhauls. Unlike commercial cargo vessels, which are designed for efficiency and safety, yacht propulsion systems are often optimized for a speed that is seldom reached, contributing to unnecessary consumption, maintenance, and a reduced lifespan for the propulsion system. The recommendation is to align yacht design more closely with actual cruising speeds, ensuring safety and reliability while minimizing material usage, fuel consumption, and maintenance needs. This approach would not only extend the lifespan of yacht propulsion systems but also contribute to the creation of more environmentally friendly yachts.

Sources

AIS data purchased from Astra Paging Ltd in Aug 2020

https://help.marinetraffic.com/hc/en-us/articles/204581828-What-is-the-Automatic-Identification-System-AIS (Consulted on 05/04/2022)

https://www.vesselmarinefinder.com/2013/07/mmsi-number-search.html
(Consulted on 05/04/2022)

Annex (informative):

Speed Profile Graph

The following figure reproduces the speed profile graph developed within the YETI project. It is based on AIS data analysis of large yachts and illustrates the distribution of yacht speeds correlations with their lengths.

Figure A1: Speed vs. Length