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Evaluating Ecodesign Methodology in Yacht Design: A Professional Workshop Case Study

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Abstract: The yachting industry faces increasing pressure to adopt sustainable practices driven by regulatory requirements and evolving consumer expectations. This study explores the application of Life Cycle Design (LCD), also referred to as ecodesign, methodologies within yacht design to address environmental challenges. Despite the critical importance of early-stage design in determining a product's environmental impact, the yacht sector lacks industry-specific sustainability guidelines.This research investigated the practical implementation of a generic LCD methodology - specifically the MPDS (Method for Product Design for Environmental Sustainability) - through an intensive workshop involving young professional yacht designers. Participants were tasked with developing concept designs for a 50-foot charter yacht, applying six LCD strategies: use extension, material consumption reduction, energy consumption reduction, material life extension, toxicity reduction, and resources conservation.The study outlined both opportunities and limitations in applying MPDS to yacht design. While participants achieved incremental improvements in certain strategies, the research highlighted the need for context-specific adaptations. Challenges included the methodology's generic nature and the complexity of yacht design processes.The findings underscore the potential of LCD principles in promoting sustainability within the nautical industry and provide a foundation for developing tailored guidelines that can effectively integrate environmental considerations into yacht design processes.

Introduction

The yachting industry has experienced remarkable growth in recent years, driven by the increasing demand for luxury vessels and an expanding global market (Yücenur, 2021; Montigneaux & Mower, 2023). However, this trend is accompanied by regulatory scrutiny and evolving consumer expectations. Stringent European and international regulations, such as the Paris Agreement (2016) and the International Maritime Organization (2023), have underscored the pressing need for sustainable practices across the sector (Jacquet et al., 2024). Beyond regulatory pressures, consumer demand for environmentally responsible luxury products has risen significantly, with sustainability becoming a relevant factor for modern yacht shipyards (Ansaloni et al., 2024; Liang & Birmingham, 2024).

The design stage is critical in determining a product's environmental impact, with over 80% of its footprint being established at this phase (EU - Directorate-General for Communication, 2020; Stark, 2024; Hauschild et al., 2018). Once a product is introduced to the market, opportunities to mitigate its environmental effects diminish considerably. As such, incorporating environmental considerations into the early stages of product development is essential for achieving meaningful impact reductions (Dahmani et al., 2021; Ahmad et al., 2018).

Current efforts within the yachting industry mainly align with the principles of Green Design, as defined by Ceschin & Gaziulusoy (2021). These efforts often focus on material or component-level solutions, such as exploring alternatives to teak or implementing low/zero-emissions propulsion systems (Liang & Birmingham, 2024). While these measures represent progress, they typically lack a comprehensive approach. A more holistic method, such as ecodesign, could better address the entire environmental impact of the product.

Ecodesign, also referred to as Life Cycle Design (LCD) (Vezzoli, 2018), is described as a systematic approach which considers environmental aspects in design and development to reduce adverse environmental impacts throughout the life cycle of a product

(International Organization for Standardization, 2020).
Although general LCD guidelines are available (Vezzoli, 2018; Ceschin & Gaziulusoy, 2021), the distinct attributes of specific product groups or individual products—such as their materials, manufacturing methods, and resource usage—significantly influence their life cycle impact, requiring customised approaches to address these differences (Chaves, 2008). Only in recent years have these been tailored to specific industries (Vezzoli & Conti, 2019; Yang & Vezzoli, 2024; Plaschke et al., 2019). However, despite the environmental challenges and opportunities within the yacht industry, no comparable guidelines have been designed yet.
The absence of industry-specific guidelines in yacht design presents a significant gap in the application of ecodesign principles. Bridging this gap is particularly difficult due to the complex characteristics of the product, considering the number of customised components, the degree of knowledge involved in production and the engineering-intensive activities (Hobday, 1998).
The aim of this paper is to contribute to addressing this gap by testing generic LCD guidelines in the context of a yacht design workshop. By evaluating their practical application and identifying their limitations, this study aims to generate insights into the specific needs of the yachting industry. The findings are intended to inform future research and guide the development of customised guidelines that can support designers and manufacturers in integrating sustainability into their processes.
In the following section, the structure of the workshop is outlined, detailing the LCD methodology and the tools used. The Results section presents the findings, focusing on the environmental performance of the developed projects and feedback on the use of the LCD methodology. Finally, the last section interprets these results, explores their broader implications for the field, and proposes directions for future research and industry practices.

Materials and Methods

MPDS

The chosen LCD methodology is MPDS (Method for Product Design for environmental Sustainability), developed by the Design and system Innovation for Sustainability (DIS) research unit of the Design Department at Politecnico di Milano (Vezzoli, 2018). The method is coherent with the UNI ISO/TR 14062:2007 norm, which deals with the implementation of environmental aspects in product design and development. MPDS is also flexible, enabling the designers to decide which proposed tools to use according to the specific activity that is being addressed in a given context.

Main phases of MPDS

The integration of MPDS is articulated according to the typical phases of new product development. During the Product Strategic Analysis (and brief) phase, the goal is to identify critical areas and LCD strategies with the greatest potential to reduce the environmental impact of the product being designed. During the Concept Design phase, the focus shifts to guiding concept generation toward environmentally sustainable solutions compared to existing products. In the Product Design (and engineering) phase, attention is directed to refining project details with an emphasis on sustainability relative to current products. To support the design process across the phases, MPDS suggests the use of the open-access ICS (Sustainable Concepts Ideation) toolkit, which integrates functions crucial for qualitative assessment, sustainability design orientation, and improvement comparison.

MPDS Product Strategic Analysis

Within the MPDS, the product strategic analysis phase is structured around three key processes, each one with suggested specific tools to apply.
The first process consists of the assessment of the environmental impact of the standard existing product, using software for complete or simplified LCA and a Checklist for evaluating existing products (ICS). The second process is the definition of environmental design priorities, linked to six LCD strategies:

1. Use extension/intensification.
2. Material consumption reduction.
3. Energy consumption reduction.
4. Material life extension.
5. Toxicity reduction.
6. Resources conservation/biocompatibility.

The design priorities can be visualised using the ESPI form (ICS).
In the last process, a visualisation of the environmental design priorities is created through the Multi-strategy radar (ICS),

indicating the priorities across the various LCD strategies.

MPDS Concept Design Phase

In the concept design phase, the MPDS includes two primary processes: sustainable idea generation and concept sustainability checks, both of which are integral to aligning product concepts with LCD strategies.

The process of sustainable idea generation starts by involving project participants in brainstorming activities to generate ideas targeting the six LCD strategies. Tools such as eco-ideas boards (ICS) and the multi-strategy radar (ICS) are employed in this process to assist in the categorisation and initial evaluation of the ideas, ensuring they align with sustainability priorities defined in the previous phase. The results of the brainstorming activities are later rearranged and organised to generate a preliminary concept.

The second process, the concept sustainability check, focuses on evaluating and refining the concept developed. This step involves the representation of the environmental features of the concept, including the definition and visualisation of its life cycle characteristics. Subsequently, an environmental improvement check is conducted to compare the new concept against the baseline product. Metrics and indicators are used to assess the relative improvements achieved across the six LCD strategies. Tools like LCD strategies pursuing evaluation checklist (ICS) and the ESPI form (ICS) are leveraged for this purpose, allowing for a structured evaluation of potential impacts. Finally, in the last step of the concept sustainability check activity, the potential for further environmental strategic improvements is visualised using the multi-strategy radar (ICS). This visualisation enables designers to identify additional areas for refinement, aligning the concept more closely with sustainability priorities.

Case study: Application of MPDS in a yacht design workshop

The application of the MPDS method was carried out during a six-day intensive workshop involving 24 young professional yacht designers, organised into six groups of four participants each. The workshop focused on the concept design phase of a 50-foot charter yacht, focusing on the innovative "Albergo Nautico Diffuso" concept. This concept reimagines the traditional use of yachts by shifting toward a service-oriented model, offering a hotel-like experience (Legge regionale 21 giugno 2021, 2021).

Due to the workshop's focus on service-oriented yacht models, the Bali Catamarans 4.8 was chosen as the standard existing product, as it is widely used in this type of activity.

To enable participants to focus on the concept design phase, the strategic product analysis phase was completed by the research team in advance of the workshop. This preparatory work included assessing the environmental impact of a standard existing product using the ICS Checklist for evaluating existing products. The results of this assessment provided a baseline for identifying environmental design priorities across the six LCD strategies.

Based on the assessment, the environmental design priorities were established in Table 1.

LCD Strategy 1 Use extension/intensification	High
LCD Strategy 2 Material consumption reduction	High
LCD Strategy 3 Energy consumption reduction	Medium
LCD Strategy 4 Material life extension	Medium
LCD Strategy 5 Toxicity reduction	Medium
LCD Strategy 6 Resources conserv./biocompatibility	Medium

Table 1. Level of priority assigned for each LCD strategy.

These priorities provided the foundation for participants to generate innovative design ideas.

During the workshop, participants used the ICS eco-ideas boards to implement their concepts in alignment with the predefined priorities. In the final phase, the participants evaluated the environmental performance of their proposed designs using the LCD strategies pursuing evaluation checklist (ICS). The improvements or deteriorations in the product's environmental profile were further analysed by comparing the concepts to the baseline product through the ESPI form, which quantified the potential impacts of the proposed strategies.

Throughout the workshop, 30-minute project review sessions were held daily, providing participants with guidance and support in applying the MPDS. Feedback on the methodology and related tools was gathered

through unstructured interviews with the participants.
The questionnaire assessed the integration of ecodesign strategies during the yacht design workshop. It focused on their influence on the design process, ease of application, and impact on decision-making. The responses provided insights into the practicality of ecodesign principles and areas for improvement in their application.

Results

Interviews with participants

Participant feedback gathered during the daily review sessions is summarised in Table 2, highlighting both the positive and negative aspects identified in the application of the methodology and its associated tools.

PROS	CONS
• In general, the implementation of ICS tools does not significantly impact project timelines • Minimal prior knowledge of sustainability is required to use ICS tools • Some eco-ideas board suggestions are easily implementable • Some guidelines already enable immediate integration of sustainability considerations	• For complex products, the numerous guidelines make it challenging to simultaneously focus on all aspects • Most of the guidelines are excessively detailed and are applicable in subsequent stages of the product development • Certain LCD strategies and guidelines fall outside the nautical designer's scope

Table 2. Pros and cons of the methodology and its tools highlighted during project reviews.

Questionnaire

The questionnaire gathered feedback on the application of LCD strategies during the yacht design workshop. The key findings for each question are outlined in Table 3.

Q1	**How did the LCD strategies influence your overall yacht design process?**
	All groups reported that the strategies influenced their design process, with 66.7% stating they significantly changed their approach. The remaining 33.3% noted moderate changes.
Q2	**Which LCD strategies did you find easiest to apply during your project?**
	The most easily applied strategy was "use extension/intensification", used by 83.3% of the groups. The second, used by 66.7% of groups, was "material life extension". "Toxicity reduction" was last, since it wasn't indicated by any group.
Q3	**How easy or difficult was it to integrate LCD strategies into your existing design process?**
	Half of the groups found the integration quite neutral, while 33.3% found the process easier. One group reported moderate difficulty.
Q4	**Were there any LCD strategies that you found difficult or impractical to implement? If so, why?**
	Participants highlighted material-connected strategies as the most challenging due to insufficient knowledge of sustainable materials and the technical complexities of yacht production. Similarly, "toxicity reduction" required expertise beyond the participants' familiarity. Time limitations further hindered in-depth exploration of these strategies.
Q5	**How did the application of LCD strategies affect the decision-making process in your design? Did they change your design approach?**
	33.3% of the groups reported that LCD strategies influenced their decision-making by emphasising sustainability, particularly in material and production considerations. 50% stated these strategies extensively guided their proposals or shaped their approach from the early stages, while one group found their integration challenging and reported only minor adjustments.

Table 3. Questionnaire regarding the application of the LCD strategies.

Qualitative assessment of projects

The results of the LCD strategies pursuing evaluation checklist (ICS) reveal how the six strategies were applied and their varying levels of effectiveness across the projects. For each strategy, the groups evaluated the degree of improvement achieved for each related guideline, using the following criteria:

- worse;
- no improvement;
- incremental improvement;
- radical improvement;
- not applicable.

The results shown in Table 4 illustrate the percentage of groups that assigned the specific level of improvement achieved for each strategy.

N/A – Not Applied **1** – Worse, **2** – No improvement, **3** – Incremental improvement, **4** – Radical improvement					
	N/A	**1**	**2**	**3**	**4**
LCD strategy 1	0%	0%	17%	83%	0%
• Design an appropriate life span • Design reliability • Facilitating renewability and adaptability • Facilitating maintenance • Simplifying repair • Simplifying re-use • Simplifying remanufacturing • Intensifying use					
LCD strategy 2	0%	0%	34%	66%	0%
• Minimizing the material content of a product • Minimizing scraps and waste • Minimizing the packaging • Choosing the most efficient material consumption system • Adopting flexible material consumption system • Minimizing material consumption in product design					
LCD strategy 3	0%	0%	83%	17%	0%
• Optimizing energy consumption for pre-prod. and production • Minimizing transportation and storage consumption • Choosing consumption systems minimizing resources in use • Adopting flexible energy system • Minimizing energy consumption in product design					
LCD strategy 4	17%	0%	33%	33%	17%
• Adopting a cascade approach • Adopting high recyclable materials • Simplifying collection and transportation after use • Identifying the materials • Minimizing the number of incompatible materials • Simplifying cleaning • Simplifying composting • Simplifying combustion					
LCD strategy 5	34%	0%	66%	0%	0%
• Reducing toxicity and harmfulness of materials • Reducing energy resources toxicity and harmfulness					
LCD strategy 6	33%	0%	50%	17%	0%
• Optimizing biocompatibility and conservation of materials • Choosing renewable and bio-compatible energy resources					

Table 4. Results of the LCD strategies pursuing evaluation checklist (ICS).

The data reveal that the strategy achieving the highest level of improvement was "use extension/intensification", with 83.3% of the groups reporting incremental improvement. This was followed by "material consumption reduction", where 66.7% of the groups similarly reported incremental improvement. Notably, none of the projects demonstrated worsening in any of the six LCD strategies, indicating that all groups achieved at least some level of environmental improvement or maintained the same environmental level of the existing product. This uniform absence of worsening underscores the participants' focus on sustainability-oriented enhancements.

Overall, most responses across the strategies fell within the categories of no improvement or incremental improvement, with radical improvement observed only once, in the case of the material life extension strategy. For most strategies, the proportion of groups reporting not applicable (N/A) was minimal or absent, suggesting that nearly all LCD strategies were addressed in the projects. However, "toxicity reduction" and "resources conservation/biocompatibility" recorded the highest percentages of non-applicability, with 33.3% of groups indicating these strategies could not be effectively integrated into their designs.

Certain strategies, such as "energy consumption reduction" and "toxicity reduction", showed limited success, as reflected by higher percentages of responses in the no improvement category.

Discussion and Conclusions

The workshop demonstrated the practical application of a generic LCD methodology in yacht design, providing valuable insights into its effectiveness and areas requiring further refinement. Participants worked on developing sustainable concepts for a 50-foot charter yacht, using MPDS tools for testing the integration of LCD principles into their workflows. One of the projects can be seen in Figure 1.

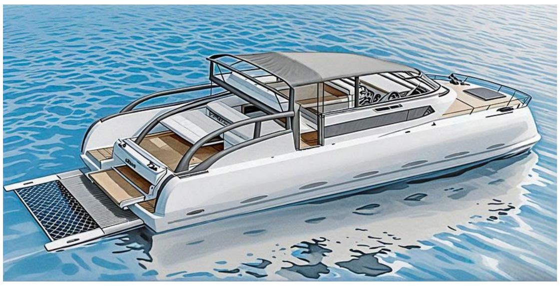

Figure 1. Rendered view of one of the projects.

As anticipated by Vezzoli (2018), the implementation of the MPDS method requires adjustments tailored to specific contexts. Indeed, the methodology often proved too generic, providing only vague instructions on the use of specific tools.
Yacht design introduces additional complexities due to the wide range of roles and expertise involved, including naval architects, interior and exterior designers, project managers, and many other stakeholders.
This challenge was evident in the feedback collected from the Questionnaire and the interviews, as some aspects of the proposed tools required skills beyond the scope of a yacht designer.
Furthermore, parts of the methodology and its tools were overly detailed for the concept design phase of nautical projects. Consequently, during the interviews, it was highlighted that some guidelines within the eco-ideas boards were impractical to implement at such an early stage. This misalignment between the level of detail provided and the requirements of the nautical concept design phase limited the methodology's applicability.
These challenges were reflected in the sustainability outcomes of the projects, as summarised in Table 4. While some improvements were achieved, they were generally modest and predominantly concentrated in strategies that were better suited to the concept design phase and more aligned with the core responsibilities of a nautical designer.
While the study focused on a small participant group and exclusively on the concept design phase, these insights provide a valuable starting point. Future research could build on these findings by involving a broader range of participants and exploring the methodology's applicability across other phases of MPDS.
The results highlight the need for a tailored methodology and toolkit specifically designed for yacht design, structured to address the multi-stakeholder nature of the process and its articulated phases. Future adaptations of the MPDS methodology should define the activities and tools appropriate for each stakeholder, ensuring that they are practical, focused, and aligned with the expertise required for each role. Additionally, new tools and methods must consider the unique complexities of yacht design, balancing the need for detail with usability across different phases of the design process. Finally, the advantages highlighted from the unstructured interview can serve as a foundation for future developments.
In conclusion, this study highlights the potential of LCD methodologies to promote sustainability in yacht design while emphasising the need for context-specific adaptations. By addressing the gaps identified, future efforts can build on these findings to advance sustainable practices in the nautical industry and beyond.

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