Analysis of Technical Standards for Boat Design: River Electromobility of Small Boats in Colombia

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Abstract

Introducing river-based electromobility in a country presents technical, environmental, and economic challenges. Once a dependable river mobility scheme is implemented, various commercial and industrial businesses can be established, benefiting multiple communities. However, it is crucial to effectively manage the diverse activities associated with watercraft. In Colombia, technical and environmental standards currently do not adequately support the use of small electric boats or promote their effective implementation. Therefore, this paper proposes a method for classifying, prioritizing, and analyzing standards for small boats using a normative framework and a Systems Life Cycle Management (SLCM) design method. Additionally, as an application of the method, the document analyzes small boat designs in Colombia based on environmental and electromobility standards. This paper categorizes and ranks relevant standards for small boats, focusing on the application of electromobility on rivers. The proposed approach simplifies referencing standards and helps classify, prioritize, and analyze them. It is noteworthy that Colombia requires the adoption of a greater number of standards to support electromobility.

Key words: Technical standard, electromobility, river transport, renewable energy, small boat.

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Introduction

The transportation industry is responsible for a quarter of global greenhouse gas emissions [1]. A portion of these emissions comes from river transport, as many boats still rely on fossil fuels [2, 3]. River transport is essential for sustainable development goals, and there is a worldwide effort to strengthen it [4]. Environmentally friendly alternatives must be implemented immediately to reduce emissions and meet climate goals [1, 5].

River electromobility is a promising solution for reducing greenhouse gas emissions and addressing climate change [6]. Additionally, it offers significant potential for improving social, environmental, and economic conditions in various regions [7].

Electromobility and eco-friendliness have become increasingly important worldwide as nations seek to reduce greenhouse gases. Transportation significantly contributes to polluting emissions due to its heavy reliance on fossil fuels. Although river transportation emits the lowest amount of pollutants, it still depends on these fuels, offering economic and technological growth potential. Therefore, it is imperative to pursue the implementation of river electromobility in the country, considering its vast waterway resources and the necessity to achieve worldwide objectives for reducing greenhouse gas emissions and promoting sustainable development [8].

Several nations have established initiatives to promote sustainable mobility and support the implementation of river electromobility [9]. However, a comprehensive technical and regulatory framework is required to address technological challenges and ensure successful implementation [10]. Standardization bodies have established specialized committees responsible for issuing regulations that guarantee procedural quality. Some countries have made significant progress in this area, while others still require more standards to enhance the competitiveness of new technologies [11].

The literature suggests creating innovative policies and regulatory frameworks to control energy efficiency and emissions in river transport. For example, one study comprehensively analyzed the regulatory framework for next-generation unmanned inland waterway vessels in Flemish waters, [12] presenting and analyzing national and international regulations related to design, construction, testing, and operation. Another study summarized the requirements for waterway regulation [13] and proposed an intelligent waterway management system. This system integrates intelligent sensors, the Internet of Things, big data, cloud computing, artificial intelligence, and wireless communication to provide navigation security services, including waterway maintenance, route planning, dynamic monitoring, automatic collision avoidance, rescue services, and traffic flow management. It will bring a new form of modern shipping with more efficient production, scientific management, flexible and transparent service, and stronger guarantees.

Standards are necessary to promote the implementation of electric boats and encourage technical development. For instance, Colombia must review more technical standards for small electric boats. Focusing on small boats rather than all boat types allows this paper to address the unique requirements of a sector with less environmental regulation restrictions and technical support, making it a critical starting point for implementing electromobility solutions. Additionally, small boats often operate in environmentally sensitive areas where immediate emissions reductions are most needed. A country that efficiently develops legal frameworks and adopts technical standards can achieve better regulation and evolve towards new technologies. However, knowledge of which regulations allow the integration of technologies for electromobility, which are adopted or could be adopted, and what needs to be added to improve the river sector, is crucial. Therefore, this paper presents a method for classifying, prioritizing, and analyzing standards for small boats, using a regulatory framework and a Systems Life Cycle Management (SLCM) design method. The document presents the relationship with international standards relative to electromobility and environmental factors for the different stages of small boat design in Colombia. Additionally, this paper considers the following contributions:

- Unlike previous studies that provide general reviews of standards applicable to boats, this paper presents a method to review different standards for the application of river electromobility.
- It introduces a standards chart to classify and prioritize norms applicable to the fluvial electromobility of small boats.
- It establishes a relationship between the Systems Life Cycle Management (SLCM) method and standards, categorizing them for each design stage.
- It identifies challenges for implementing electromobility in Colombia and proposes strategies to effectively integrate small electric boats.

Materials and methods

This methodology unfolds in three distinct sections. First, a thorough exploration of information is conducted, including a detailed identification of information sources. Second, the structure of the standards chart is developed, integrating data relevant to each standard. Finally, a comprehensive analysis of the Systems Life Cycle Management (SLCM) method is performed, examining its alignment with corresponding standards across every design stage.

Information search

To design business processes, it is essential to identify all necessary standards, regulations, or laws. For this reason, technical standards from various standardizing organizations and committees involved in ship design were reviewed. The search criteria focused on standards related to quality, design, maintenance, safety, and environmental aspects of ships.

The information was sourced from the official websites of organizations and classification societies responsible for setting standards, including the International Organization for Standardization (ISO), the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), and the International Association for Waterborne Transport Infrastructure (PIANC). Each organization comprises committees focused on specific areas. [14].

The standards chart was developed based on the following committees:

- **ISO TC 8:** Focuses on large craft, standardizing design, construction, structural elements, equipment, and marine environmental issues.
- **ISO TC 8:** ISO TC 188: Focuses on small craft, standardizing equipment and construction details for leisure and small craft up to 24 meters in hull length.
- **CEN/ TC 15:** Establishes standards for shipbuilding related to inland waterway vessels.
- **CEN/ TC 15/ WG 1:** Electrical grounding
- **CEN/ TC 15/ WG 2:** Maintenance of inland navigation standards
- **CEN/ TC 15/ WG 3:** Methanol fuel intake.
- **PIANC InCom:** Oversees inland navigation standards.
- **PIANC MarCom:** Addresses seaport and navigation channel issues.

Structure and Components of the Standards Chart

Using technical content and data standards, the standards chart helps classify available information quickly and appropriately. Table 1 presents the representation of the standards chart and how all the information extracted from the standards can be organized for further use. This information includes the organization (OR), committee (CM), construction group (CG), number (NN), name (NB), summary (SM), and category (CT). The qualification (QF) can be as broad as the objectives of each industrial project. In this paper, the assigned ratings determine the adoption of standards in Colombia (AC), applicability to ship types (ST), relation to electromobility (EM), classification of document type (DT), and standards eligible for prioritization in Colombia (PC).

The standards chart comprises the following components:

- **Organization (OR)**: Denotes the standardization body responsible for the standard's development and publication (ISO, CEN-CENELEC, or PIANC).
- **Committee (CM):** Identifies the governing technical committee under which the standard was developed.
- **Constructive group (CG):** Represents the shipbuilding sector classification assigned by naval engineering experts. This classification facilitates the systematic organization of technical specifications, construction procedures, maintenance protocols, and modification requirements [15].
- **Standard number (NN):** Designates the unique alphanumeric identifier assigned by the issuing organization.
- **Name of the standard (NM):** Specifies the official title of the standard document.
- **Summary (SM):** Presents a comprehensive overview of the standard's scope and objectives.
- **Category (CT):** Establishes the standard's classification based on the fundamental principles outlined in "Ship Design and Construction" [16]. The categories are defined as follows:
  - **Quality:** This category defines the quality standards to be followed throughout the construction process, from the procurement of materials to the final inspection.
  - **Design:** This category sets the standards and guidelines for ship design and architecture. This includes hull shape, deck design, load distribution, stability, and maneuverability.
  - **Maintenance:** Maintenance standards focus on the maintenance and ongoing care of ships. This includes regular inspection of equipment and systems and maintenance of engines, electrical systems, water systems, and other critical components.
  - **Safety:** Standards that include measures and protocols to ensure the physical integrity of persons on board and the prevention of accidents and emergency. These standards relate to safe navigation, fire prevention, rescue, and response to maritime emergencies.
  - **Construction:** Construction standards focus on the materials used in shipbuilding and the construction

Table 1. Structure of a standards chart.

OR	CM	CG	NB	NM	SM	CT	QF				
							AC	ST	EM	DT	PC

processes. These standards cover material strength, watertightness, and other aspects related to the construction of hulls, structures, and onboard systems.

- **Environmental:** Environmental standards prevent and control environmental impacts throughout ships' life cycles. These standards promote environmentally sound practices and sustainability in the maritime industry.

- **Standard adopted in Colombia:** ICONTEC is the national Colombian standardization institute. It is organized into Technical Committees for Standardization (CTN), which are composed of multidisciplinary experts representing industry and consumers with general interests. These committees establish, by consensus, the basic requirements for quality, safety, health, and environmental protection for products, processes, or systems [17]. The committee responsible for adopting technical standards for vessels is known as **"255 Small Vessels"**, which has adopted 32 standards in Colombia. Therefore, the criterion for determining whether a standard is adopted in Colombia is whether it belongs to the 255 Committee.
- **Applicable to small boats:** This criterion is used to classify boats based on their length in Colombia. Each standard is categorized according to whether it applies to boats under 24 meters in length, which are classified as small boats. Boats over 24 meters in length are classified as large boats.
- **Electromobility and environmental factors:** One of the most relevant areas for assessing each standard and prioritizing the implementation of new technical standards is electromobility and its environmental implications for energy transition and conservation. Experts classify the standards in the standards chart based on their relevance to these topics, using predefined criteria.
- **Document type:** Standards establish technical, administrative, and commercial actions, defining the regulations and features for different uses depending on whether they pertain to products, processes, or methods. Seven types of documents are considered for classifying standards: conformity assessment, test method, process, product, service, management system, and terminology. This classification improves the visualization of the standards and, based on objectivity, identifies the priorities that Colombia should adopt.
- **Prioritization in Colombia:** The standards chart can be used to determine which boat design standards are most likely to be prioritized for implementation in Colombia. This specifically pertains to standards that have not yet been adopted, are relevant to small boats, address electromobility, and relate to environmental concerns.

List of construction groups

The naval architecture framework includes ten construction groups, systematically organized from groups 000 to 900, which provide comprehensive technical specifications. These groups, established by the Colombian Navy in their Naval Material Doctrine Volume II [15], encompass the integrated systems and equipment that define vessel functionality and operational capabilities, including propulsion systems, armament configurations, communication networks, detection apparatus, and surveillance infrastructure. This hierarchical classification enables methodical information management, facilitating progression from conceptual overview to granular technical detail, applicable across diverse vessel categories [15]. Table 2 shows the scope and composition of each group.

Systems Life Cycle Management

The SLCM method maximizes a system's

Table 2. Construction Groups Classification for Naval Architecture.

Group	Name	Description
Group 000	General information and administration	General requirements for planning, development, design, design, construction, and associated documentation.
Group 100	Hull structure	Includes general structure, main hull, superstructure compartment, structural subdivisions, structural attachments, rigging and rigging structure, anchor blocks and foundations, fixed ballast, welding and attachments, and hull openings.
Group 200	Propulsion plant	Installed components for propulsion systems and subsystems.
Group 300	Electric plant	General electrical power systems, power distribution boards, cables, and related material specifications.
Group 400	Command and control	General, power supply, insulation, welding and joining, accessories, cables, connections, metallic protections, gaskets, among others.
Group 500	Auxiliary systems	Fittings, flanges, flexible pipe connections, gauges, gaskets, joints, hangers, hoses, instrumentation, insulation, mechanical accessories, motors, piping, safety devices, valves, vents, control systems, machinery and controls, stabilizers, cables, pumps, casings, welds and fasteners, hangers, brackets, switches, and controls.
Group 600	Habitability and equipment	General information, armament, equipment, welding, insulation and dampers, motors, and rat-proofing material.
Group 700	Weapons	General information, armament, ammunition handling, stowage, fire control elements, welding, regulators, cables, pumps, controllers, motors, valves, pipes, fittings, testers, isolator assemblies, instruments and supports.
Group 800	Naval architecture and security	Builder's engineering, projects, and technical services (engineering integration), plans, drawings, etc.
Group 900	Ship assembly and support services	For identification in ship assembly and allocation of costs for support services, production, and construction.

capabilities throughout its life cycle. This is accomplished by managing its performance, cost, schedule, quality, operating environments, integrated logistical support, and obsolescence. The method involves total control from inception to termination. The SLCM policy has five key principles: dedication to managing a system's life cycle, cooperation and interoperability, efficiency, collaboration with industry, and quality. These principles outline a method that recommends a systematic approach to facilitating the development of a system across multiple stages [18].

This section seeks to present the results of the normative review conducted for constructing the standards chart in three parts. First, an analysis of the frequency of information corresponding to each standard in various items of the standards chart aims to summarize the technical standards involved in designing a boat. Next, a list of standards selected as prioritized to be adopted by Colombia is presented. This section provides the utility of the standards chart by presenting a prioritization example. The third section shows how the standards chart can be beneficial regarding the correlation between the SLCM method and incorporating technical standards as necessary inputs for each design stage. This method organizes instructions and rules for the execution and achievement of the system's mission through these stages and processes. Szabo and Koblen state that LCM is the systematic and controlled approach to managing the evolution of a product, from the initial idea to its disposal and recycling [19].

This method has various essential objectives. Some of them go from defining system requirements clearly and precisely to creating a continuous and fluid life cycle management process throughout all stages of the system/

product life cycle [19]. Therefore, it is crucial to establish the technical regulatory relationship necessary at each stage to ensure efficient system/product development.

The methodology is implemented across distinct developmental phases of the ship system, encompassing Pre-concept, Concept, Development, Production, Utilization, Support, and Retirement [19]. These phases are characterized as follows:

- **Pre-concept:** This stage involves the initial exploration of the system's feasibility and potential requirements.
- **Concept:** At this stage, a detailed concept is developed, including preliminary designs and technical specifications.
- **Development:** In this phase, the design is refined, and the system undergoes testing and validation.
- **Production:** This stage focuses on the manufacturing and assembly of the system .
- **Utilization:** During this phase, the system is deployed and operated in its intended environment.
- **Support and retirement:** The final stage includes maintenance, upgrades, and eventual decommissioning or recycling of the system.

The standards chart serves as an instrumental framework for selecting applicable standards corresponding to each SLCM methodological phase. This relationship between method and standards makes it possible to achieve the objectives of the method.

Results

This section presents an analysis of technical standards for boat design, with emphasis on their applicability to river electromobility in Colombia. The analysis is structured in three main components. First, the research presents a frequency analysis of technical requirements across different boat design aspects, providing a comprehensive overview of existing standards. Second, the study identifies and prioritizes the most relevant standards for Colombia's context. Finally, the investigation examines how these technical standards integrate with the Systems Life Cycle Management (SLCM) method, demonstrating their practical application at each design stage.

Standards chart

The standards chart provides access to the technical standards required to initiate each stage of a product or system development. Through this chart, it is possible to analyze the available information, identify starting points, and recognize any technical gaps in the design. In addition, the standards chart helped identify which standards require prioritization for adoption in Colombia.

The following sections present the results of the analysis conducted on the type of information acquired for each standard.

Number of standards per construction group

According to Fig. 1, the group with the highest number of standards is Group 500 (Systems and Auxiliaries), which accounts for 37% of the total standards. The next largest group is Group 800 (Shipbuilding and Safety), which represents 9%. Group 400 (Command and Control), Group 600 (Accommodation and Equipment), and Group 000 (General and Administration) are the third-largest groups, each accounting for 7% of the total. This is followed by Group 200 (Propulsion Systems), Group 100 (Hull Structure), Group 300 (Electrical Systems), and Group 900 (Ship Assembly and Support Services), which represent 5%, 4%, 3%, and 1%, respectively. Additionally, PIANC infrastructure standards represent 20% of the total, while environmental management standards account for only 3%.

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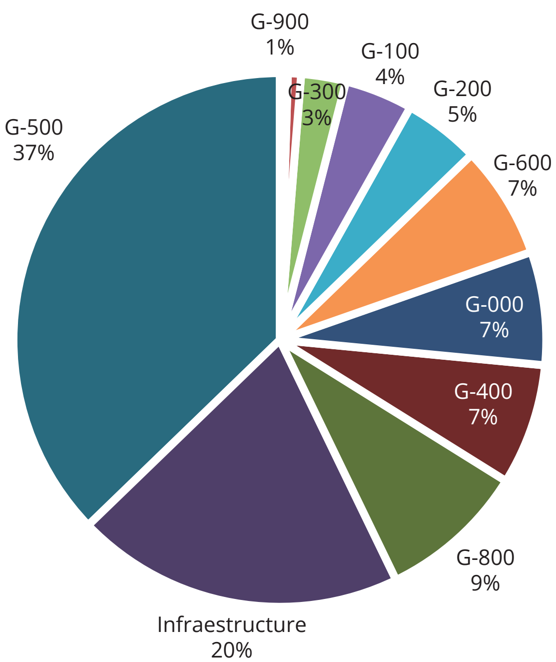
Fig. 1. Number of standards of each construction group obtained with the standards chart. The information is sourced from the official websites of the organizations or classification societies responsible for setting the standards.



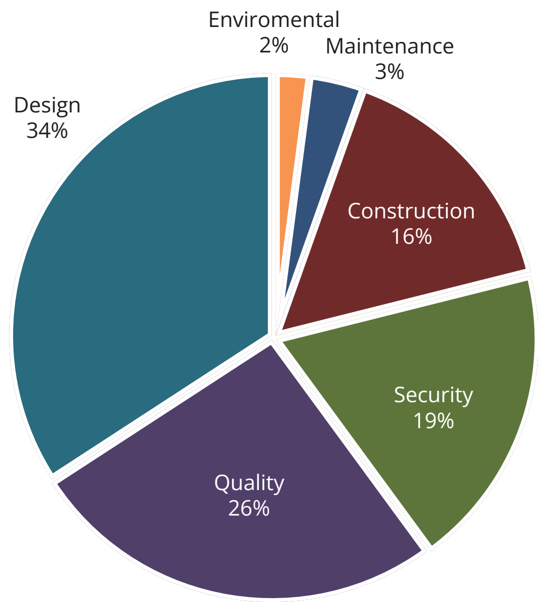
Standards by category

According to Fig. 2, the category with the lowest number of standards is Environment, which accounts for just 2% of the total standards. Maintenance standards represent 3%. The categories of Construction, Safety, Quality, and Design represent 16%, 19%, 26%, and 34% of the total number of standards, respectively. The category with the highest number of standards is Design, while the category with the lowest is Environment, highlighting an area that requires further attention.

Standards by type of document

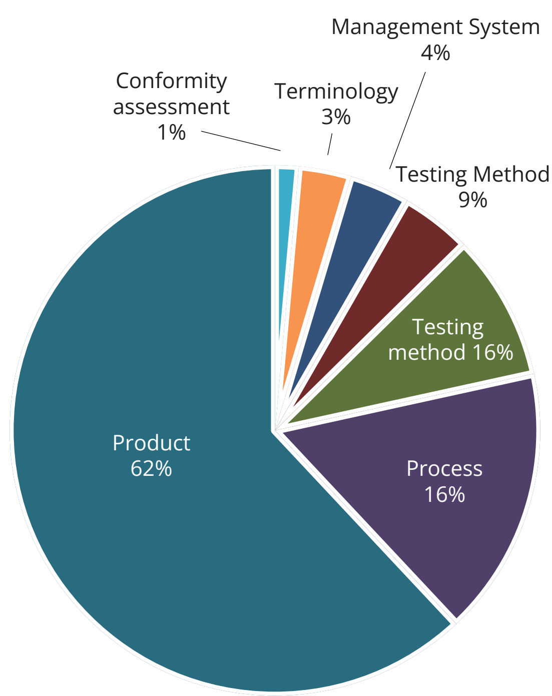
According to this classification, Fig. 3 shows that the document type with the highest number of standards is Product, with 62%. The other document types range from 17% to 1%, as follows: process with 17%, test method with 9%, service and management

Fig. 2. Number of standards in each category obtained with the standards chart.



system with 4% each, terminology with 3% and conformity assessment with 1%.

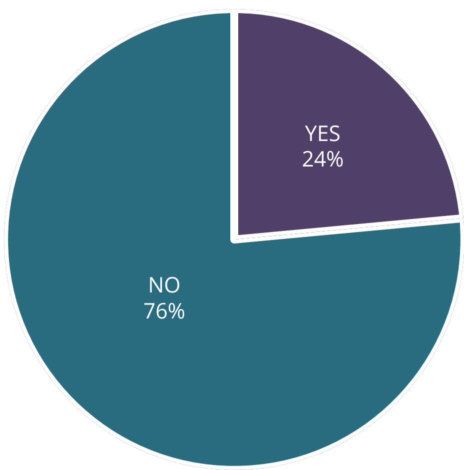
Fig. 3. Type of document obtained with the standards chart.



Number of standards applying to small craft and electromobility

Fig. 4 shows the total number of standards that apply to small craft. These standards represent 14% of the total number of standards selected. Of this 14%, there are 20 standards that apply specifically to electromobility, accounting for 24% of the standards for small craft. Additionally, 65 standards do not apply to electromobility, representing the remaining 76%.

Fig. 4. The number of standards applicable to small boats and electromobility.



The largest number of standards observed is directly related to the main subject of this analysis: small craft. This is evidenced by the highest number of standards in Group 500 (Auxiliary Systems) within the Design category. Therefore, the method proposed in this study helps identify and select the appropriate standards for each topic.

Example of standards chart use

Within the context of developing a research project, it is imperative to identify the normative and regulatory framework for the expected implementation. In Colombia, Committee 255 has adopted 32 standards related to small vessel design [20], which are published on the ICONTEC entity's website. The identification of technical standards for this design facilitated a comprehensive understanding of the standards to prioritize in the country. The standards that have not yet been adopted in Colombia, which apply to small vessels and electromobility, were studied by technical standardization experts in the country, assigning a category for each standard according to the relevance of the type of document with which the standard is classified. Table 3 clearly represents these prioritized standards to be adopted by the Small Vessels Committee 255.

Table 3. Prioritized standards to be adopted in Colombia for the design of small vessels.

Standard Number	Standard Name	Categories	Document type
ISO 14509-3:2009	Small craft. Small craft - Airborne sound emitted by powered recreational craft - Part 3: Assessment of noise using calculation and measurement procedures (ISO 14509-3:2009).	Quality	Conformity assessment
ISO 16315:2016	Small vessels. Electric propulsion system	Design	Product
ISO/TS 23625:2021	Small vessels: Lithium-ion batteries	Design	Product
ISO 10133:2012	Small vessels. Small craft - Electrical systems - Very low voltage d.c. installations (ISO 10133:2012) Small craft - Very low voltage d.c. installations (ISO 10133:2012) This is the first publication.	Design	Product
ISO 12133:2011	Small vessels: carbon monoxide (CO) detection systems	Design	Product

ISO 14509-2:2008	Small craft. Small craft - Airborne sound emitted by powered recreational craft - Part 2: Assessment of noise using reference vessels (ISO 14509-2:2006) Small craft - Airborne sound - Part 2: Noise assessment using reference vessels (ISO 14509-2:2006)	Quality	Test method
ISO 18854:2015	Small craft - Measurement of exhaust gas emissions from reciprocating internal combustion engines - Test bench measurement of gas and particulate emissions (ISO 18854:2015).	Design	Test method
ISO 16180:2013	Small vessels. Small craft - Navigation lights - Installation, location and visibility (ISO 16180:2013) Small craft - Navigation lights - Installation, location and visibility (ISO 16180:2013) This is the first publication	Safety	Process
ISO 19009:2015	Small craft. Small craft - Electric navigation lights - Performance of LED lights (ISO 19009:2015) Small craft - Performance of LED lights (ISO 19009:2015).	Safety	Product
ISO 8846:1990	Small craft - Electrical apparatus - Protection against ignition of surrounding flammable gases	Design	Test method
ISO 25197: 2020	Small boats: electric/electronic control systems for steering, gear and throttle	Design	Product
ISO 8849:2003	Small craft - Bilge pumps - Direct-current electric bilge pumps (ISO 8849:2003) Small craft - Electric d.c. bilge pumps (ISO 8849:2003)	Maintenance	Product

Prepared by the author.

Systems Life Cycle Management (SLCM)

The search for standards was based on several objective criteria: quality, design, maintenance, safety, and the environment. These criteria correspond to various stages of the system development, such as the design of the vessel. Specifically, design standards and environmental aspects are relevant to the preconcept, concept, and development stages of the SLCM method.

By running the normogram in the SLCM method, the standards related to each stage of the method can be identified. Therefore, in Tables 4 and 5, the standards that describe the processes used in these stages for any type of vessel are shown.

Table 4. Vessel design standards.

Standard Number	Standard Number	Standard Number
ISO 8846:1990	ISO 21131:2019	ISO8845:1994/ISO 8845:1994/ COR 1:1995
ISO/TR 10134:2020	ISO 21711:2019	ISO 8847:2004
ISO 13297:2020	ISO 23577:2021	ISO 9650-1:2005
ISO 25197: 2020	ISO 24041:2020	ISO 9650-2:2005
ISO/TS 23625:2021	ISO 24042:2020	ISO 10133:2012
ISO 799-1:2019	ISO 24045:2021	ISO 11105:2020
ISO 5488:2015	ISO 24059:2021	ISO 11192:2005
ISO 5489:2008	ISO 24061:2021	ISO 11592-1:2016
ISO 7061:2015	ISO 1069:1973	ISO 11592-2:2019

ISO 7364:2016	ISO 8468:2007	ISO 12133:2011
ISO 15370:2021	ISO 8728:2014	NTC-ISO-12215-4
ISO 15371:2015	ISO 8729-1:2010	NTC-ISO-12215-5
ISO 16437:2012	ISO 8729-2:2009	NTC-ISO-12215-6
ISO 16707:2016	ISO 13643-1:2017	ISO-12215-7
ISO 17338:2009	ISO 13643-2:2017	NTC-ISO-12215-8
ISO 19891-1:2017	ISO 13643-3:2017	NTC-ISO-12215-10
ISO 24136:2021	ISO 13643-4:2017	ISO 12216
ISO 24409-1:2020	ISO 13643-6:2017	ISO 12217-1:2015
ISO 16446:2013	ISO 15016:2015	ISO 12217-3:2017
ISO 18309:2014	ISO 16425:2013	ISO 13590:2003
ISO 19030-1:2016	ISO 17884:2004	ISO 13591:1997
ISO 21963:2020	ISO 17899:2004	ISO 14895:2016
ISO 23765:2021	ISO 19697:2016	ISO 14945:2004
ISO 484-1:2015	ISO 19847:2018	ISO 15085:2003
ISO 2412:1982	ISO 19848:2018	ISO 15584:2017
ISO 3715-1:2002	ISO 3876:1986	ISO 16147:2018
ISO 3715-2:2001	ISO 3926:1980	ISO 16315:2016
ISO 7547:2002	ISO 4050:1977	ISO 21487:2019
ISO 7547:2002/COR 1:2008	ISO 4051:1977	ISO 21487:2012/AMD 1:2014
ISO 8277:2013	ISO 4089:1979	ISO 18854:2015
ISO 8862:1987	ISO 4127-1:1979	EN 12339: 1997
ISO 8863:1987	ISO 4127-2:1980	EN 12827: 1999
ISO 8864:1987	ISO 4175:1979	EN 1305: 2018
ISO 9099:1987	ISO 5485:1986	EN 1306: 2018
ISO 9785:2002	ISO 6216:1980	EN 13551: 2003
ISO 14726:2008	ISO 6217:1982	EN 13574: 2001
ISO 15364:2021	ISO 6218:2019	EN 14330: 2003
ISO 15748-1:2002	ISO 6765:1985	EN 14965: 2005
ISO 15748-2:2002	ISO 6766:1984	EN 15272-3: 2007
ISO 15749-1:2004	ISO 7222:1985	EN 15272-4: 2007
ISO 15749-2:2004	ISO 7608:1985	EN 15869-1: 2019
ISO 15749-3:2004	ISO 9382:1990	EN 16840: 2017

ISO 15749-4:2004	ISO 9437:1986	EN 16865: 2016
ISO 15749-5:2004	ISO 5480:2020	EN 17361: 2020
ISO 15837:2004	ISO 5778:1998	EN 17556: 2021
ISO 15838:2003	ISO 5779:1987	EN 29519: 1993
ISO 15840:2004	ISO 5780:1987	EN 60092-507: 2015
ISO 17602:2014	ISO 5797:2004	InCom WG 26
ISO 18139:2017	ISO 5894:2018	InCom WG 151/I
ISO 18154:2017	ISO 6042:2015	InCom WG 140
ISO 19037:2019	ISO 6050:1987	InCom WG 151/II
ISO 20602:2019	ISO 7461:1984	InCom WG 154
ISO 20602:2019/AMD 1:2021	ISO 9203-2:1989	InCom WG 173
ISO 21157:2018	ISO 9519:1990	InCom WG 141
ISO 21159:2018	ISO 14409:2011	MarCom WG 2
ISO 21562:2020	ISO 17682:2013	MarCom WG 5
ISO 23055:2020	ISO 17683:2014	MarCom WG 15
ISO 23212:2021	ISO 17939:2015	MarCom WG 21
IEC/IEEE 80005-1:2019	ISO 20313:2018	MarCom WG 13
IEC/IEEE 80005-2:2016	ISO 21005:2018	MarCom WG 30 (2)
IEC/IEEE DIS 80005-3	ISO 21635:2018	MarCom WG 18
ISO 1704:2008	ISO 23121-1:2019	MarCom WG 34
ISO 4568:2021	ISO 23121-2:2019	MarCom WG 33
ISO/DIS 4853	ISO 24169:2022	MarCom WG 40
ISO 16855:2013	ISO 7255:1985	MarCom WG 121
ISO 17905:2015	ISO 11336-1:2012	MarCom WG 135
ISO 18296:2014	ISO 11336-2:2020	MarCom WG 158
ISO 19354:2016	ISO 16556:2014	MarCom WG 165
ISO 19355:2016	ISO 22252:2020	MarCom WG 153
ISO 19357:2016	ISO 8666:2016	MarCom WG 172
ISO 19360:2016	ISO 4566:1992	MarCom WG 144
ISO 21125:2019	ISO 8099-1:2018	MarCom WG 184
		MarCom WG 208

Prepared by the author.

Table 5 displays the environmental criteria for the Preconcept, Concept and Development phases of SLCM.

Tables 6 and 7 present the standards relating to vessel quality and construction, respectively. These standards pertain to the production stage of the SLCM method.

Table 5. Environmental standards.

Standard Number
ISO 14045:2012
ISO 14040:2006
ISO 14044:2006

Table 6. Quality standards.

Standard Number	Standard Number	Standard Number
ISO 15372:2000	ISO 15402:2000	InCom WG 20
ISO 15372:2000/AMD 1:2021	ISO 15583:2005	InCom WG 14
ISO 15736:2006	ISO 16145-2:2012	InCom WG 24-2004
ISO 19897:2019	ISO 16145-5:2014	InCom WG 23
ISO 19898:2019	ISO 16155:2006	InCom WG 21
ISO 24408:2005	ISO 17894:2005	InCom WG 99
ISO 18611-1:2014	ISO 20155:2017	InCom WG 110
ISO 18611-2:2014	ISO 20233-1:2018	InCom WG 111
ISO 18611-3:2014	ISO 20233-2:2019	InCom WG 125/I-2012
ISO 19030-2:2016	ISO 21984:2018	InCom WG 125/II-2012
ISO 19030-3:2016	ISO 22098:2020	InCom WG 125/III-2012
ISO 20083-2:2019	ISO 22987:2020	InCom WG 127
ISO 20083-3:2019	ISO 20858:2007	InCom WG 119
ISO 21072-2:2020	ISO 21745:2019	InCom WG 155
ISO 21072-3:2020	ISO 11209:2012	InCom WG 139
ISO 21716-1:2020	ISO 21173:2019	InCom TG 204
ISO 21716-2:2020	ISO 21851:2020	InCom PWG 125/I-2019
ISO 21716-3:2020	ISO 22013:2021	InCom PWG 125/III-2019
ISO 23048:2018	ISO 23040:2021	InCom WG 192
ISO 484-2:2015	ISO 23446:2021	InCom WG 179
ISO 15540:2016	ISO 23732:2021	InCom WG 201
ISO 15541:2016	ISO 23734:2021	InCom WG 198
ISO 19921:2005	ISO 7840:2013	MarCom WG 3a
ISO 19922:2005	ISO 8469:2013	MarCom WG 3

ISO 19356:2016	ISO 8665:2006	MarCom WG 6
ISO 21539:2019	ISO 8848:1990	MarCom WG 4
ISO 21885:2019	ISO 9650-3:2009	MarCom WG 10
ISO 22419:2019	ISO 9775:1990	MarCom WG 9
ISO 10596:2009	ISO 10087:2019	MarCom WG 17
ISO 11606:2000	ISO 10088:2014	MarCom WG 19
ISO 11606:2000/COR 1:2005	ISO 10240:2019	MarCom WG 12
ISO 13643-5:2017	ISO 10592:1994	MarCom WG 12 AF
ISO 14859:2012	NTC-ISO-12215-1	MarCom WG 24
ISO 16328:2014	NTC-ISO-12215-2	MarCom WG 22
ISO 16329:2003	ISO 12217-2:2015	MarCom WG 31
ISO 19019:2005	ISO 14509-1:2008	MarCom WG 23
ISO 19379:2003	ISO 14509-2:2008	MarCom WG 28
ISO 22090-1:2014	ISO 14509-3:2009	MarCom WG 36
ISO 22472:2016	EN 14606: 2004	MarCom WG 44
ISO 3674:1976	EN 1502: 2020	MarCom WG 102
ISO 3948:1977	EN 15272-1: 2007	MarCom WG 103
ISO 3969:1979	EN 1914: 2016	MarCom WG 112
ISO 7221:1984	InCom WG 1	MarCom WG 113
ISO 8303:1985	InCom WG 4	MarCom WG 115
ISO 8304:1984	InCom WG lifts	MarCom WG 117
ISO 8384:2019	InCom WG 10	MarCom WG 120
ISO 8385:2018	InCom WG 8	MarCom WG 145
ISO 614:2012	InCom WG 9	MarCom WG 144
ISO 5572:1987	InCom WG 11	MarCom WG 152
ISO 6345:1990	InCom WG 5	MarCom WG 162
ISO 7462:1985	InCom WG 6	MarCom WG 196
ISO 9203-1:1989	InCom WG 17	MarCom WG 161
ISO 9203-3:1989	InCom WG 16	MarCom WG 159
		MarCom WG 185

Prepared by the author.

Table 7. Building standards.

Standard Number	Standard Number	Standard Number
ISO 5483:2003	ISO 21792:2019	NTC-ISO-12215-9
ISO 5620-1:1992	ISO 22090-3:2014	ISO 13342:1995
ISO 5620-2:1992	ISO 22554:2015	ISO 13592:1998
ISO 5621:1984	ISO 22555:2007	ISO 13929:2001
ISO 5625:1978	ISO 25862:2019	ISO 14227:2001
ISO 6454:1984	ISO 6764:1985	ISO 14946:2001
ISO 8861:1998	ISO 7236:2014	ISO 15083:2020
ISO 9943:2009	ISO 7607:1984	ISO 15652:2017
ISO 3078:2016	ISO 18421:2016	EN 13056: 2000
ISO 3730:2012	ISO 1751:2012	EN 14714: 2005
ISO 3828:2008	ISO 1964:1987	EN 15869-2: 2019
ISO 6043:1985	ISO 3434:2012	EN 15869-3: 2019
ISO 6044:1985	ISO 3796:1999	EN 17360: 2020
ISO 6045:1987	ISO 3797:1976	EN 526: 1993
ISO 6115:1988	ISO 3902:1990	EN 790: 2001
ISO 6325:1987	ISO 3903:2012	EN ISO 7236: 2016
ISO 6482:2017	ISO 3904:1990	EN ISO 8384: 2019
ISO 6555:1988	ISO 15401:2000	InCom WG 96
ISO 7365:2012	ISO 17940:2015	InCom WG 106
ISO 7824:1986	ISO 17941:2015	InCom WG 137
ISO 7825:2017	ISO 19636:2019	InCom WG 138
ISO 8146:1985	ISO 20154:2017	InCom WG 156
ISO 8147:1995	ISO 23430:2019	InCom WG 166
ISO 8148:1985	ISO 11336-3:2019	InCom PWG 125/II-2019
ISO 8314:1987	ISO 11347:2012	InCom WG 189
ISO 8431:1988	ISO 14884:2015	InCom WG 191
ISO 9089:2019	ISO 23731:2021	MarCom WG 20
ISO 13799:2020	ISO 9093-1:2002	MarCom WG 11
ISO 9876:2015	ISO 9093-2:2002	MarCom WG 30 (1)
ISO 20672:2007	ISO 10239:2014	MarCom WG 41

ISO 20672:2007/COR 1:2008	ISO 11812:2001	MarCom WG 114
ISO 20673:2007	NTC-ISO-12215-3	MarCom WG 180

Prepared by the author.

The final phases of the vessel's life cycle, as per the SLCM approach, involve the utilization and support stages. Maintenance and safety are the pertinent standards for these stages, presented in tables 8 and 9. Table 9 shows the safety standards for the usage and support stages of SLCM.

Table 8. Maintenance standards.

Standard Number	Standard Number	Standard Number
ISO 799-2:2021	ISO 21132:2019	InCom WG 25
ISO 19912:2019	ISO 23323:2021	InCom WG 129
ISO/PAS 23678-1:2020	ISO 24060:2021	InCom WG 197
ISO/PAS 23678-2:2020	ISO 28005-1:2013	MarCom WG 14
ISO/PAS 23678-3:2020	ISO 8849:2003	MarCom WG 8
ISO/PAS 23678-4:2020	EN ISO 8385: 2018	MarCom WG 17
ISO 13613:2011	InCom WG 17	MarCom WG 17-2004

Prepared by the author.

Table 9. Safety standards.

Standard Number	Standard Number	Standard Number
ISO 4001:1977	ISO 28520:2009	ISO 16145-4:2013
ISO 4143:1981	ISO 28521:2009	ISO 16548:2012
ISO 13122:2011	ISO 28522:2009	ISO 28005-2:2021
ISO 15516:2006	ISO 28523:2009	ISO 14885:2014
ISO 15734:2001	ISO 6812:1983	ISO 14886:2014
ISO 15738:2019	ISO 13713:2020	ISO 6185-1:2001
ISO 16706:2016	ISO 13728:2020	ISO 6185-2:2001
ISO 17339:2018	ISO 13729:2020	ISO 6185-3:2014
ISO 17631:2002	ISO 13733:2020	ISO 6185-4:2011
ISO 17631:2002/AMD 1:2010	ISO 13742:2020	ISO 9094:2015
ISO 17631:2002/COR 1:2002	ISO 13755:2020	ISO 11547:1994

ISO 18079-1:2018	ISO 13767:2020	ISO 11591:2019
ISO 18079-2:2018	ISO 13776:2020	ISO 15084:2019
ISO 18079-3:2018	ISO 13795:2020	ISO 16180:2013
ISO 18079-4:2018	ISO 13797:2020	ISO 19009:2015
ISO 18079-5:2018	ISO 13798:2020	EN 13281: 2000
ISO 18813:2006	ISO 16856:2013	EN 13573: 2009
ISO 19292:2014	ISO 16857:2013	EN 13711: 2002
ISO 21195:2020	ISO 16858:2013	EN 14144: 2003
ISO 22488:2011	ISO 17357-1:2014	EN 14145: 2003
ISO 22673:2008	ISO 17357-2:2014	EN 14206: 2003
ISO 23269-1:2008	ISO 17907:2014	EN 14329: 2004
ISO 23269-2:2011	ISO 18289:2014	EN 14503: 2003
ISO 23269-3:2011	ISO 20438:2017	EN 14504: 2019
ISO 23269-4:2010	ISO 21130:2019	EN 14744: 2005
ISO 24409-2:2014	ISO 23113:2020	EN 14744: 2005 / AC: 2006
ISO 24409-3:2014	ISO 23115:2020	EN 14874: 2005
ISO 27991:2008	ISO 23116:2020	EN 15271: 2007
ISO 13073-1:2012	ISO 24043:2020	EN 15272-2: 2007
ISO 13073-2:2013	ISO 24044:2020	EN 1864: 2008
ISO 13073-3:2016	ISO 9875:2000	EN 711: 2016
ISO 13617:2019	ISO 9875:2000/COR 1:2006	EN ISO 18422: 2017
ISO 16165:2020	ISO 11674:2019	EN ISO 6218: 2019
ISO 16304:2018	ISO 16273:2020	EN 60092-507: 2015 / AC: 2015
ISO 17325-1:2014	ISO 19018:2020	InCom WG 3
ISO 17325-2:2014	ISO 22090-2:2014	InCom WG 7
ISO 17325-3:2018	ISO 25861:2007	InCom WG 12
ISO 17325-4:2018	ISO 3652:1975	InCom WG 18
ISO 20053:2017	ISO 3786:1975	InCom WG 19
ISO 21070:2017	ISO 18422:2014	InCom WG 24
ISO 18215:2015	ISO 16145-1:2012	MarCom WG 35
ISO 18770:2005	ISO 16145-3:2012	MarCom WG 116
	MarCom WG 122	MarCom WG 118

Prepared by the author.

The SLCM method has a clear purpose: to manage systems sustainably and efficiently at all stages. This method focuses on technical aspects linked to specific rules for each phase and considers economic, social, and environmental dimensions. These dimensions reflect the needs and expectations of the parties involved. The grouping of technical rules at each stage allows the purpose of the SLCM method to be fulfilled. All of the above shows the value of the standards chart in implementing this method.

Application in Colombia

Colombia has made progress in the shipyard sector by creating two technical standardization committees to develop National Technical Standards (NTCs) as management tools for organizations in the sector, including small and large crafts. Both committees aim to establish a normative base that satisfies the country's requirements in the near future. Furthermore, these committees help organizations employ quality tools in their industrial processes, improving quality and safety standards and achieving strategic goals.

It is worth noting that the Large Vessel Committee is currently working on creating Colombia's technical regulatory framework. Although Colombia has adopted 32 technical standards for small ship design, it has yet to progress significantly in regulating larger vessels. However, these standards for small ship design lack clear technical and environmental guidelines and requirements for the design, construction, operation, and end-of-life disposal of electric boats. The number of standards adopted in Colombia is low compared to those implemented globally. Therefore, Colombia must prioritize standardizing the electric river sector and work toward faster progress.

A significant challenge for Colombia and its organizations is the lack of participation in international standardization committees. In other words, the country's position regarding technological development and the context of ship operation must be presented in international forums. Similarly, alongside standardization processes, it is essential that national standards are adapted according to the industrial capacity of the country.

An example of these requirements can be observed in the shipyard sector in Colombia. Despite the progress made, there is still a need for more standards adapted to the country's specific requirements.

Conclusions

This study presents a method for classifying, prioritizing, and analyzing technical standards applicable to the design of small boats, with a particular focus on river electromobility in Colombia. The results highlight several key findings:

- The technical standards review method facilitated the development of a regulatory framework that provides organized access to preliminary information for each standard, covering aspects such as category, construction group, and relevance in electromobility and environmental sustainability. This structure helps optimize the time required to consult the standards at various stages of the vessel design process.

- The standards framework enables the efficient organization of technical standards, allowing the classification and identification of those relevant to the development of sustainable river electromobility in Colombia. This prioritized list includes 12 standards covering fundamental areas such as quality, environmental, and vessel design standards. Although these standards represent a significant step toward national standardization, further efforts are needed to achieve complete alignment with international standards.

- The correlation between the SLCM method and the systematically organized standards framework by category serves as a tool for understanding specific requirements at each phase of the design process. This structured approach provides greater clarity in identifying critical and relevant issues for system design while enabling the prioritization of applicable standards. Thus, the standards framework is consolidated as a fundamental tool for guiding the selection and ranking of necessary regulations in river electromobility.

- Colombia must actively participate in international standardization committees to benefit from global discussions on technological advances related to the design, construction, operation, maintenance, and disposal of electric vessels. Participation in these committees allows Colombia to contribute significantly to the energy transition and align with international requirements and standards.

It is necessary to extend the search for other regulations related to environmental aspects, in future work, to analyze with more detail those required for electromobility. Furthermore, future research should conduct comprehensive analyses of transport electrification standards in other Latin American countries, mainly focusing on their regulatory frameworks, implementation strategies, and barriers to adoption. This comparative analysis would help identify best practices and potential harmonization opportunities for sustainable transportation standards across the region.

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About the article

Author Contribution

- Paola Andrea Ruiz Franco 1: Contribution: Conceptualization, methodology, manuscript writing, data analysis, final editing
- John E. Candelo-Becerra 2: Contribution: Data analysis, drafting of the manuscript, revision of the manuscript)
- Gersson Fredy Torres Baquero 3: Contribution: drafting of the manuscript, validation of the manuscript
- Edwin Paipa Sanabria 4Contribution: Methodology, validation, mansucrtude review
- Yamileth Aguirre Restrepo 5: Contribution to the drafting of the manuscript, validation

Conflict of Interest Statement

The authors declare that there are no conflicts of interest that may have influenced the results or interpretation of the data presented in this article.

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