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Towards Smart Green Blue Infrastructure

MEASURING GREEN PORT MANAGEMENT AS DETERMINANT OF PORT ATTRACTIVENESS AND COMPETITIVENESS

Abdelhamid ADARRAB [(1)] and Mohamed MAMAD [(2)]

(1) Laboratory of Economics and Management of Organizations, Ibn Tofail University, Kénitra, Morocco, abdelhamid.adarrab@uit.ac.ma

(2) Laboratory of Economics and Management of Organizations, Ibn Tofail University, Kénitra, Morocco, mamad.mohamed@uit.ac.ma

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1. **ABSTRACT:** This paper introduces 'Green Port Management (GPMan)' as a pivotal element among the 'nine Port Attractiveness Determinants (PADs)', leveraging an extensive review of 87 publications from 1970 to 2022. Through a rigorous methodology, the study refines the concept of 'GPMan', with 15 seminal works that were scrutinized in-depth. This analysis culminated in the identification of seven critical attributes that encapsulate 'GPMan', addressing a notable gap in existing literature which often discusses 'GPMan' without presenting clear, measurable indicators for port attractiveness. To bridge this knowledge gap, the findings propose a structured framework for evaluating the green attractiveness of ports. This framework is crucial for academics and managers alike, enabling the assessment of a port's capacity to attract eco-friendly actors economically and to quantify its ecological impact on stakeholders. Significantly, the research underscores three predominant attributes: the dynamic implementation of green port projects aimed at mitigating environmental impact, the establishment of a robust regulatory framework through the adoption of environmental regulations at national, regional, and global levels, and the implementation of a system to reward or penalize port operators based on their adherence to predefined environmental criteria. Additionally, the paper showcases various projects across Africa, illustrating the diverse green and sustainable strategies that port managers have adopted to enhance Green Port Management effectively. By filling the existing research void and offering insights for a future research agenda, this study not only advances the discourse on 'GPMan' but also provides a comprehensive approach to enhancing port attractiveness through sustainable practices.

2. INTRODUCTION

Ports, in their 'multum in parvo' essence, occupy a multifaceted role in today's world. Beyond their geographical significance as territories, ports are engines of economic growth, catalysing value creation and employment. From the perspective of civil engineering, ports are complex constructions; computer scientists, however, see them as digitization-ready infrastructures. Ecologists often view ports as potential threats to the lithosphere, hydrosphere, atmosphere, and the encompassing biosphere. The environmental impact of port and maritime operations, particularly concerning the emission of Greenhouse Gases (GHG), has become increasingly pivotal—especially in high-energy sectors like the cruise and ferry industries. This concern has instigated a paradigm shift among port authorities, urging a focus on energy efficiency, sustainable practices, and the transition to cleaner energy sources (such as Green Hydrogen,

LNG, renewables, and marine energies), as well as the implementation of CO_2 capture mechanisms and strict adherence to ecological regulations. In this complex and varied landscape, the discipline of port marketing becomes essential, converging different viewpoints to craft strategies that augment the allure of ports. Emphasizing sustainable and eco-friendly practices, this strategic approach goes beyond merely drawing investors. It encompasses attracting tourists, enhancing local community engagement, influencing the choices of ship-owners, involving port operators in green cargo handling, and appealing to service providers. Furthermore, the concept of port attractiveness extends past the physical limits of ports, involving international entities, institutional organizations, communication experts, and scholars in port marketing research. Despite its growing significance, the discipline of port marketing is still evolving.

Territorial marketing strategies, emphasizing the economic, social, and environmental attributes of local communities, have gained increasing significance in the realm of port development strategies. These approaches markedly diverge from conventional marketing frameworks. Indeed, traditional marketing models have been extensively developed over the years, both in scientific research and theoretical advancements. This is exemplified by the 4Ps of product marketing—Product, Price, Place, and Promotion, initially conceptualized by McCarthy in 1960 [28], and the 7Ps of service marketing—Product, Price, Place, Promotion, People, Process, and Physical evidence, introduced by Booms and Bitner in 1981. However, for the marketing mix of a territory, specifically a port or an airport, the theoretical foundation of other traditional marketing typologies proves analogously inadequate for transposition into such a complex environment, considering the diverse stakeholders, parties, and clients involved. In this context, a recent study has identified nine elements to assess the overall attractiveness of a port [3]. Termed 'Port Attractiveness Determinants (PADs)', these elements can analogously be applied to a given territory or, more specifically, to a port or an airport, forming their marketing mix. The so-called 'nine PADs'—or 9Ps to speak the marketing mix's language, comprise 'Port Location, Port Connectivity, Port Facilities, Port Costs, Port Service Quality, Port Policy and Management, Port Governance, Port External Environment, and Green Port Management' [3]. This framework offers a more nuanced and comprehensive approach to territorial marketing, particularly in the context of ports and airports, where traditional marketing models fall short.

This study focuses on 'Green Port Management (GPMan)' as a one of key element in port attractiveness development strategies. An examination of 15 papers from an initial set of 87 identified seven key elements. However, there is a discernible gap in integrating this determinant into academic research on port attractiveness and competitiveness. Recent scholarly work, notably by Munim *et al.* [30], indicates a burgeoning interest in incorporating environmental factors into port attractiveness assessments, underscoring the growing importance of environmental considerations in the wider context of port competitiveness and attractiveness. In addressing the central question, 'What are the attributes of Green Port Management as a determining factor in port attractiveness?', this paper delves into several sub-questions: 'How is 'GPMan' conceptualized and defined in the context of Port Attractiveness Determinants (PADs)?', 'What specific port traffic and continent are the most frequently studied in case of 'GPMan' ?', 'Which are the methods and/or approaches most utilized by authors?' and, 'How can 'GPMan' be operationalized for practical application in ports?'. The research's primary objectives are to fill the existing knowledge gap regarding the role of 'GPMan' in the 'PADs' through proposing a model for evaluating 'GPMan', and offering practical insights and guidance for its implementation and future scholarly inquiries.

For this purpose, we undertake a thorough investigation, unveiling bibliometric results and content analysis findings in Section 5.1, followed by Section 5.2 which focuses on developing a

model for measuring 'GPMan' within the framework of the nine Port Attractiveness Determinants. The discussion Section will focus on examining the evolution of environmental considerations in shaping port attractiveness (Section 6.1) and zooming on the distinction between 'GPMan' determinant from other environmental indices (Section 6.2). The Section 6.3 offers scientific recommendations for the practical implementation of the research-derived tool followed by advocating for a forward-looking research agenda (Section 6.4). After that, The Section 6.5 enumerates a series of African real-world case studies related to the application of the seven attributes inherent to the 'GPMan' determinant from African ports. Finally, the Section 6.6 lists the limitations of this study and suggest some recommendations to the potential next contributions. Before detailing the methodology employed, the following section provides a synthesis of the literature review concerning the concepts of Green Port, Port Attractiveness, Port Competitiveness and concludes with an examination of the interconnections among these themes.

3. LITERATURE REVIEW

As highlighted in the introduction, the environmental issues within the port ecosystem hold paramount importance both from an ecological perspective, meaning the protection of planet Earth, and from an economic standpoint through the development of businesses. What is even more surprising in the port context is that the more efficient we become, the less polluting we are. In terms of port operations, increased speed in loading or unloading automatically translates into reduced emissions. For instance, when container ships spend less time at ports, it becomes feasible to lower their cruising speed [19]. According to Ding *et al.* [15], the transition towards sustainability in port operations is imperative as it emphasis the importance of ecological initiatives and responsibility within the maritime and port sectors. Furthermore, Ding *et al.* highlight the increasing efforts by port stakeholders to ensure operational safety and efficiency, in addition to implementing policies for green energy. In fact, the shift towards eco-friendly practices is critical; ports adhering to high environmental standards are more likely to attract shipping companies, underscoring the role of sustainability in enhancing port attractiveness and competitiveness [15]. This is only from an operational perspective, while other issues concern the environmental aspect in the port and maritime industry as a whole. Acciaro *et al.* [2] and Parola *et al.* [35] both underscore the necessity of innovation in the port and shipping sectors for sustainability, emphasizing that successful adoption of technologies such as onshore power supply and alternative fuels hinges on alignment with port stakeholders' demands and the broader institutional context, alongside the implementation of environmental strategies to harmonize efficiency, growth, and sustainable transportation and logistics. Indeed, incorporating sustainable hinterland strategies is pivotal for enhancing port competitiveness and fosters a strategic commitment to environmental sustainability in port infrastructure development [33]. While Lam and Notteboom [24] focus on how leading ports in Asia and Europe utilize pricing, monitoring and measuring, and market access control to enhance green port development, Acciaro *et al.* [1] argue that active energy management can lead to substantial efficiency gains, contribute to new revenue sources, and ultimately enhance the competitive position of ports. Meanwhile, Ergin and Eker [19] discuss how green port projects, aimed at reducing environmental impacts of ship and port operations, have become a competitive necessity. Amidst these multitudes of perspectives, and given the complexity of the port and maritime sectors, Acciaro *et al.* [2] deduce that there is a need for advanced conceptual frameworks that account for the multi-stakeholder nature of the port industry and the interactions required for environmental sustainability.

Generally, the concept of port attractiveness is articulated as a comprehensive framework evaluating a port's ability to satisfy and surpass the diverse needs of its stakeholders by

leveraging a constellation of determinants and attributes [3]. By integrating these elements, it offers a nuanced perspective on the factors that make a port a favorable destination for shipping lines, cargo owners, service providers, external investors, and tourists, to name a few. As a reminder, among the determinants of attractiveness previously mentioned is 'Green Port Management' [3,30]. In the same vein, Munim *et al.* [30] highlight the growing importance of green port practices in determining a port's attractiveness. They noted that alongside operational and performance indicators, environmental performance indicators are increasingly significant for users when selecting a port [30]. Indeed, according to Acciaro *et al.* [2], environmental sustainability and innovation contribute to a port's attractiveness by enhancing its green profile and compliance with environmental regulations. This attractiveness could be seen as stemming from a port's ability to meet green objectives and implement successful environmental innovations, making it more appealing to stakeholders concerned with sustainability and an eco-friendly environment. Lam and Notteboom [24] underline that environmental aspects play an increasing role in influencing port attractiveness, as trading partners and investors are likely to prefer (or choose) ports with strong environmental records. This includes the implementation of green port initiatives as a means to boost port attractiveness through improved environmental performance and compliance with regulatory standards [24].

Port competitiveness, as discussed in Ding *et al.* [15], is closely linked to the concept of port attractiveness. The competitiveness of a port is perceived as a function of its ability to meet the demands of port users and provide superior services, which in turn is influenced by the port's attractiveness determinants. In other words, port attractiveness, determined by specific key factors, serves as a prerequisite for achieving competitiveness [15]. This aspect is further explored as the ability of ports to satisfy user demands through superior service offerings, thereby enhancing user satisfaction and loyalty [15]. Moreover, improved competitiveness is seen as a way to enhance a port's attractiveness [30]. Acciaro *et al.* [1,2] emphasize the critical role of energy management in boosting port competitiveness, positing that ports focusing on energy efficiency and sustainability are better positioned in the market. They argue that while environmental performance may result from competitive pressures necessitating a balance between efficiency, regulatory compliance, and sustainability, innovation in green practices is essential for maintaining competitiveness. Likewise, Lam and Notteboom [24] assert that the adoption of green port practices plays a significant role in port competitiveness, not only by improving operational efficiency but also by ensuring compliance with environmental regulations and meeting the expectations of various stakeholders.

In exploring the linkage between 'GPMan', port attractiveness, and competitiveness, existing literature underscores a fundamental interconnectedness that pivots on sustainability as an indirect enhancer of port customer satisfaction. Acciaro *et al.* [1,2] delineate how active engagement in energy management and sustainability practices not only bolsters a port's environmental credentials but also augments its attractiveness and competitive edge by aligning with the evolving sustainability expectations of stakeholders. This sentiment is echoed by Parola et al. [35], who articulate that the challenges of sustainability are intrinsically linked to a port's competitiveness and attractiveness, advocating for sustainability to be viewed as a strategic imperative rather than merely a compliance obligation. Similarly, Lam and Notteboom [24] illustrate that the integration of comprehensive environmental management tools serves dual purposes: mitigating port operation impacts and enhancing global maritime competitiveness. They advocate for an integrated approach that synergizes various management tools to foster sustainability while preserving competitive advantage. Notteboom and Rodrigue [33] extend this discourse by highlighting how sustainable practices in hinterland development not only fulfill environmental responsibilities but also optimize operational

efficiency, thereby enhancing the port's appeal and competitive stance in global supply chains. Ergin and Eker [19] further contribute to this narrative by suggesting that green port initiatives, as an integral component of environmental criteria, elevate a port's environmental performance alongside its competitiveness by addressing global environmental concerns and operational efficiency. Collectively, these studies illuminate a synergistic relationship where 'GPMan' is a determinant of port attractiveness and competitiveness, indicating that embracing sustainability is a strategic pathway to achieving market superiority and ecological equilibrium in the logistics sector.

4. METHODOLOGY

The methodological foundation of this paper is derived from Adarrab *et al.* [3]'s study that employs a systematic review methodology, superior to narrative reviews, using well-established, rigorous criteria to select, assess, and integrate findings from both peer-reviewed and gray literature. The scope of the review spans from the 1970s to 2022, segmented into three distinct periods for detailed analysis. The research involves a keyword selection process using the "snowballing" method and Boolean operators (*See the list of keywords in Adarrab et al. [3]*). The query is first conducted on Scopus search engine. The selection focuses on English-language publications (exclusion criterion) to cater to a global audience, encompassing diverse formats like articles, book chapters, and conference papers (inclusion criterion). From an initial pool of 131 relevant articles, the study narrows down to 99 for thorough evaluation. After a comprehensive review, 32 papers with a narrow focus on specific maritime and port industry aspects are excluded. The final analysis includes 75 papers from a mix of 37 peer-reviewed journals. Secondly, due to their scientific relevance, 12 unindexed references from various sources were added to the group of indexed paper, to minimize the exclusion criteria and the database bias. The final list retained for the literature review, as depicted in Figure 1, underwent both automated and manual analysis. This comprehensive process facilitated the identification of 116 attributes that define the 'nine Port Attractiveness Determinants (PADs)'. This includes seven specific attributes associated with 'GPMan', extracted from 15 out of the 87 papers analyzed. To achieve these findings, the two distinct analytical methods used to achieve these findings are as follow:

- **Automated Analysis**: This involved using software for analysing the authors of the sample and conducting a thorough textual analysis of all abstracts and titles;

- **Manual Analysis**: This method involved a comprehensive examination of the sample (87 papers) to extract the port attractiveness attributes (items). Four reviewers conducted in-depth screening of papers to comprehend the diverse semantics involved and to classify the attributes into the related 'PADs'.

In the following section, the results related to the 'GPMan' as 'PAD' are structured into two parts. The first subsection focuses on the corpus' metrics, while the second one lists the seven key items. Subsequently, all determinants are modelled, placing particular emphasis on the attributes of 'GPMan'.

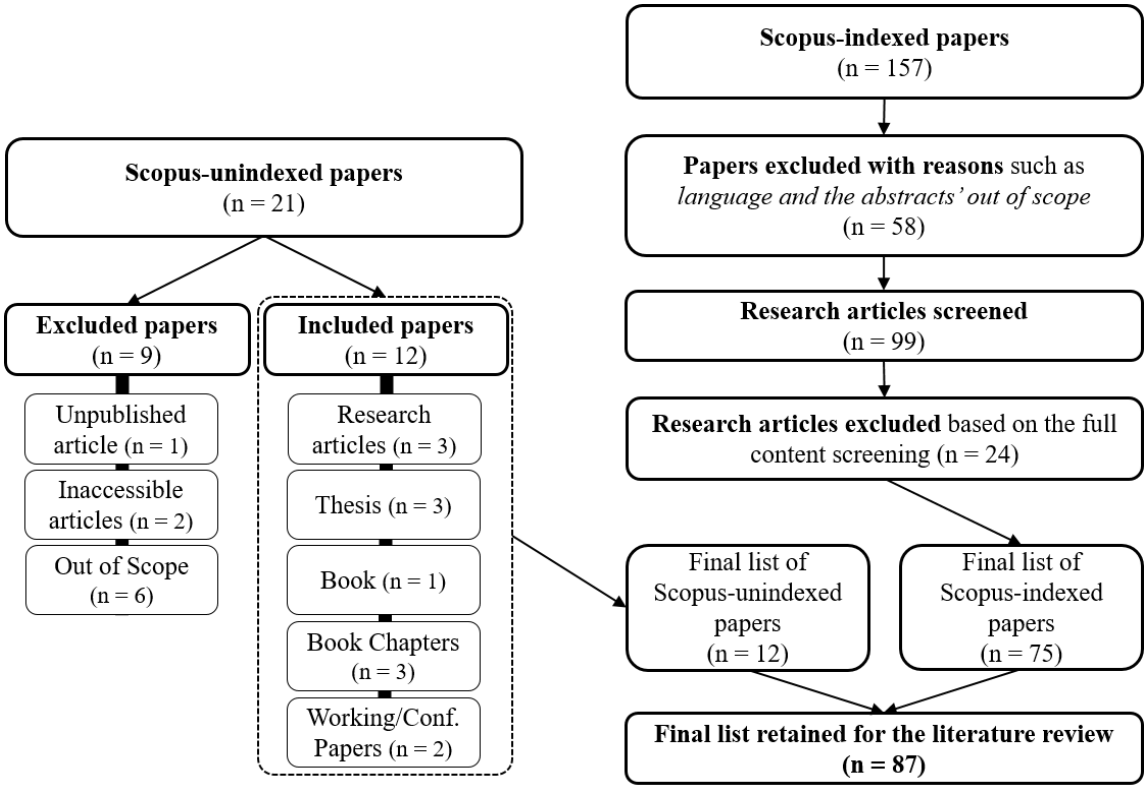

Figure 1: Process summary

Source: Adarrab *et al.* [3]

5. RESULTS

In total, 116 items were identified to gauge the 'nine PADs', among them seven items related to 'Green Port Management (GPMan)'.

5.1 Corpus' metrics

Building on the methodology previously outlined, a comprehensive analysis of the sample led to the selection of 15 papers from an initial set of 87 references. This exercise resulted in the identification of seven key attributes related to the attractiveness determinant of 'GPMan'. The metrics for this refined sub-sample encompassed a variety of bibliometric and content criteria, itemized as below:

- **Bibliometric Criteria**: Encompassing six key aspects – publication year, authorship, paper type, citation frequency according to Google Scholar metric, the publishers or journals where these papers appeared, and the H-index of these publications based on Scimago Journal Ranking. (See Table 1)

- **Content Criteria**: This category includes four principal areas: types of traffic discussed, methods used, and details of the case studies undertaken.

In the exploration of the sub-sample with respect to the most frequently studied type of traffic, it was noted that 40% of the papers used for extracting attributes of 'GPMan' determinant focused on ports handling container traffic, representing 6 of the 15 papers.

Similarly, 40% of the papers did not differentiate between specific types of port traffic.

Regarding the methods utilized by the authors' sub-sample, a preference for multi-criteria methods was evident. For instance, Mittal and McClung [29] adopted the Analytic Hierarchy Process 'AHP', while Ergin and Eker [19] implemented the Technique for Order of Preference by Similarity to Ideal Solution in its Fuzzy form 'Fuzzy TOPSIS'. Ding *et al.* [15] and Wang *et al.* [43] both employed combined methods, with the former incorporating 'AHP' and the 'Decision-Making Trial and Evaluation Laboratory' approach, while the latter utilized 'Fuzzy DELPHI' and 'TOPSIS'. Additionally, Munim *et al.* [30] utilized Confirmatory Composite Analysis using Partial Least Squares Structural Equation Modelling.

In terms of the geographic focus, of the 10 papers that specified port locations, Asian ports were the most examined, represented in 6 papers, followed by European ports in 5, and North American ports in 3. No studies within this corpus focused on ports in Africa, South America, or Australia in the context of 'GPMan' as a determinant of port attractiveness.

Table 1. Metrics of the Green Port Management's corpus

Year	*Author(s)*	*Paper Type*	*Google scholar citation**	*Editor/Journal title*	*SJR H-index**
1986	Branch [7]	Book	194	n.a	n.a
2005	Notteboom and Rodrigue [33]	Article	1713	Maritime Policy and Management	67
2008	De Martino and Morvillo [14]	Article	170	Maritime Policy and Management	67
2012	Bergqvist and Egels-Zandén [9]	Article	130	Research in Transportation Business and Management	45
2014	Lam and Notteboom [24]	Article	368	Transport Reviews	100
2014 a	Acciaro *et al.* [1]	Article	348	Energy Policy	254
2014 b	Acciaro *et al.* [2]	Article	295	Maritime Policy and Management	67
2014	Wang *et al.* [43]	Article	86	Transport Policy	113
2016	Mittal and McClung [29]	Article	18	Journal of the Transportation Research Forum	5
2017	Parola *et al.* [35]	Article	220	Transport Reviews	100
2018	Marek [49]	Conference Paper	3	SHS Web of Conferences - GLOBMAR 2018	n.a

2019	Ding *et al.* [15]	Article	30	Maritime Policy and Management	67
2019	Ergin and Eker [19]	Article	12	Transactions of the Royal Institution of naval Architects Part A: International Journal of Maritime Engineering	20
2019	De Icaza *et al.* [13]	Article	6	Decision Analysis	26
2022	Munim *et al.* [30]	Article	2	Case Studies on Transport Policy	31

**Data updated on December 3th, 2023*

Source: Authors

5.2 Green Port Management's measurement

The emphasis is on ports' environmental sustainability, including enhancing water quality, lowering air pollution, and aiming for carbon neutrality, as key issues. Notably, 14 out of the 15 reviewed papers have discussed this aspect. In addition, the practice of incentivizing or penalizing port operators based on their adherence to specific environmental objectives has been identified in five of the papers. Meanwhile, the stringency of environmental regulations within port jurisdictions has been recognized as a competitive advantage, but when it comes to practical application, it frequently becomes a topic of ongoing debate and negotiation. Other noteworthy aspects include the provision of waste reception facilities within the port (mentioned twice) and the communication of information on green activities through environmental reports (mentioned four times). The implementation of an 'Environmental Management System' (EMS) and the utilization of renewable energy resources have each been emphasized twice, underscoring their importance in the discourse on 'GPMan'. Furthermore, the consideration of national, regional, and global environmental regulations has emerged as a recurring theme, cited seven times, reflecting the broader regulatory context within which 'GPMan' operates. It is important to note that the frequency of citation serves as an indicator of how often specific attributes are discussed in the literature (Table 2). However, it is crucial to recognize that attributes with lower citation frequencies are not necessarily less important than those with higher frequencies. This observation holds true for the entire model, as illustrated in Figure 2, signifying the significance of each attribute in the assessment of determinants by decision-makers and their impact on the attractiveness of a specific port.

Table 2. Framework for evaluating GPMan as PAD.

Green Port Management (GPMan) as Port Attractiveness Determinant (PAD)			
Item Code	*Measurements*	*Frequency of citation*	*Sources*
Gpm_Gppr	Environmental sustainability of the economic activities linked to the port that include green port	14	Munim *et al.* [30] ; Ding *et al.* [15] ; Ergin and Eker [19] ; Marek [27] ; Bergqvist and Egels-Zanden [9] ; Notteboom and Rodrigue [33] ;

	projects such as protecting water quality and animals, reducing harmful air emissions, carbon neutrality/carbon footprint, and others environmental solutions-alternatives initiatives		De Martino and Morvillo [14] ; Lam and Notteboom [24] ; Acciaro *et al.* [1] ; Acciaro *et al.* [2] ; Parola *et al.* [35] ; Branch [7] ; Mittal and McClung [29] ; De Icaza *et al.* [13]
Gpm_Rpeg	Reward or punishment of port operators over/under performing against specific environmental goals	5	Munim *et al.* [30] ; Bergqvist and Egels-Zanden [9] ; Lam and Notteboom [21]; Acciaro *et al.* [2] ; Wang *et al.* [43]
Gpm_Ware	Waste reception facilities within the port	2	Munim *et al.* [30] ; Acciaro *et al.* [1]
Gpm_Ciga	Communication of information on green activities of the port (e.g. environmental report)	4	Munim *et al.* [30] ; Ergin and Eker [19] ; Lam and Notteboom [24] ; Acciaro *et al.* [2]
Gpm_Iems	Implementation of 'Environmental Management System' (EMS)	2	Lam and Notteboom [24] ; Acciaro *et al.* [2]
Gpm_Ispe	Implementation of system for the production of energy from renewable resources	2	Acciaro *et al.* [1] ; Acciaro *et al.* [2]
Gpm_Iner	Implementation of national/regional/global environmental regulation.	7	Munim *et al.* [30] ; Ding *et al.* [15] ; Bergqvist and Egels-Zanden [9] ; Notteboom and Rodrigue [33] ; Lam and Notteboom [24] ; Acciaro *et al.* [1] ; Acciaro *et al.* [2]

Source: Authors

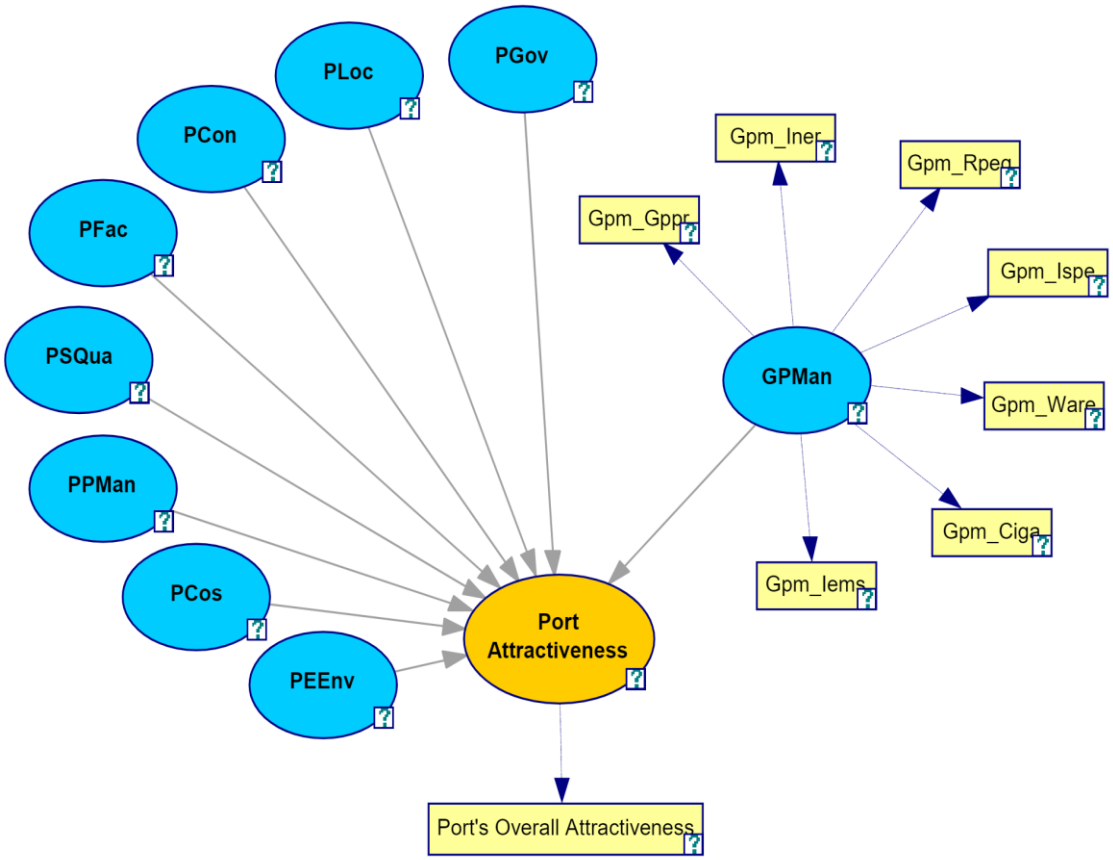

Figure 2: Modelling the measurement of 'GPMan' as one of the Nine PADs

Source: Authors, based on 'GeNIe Modeler' software and inspired by Adarrab *et al.* [3]

6. DISCUSSION

The discussion concerning the crucial impact of 'GPMan' on enhancing the appeal of ports has drawn significant scholarly interest. Numerous key measurement factors have been highlighted for their relevance in scholarly works. In summary, these factors collectively contribute to a comprehensive understanding of the determinants of port attractiveness, especially in the context of 'Green Port Management'.

6.1 Evolution of environmental considerations in port attractiveness

Branch's [7] pioneering work emphasized ecological aspects in port environments, leading to the rise of 'GPMan' in Notteboom and Rodrigue's [33] studies and further development by De Martino and Morvillo [14]. In today's context of increasing environmental concerns, 'GPMan' has shifted from optional to essential for attracting environmentally-focused partners and investors [26]. Acciaro *et al.* [1] explored energy efficiency in ports, highlighting its environmental impact. Avom and Gandjon Fankem [6] argued for public policies that balance environmental and territorial attractiveness, a concept Alix and Guy [5] noted is gaining attention, especially regarding environmental factors. Ergin and Eker [19] stated that environmentally friendly initiatives in ports are crucial, making environmental considerations a core element in port attractiveness research.

6.2 Comparative analysis of 'GPMan' and other Indices tools

This study does not seek to create a novel index for evaluating the environmental impact of maritime and port activities. Rather, the findings detailed in Section 4.2 present a collection of items and attributes designed to assess 'GPMan' within the context of port attractiveness. It is crucial to distinguish this approach from indices that evaluate environmental issues in terms of impact or performance, which have been developed by international organizations (for instance, the 'Environmental Ship Index (ESI)' initiated in 2011 by the 'International Association of Ports and Harbors (IAPH)' [17], and the 'Environmental Port Index (EPI)' developed by 'Det Norske Veritas (DNV)' in partnership with various experts [18]), or by researchers such as the 'Maritime Environmental Performance Indices (MEPI)' [11] and the 'Port Environmental Performance Index (PEPI)' [37]. Yet, the 'GPMan' determinant's seven attributes enhance port environmental appeal, strategically complementing, not duplicating, other tools.

6.3 How it works?

One prominent characteristic of ports is their uniqueness, which highlights the need to adapt any assessment tool to a variety of context-specific factors, such as the type of cargo handled, the governance structure, and the port's geographical location. For the successful implementation of the 'GPMan' tool described in this study, the first step involves determining the relative importance of the seven attributes of 'GPMan' among decision-makers. The purpose of this stage is to establish an assessment of the importance of each attribute from the perspective of the port stakeholders implementing the 'GPMan' Tool. In this context, a range of methods are available to assess the importance of these attributes, including multi-criteria techniques such as the Analytic Hierarchy Process (AHP), developed by Thomas Saaty in 1971 [45], the Analytic Network Process (ANP) and its Fuzzy variant (FANP) [39], the Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) [8], and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) introduced by Hwang and Yoon [22], and its Fuzzy version [10]. Moreover, the ELEmination and Choice Translating REality (ELECTRE) method, introduced by Bernard Roy in 1968 [38] and later developed in various forms, as well as the DEcision MAking Trial and Evaluation Laboratory (DEMATEL) method, introduced by Fontela and Gabus in 1972 [40], are also relevant. It is noteworthy that while the results may vary depending on the method used for evaluating significance, the overarching goal remains the same: to gauge the perceptions of decision-makers about the comparative importance of one attribute versus another in enhancing the attractiveness of the port in study. After contextualizing the importance of these elements, the second step involves measuring these attributes among the port's clients. The final outputs allow for the identification of the environmental attributes of the port that contribute to its attractiveness and those that are its weaknesses. Therefore, a strategic plan can be developed, one that various stakeholders with different perspectives should adhere to.

6.4 Insights into the future research agenda

Regarding future research directions, it is advisable for academics to explore the theme of port attractiveness by conducting case studies on African ports. The findings of this study reveal a significant gap in existing literature, particularly in the context of 'Green Port Management'. This gap is evident in two distinct areas: firstly, within the African continent, and secondly, in the sector of cruise activities and ferry services [25] when considering the 'Type of Port Activity' perspective.

Within the managerial domain, numerous Green port initiatives have been instituted by port

authorities and governmental institutions at various African ports. Prominent among these are the Tanger Med Port Authority in Morocco [42], the National Ports Agency in Morocco [4], Djibouti Ports and Free Zones Authority (DPFZA) [16], the Autonomous Port of Abidjan in Côte d'Ivoire [41], the Autonomous Port of Dakar in Senegal [20], Somaliland Ports Authority in Somalia [34], the Autonomous Port of Cotonou in Benin [36], and the Alexandria Port Authority in Egypt [21]. These entities integrate environmental protection into their core missions, balancing it with operational regulation and combating pollution. Their initiatives (See Section 5.5) encompass energy transition strategies, green infrastructure, and conducting environmental impact assessments for sustainable development.

In concluding insights, it is imperative for both researchers and managers to actively engage in the democratization of emerging technologies. Key technologies, including the Internet of Things (IoT), Machine Learning Models (MLM), and No Code tools, should be utilized to their fullest potential. These technological advancements are instrumental in processing extensive data from varied sources and integrating multiple indices collaboratively developed by both organizations and the academic community. Importantly, no singular model exists for the comprehensive analysis of environmental indicators, be it in assessing the impact of port activities or in enhancing port attractiveness. The strategic deployment of IoT alongside Artificial Intelligence (AI) in data processing emerges as a critical factor in unifying stakeholders within the port and maritime sectors. This unification is crucial for advancing sustainable development in port and logistics activities, thereby aligning with the framework of "Sustainable Resilient Infrastructure Perspective in Ports and Logistics" which is the general theme of the Marlog'13's conference.

6.5 Renewable energy and green port initiatives: Case studies from Africa

Theoretically, recent research has illuminated the complex landscape of renewable energy in Africa. Chukwuemeka *et al.* [12] explore the emerging renewable energy sector on the continent, driven by policy reforms and investment, while also recognizing significant socio-political and economic challenges. Meanwhile, Müller *et al.* [31] examine the shift from fossil fuels to renewable energy, highlighting the need for innovative resource extraction methods in the 'Global South'.

In practical terms, numerous African ports have initiated the implementation of environmentally sustainable management practices. For instance, the Namibian Ports Authority has demonstrated a significant commitment to reducing its energy and water consumption by focusing on alternative energy strategies. Key initiatives include a comprehensive study assessing the feasibility of solar and wind energy adoption at the Port of Walvis Bay, as well as a pilot project aimed at adapting a tugboat for dual-fuel use, utilizing hydrogen and diesel [32].

When analysing the sources of carbon emissions by the Namibian Ports Authority, it is noteworthy that petroleum consumption decreased by 22%, declining from 76,422 litters in 2019 to 59,502 litters in 2023, while diesel consumption dropped by 17.8%, decreasing from 2,060,521 litters in 2019 to 1,692,826 litters in 2023. Conversely, electricity consumption exhibited a notable reduction of 26.65%, declining from 7,724,302 kWh in 2019 to 5,665,637 kWh in 2023. Efforts in reducing water consumption at the port are essential, and this can be achieved by implementing seawater desalination facilities. Nevertheless, overall, Namport's efforts in implementing green projects are evident in the decrease of CO_2e, the standard unit for measuring greenhouse gas emissions, which decreased from 11,275 CO_2e in 2018/19 to 8,766 CO_2e in 2022/23, considering both direct emissions (from fuel and diesel) and emissions related to electricity consumption [32].

Another pertinent example is the Autonomous Port of Cotonou in Benin, which has established an Environmental Management System (EMS) to monitor the performance of specific port-related indicators (e.g., indicators related to compliance with laws and regulations, such as the number of pollution-related complaints per month, the percentage of port operators conducting internal environmental audits, and the number of initiatives aimed at reducing energy consumption) [36].

Finally, a third case is that of the National Ports Agency in Morocco, which has implemented a sustainable development roadmap categorized into four main axes: Energy, Water, Port and Marine Environmental Preservation, and Resilience to Climate Change. For instance, the installation of five wind turbines in three ports is expected to mitigate 4.7 million kilograms of CO^2 emissions. Regarding water, desalination stations will demineralize up to 34 litters per second and will be powered by 50% solar energy. Furthermore, the Table 3 below provides qualitative insights into the variable 'Green Port Management' as one of the determinants for assessing port attractiveness. It establishes connections between the attributes used to measure it and provides examples of green initiatives undertaken by ports in the context of the African continent.

These initiatives collectively contribute to the enhancement of the attractiveness of the 'C-C-R-C-P', which stands for five territorial dimensions: Continent-Country-Region-City-Port nexus.

Table 3. Some African cases related to the Green Port Management's items

Item Code	*African case concerned*			*Title of the Project/Action*	*Project/Action's case consistency*
	Port	*Authority or Manager*	*Country*		
Gpm_Gppr	Port of Durban	Transnet National Ports Authority	South Africa	WILDOCEANS Blue Port Project	Durban Port's eco-restoration project focuses on cleaning and restoring the port's natural ecosystem. It includes low-cost waste management trials and a mobile app for reporting pollution. Supported by Grindrod Bank, the Blue Fund, and Nedbank's YES program, it also offers capacity building and work experience for local unemployed youth [44].
	Port of Mohammedia, Port of Casablanca, Port of Jorf Lasfar, Port of Safi and Port of Agadir	National Ports Agency	Morocco	Port Sanitation Project	The project aims to implement cleanliness measures, with a focus on identifying sources of liquid and solid discharges that could impact the water quality in port basins and adjacent areas. Biannually, water and sediment samples are collected from ports across the Kingdom by a state-approved laboratory. This is done to monitor the progression, nature, and sources of marine waste.
Gpm_Rpeg	Real Case of Punishment of an Operator at Port A	National Ports Agency	Morocco	Water and Land Area Patrol and Enforcement through the application of Article 110 of Law No. 67-14 on Port Police	The case, illustrating the consequences of environmental breaches in port operations, recounts an incident in which an operator triggered pollution while handling cargo within the port's land area. This narrative underscores the implementation of Article 110 of Moroccan port police legislation, which prescribes a penalty of 50,000 Moroccan Dirhams (DH).
	Real Case of Punishment of a Ship at Port B			Water and Land Area Patrol and Enforcement through the application of Article 125 of Law No. 67-14 on Port Police	This case highlights environmental violations in port operations as it describes a vessel's role in polluting a port basin with hydrocarbon discharges. It underscores the enforcement of Article 125 in Moroccan port police regulations, imposing imprisonment for 1 to 3 months and a fine of 20 Moroccan Dirhams per ton (with a minimum of 6,000 DH and a maximum of 200,000 DH).
Gpm_Ware	Tanger Med Port	Tanger Med Port Authority	Morocco	Waste reception facilities	The port complex at Tangier Med has implemented two wastewater treatment facilities, incorporating Sequencing Batch Reactor (SBR) systems for innovative and biological wastewater processing, conducted within cylindrical reactor units.
Gpm_Ciga	Port Cotonou	Port Autonome de Cotonou	Benin	Environmental Status of the Port of Cotonou	In August 2023, the 'Port Autonome de Cotonou', in collaboration with Anvers Bruges International Ports, released a report on the environmental status of the Port of Cotonou. This comprehensive document details the port's environmental initiatives and challenges. [36]
	Namport	Namibian Ports Authority	Namibia	Carbon emissions reporting	Namport's carbon emissions annual reporting chapiter details data across three scopes: direct emissions, indirect electricity-related emissions, and broader indirect emissions. The reporting offer a comparison of the Carbon emissions during 5 last years [32].
Gpm_Iems	Tanger Med Port	Tanger Med Port Authority	Morocco	Waste management system	The port effectively manages liquid and solid waste from ships in compliance with MARPOL regulations. Liquid waste is collected and treated using barges and tanker trucks, while solid waste is gathered and processed by trucks. Furthermore, emissions from ship gas purifiers are collected and treated.
Gpm_Ispe	Port of Casablanca, Port of Mohammedia, Port of Jorf Lasfar	National Ports Agency	Morocco	Renewable Solar Energy	In order to enhance sustainability and reduce energy costs, the port authority have implemented the installation of both solar panels and photovoltaics, effectively harnessing renewable energy sources.
Gpm_Iner	Mombasa port	Kenya Ports Authority	Kenya	Green Port Policy	The Kenya Ports Authority (KPA) has adopted a Green Port Policy (GPP) to promote environmental sustainability in maritime activities. The policy requires transitioning incoming vessels from diesel to electric power to reduce emissions and enhance biodiversity conservation. This initiative highlights KPA's commitment to sustainable port management and the protection of marine ecosystems and resources [23].
	All Moroccan ports	Tanger Med Port Authority and National Ports Agency	Morocco	Law No. 67-14 on Port Police	Recently adopted in 2020, this law represents a significant update to Morocco's port legislation, with a specific focus on environmental matters. It has a broad impact on all ports within the Kingdom, aiming to establish a robust legislative framework that ensures optimal management and operations. This Law prioritizes safety, security, environmental protection, quality, and performance as key facets of port.

Source: Collected by authors

6.6 Limitations and Recommendations

The primary limitation of this study is its exclusive dependence on literature indexed by Scopus, which may inadvertently neglect relevant research not indexed within this database.

Additionally, conducting searches solely through Scopus's search engine inherently excludes potentially pertinent studies, suggesting an inherent selection bias. To mitigate this limitation, it is advisable to broaden the research scope by incorporating other databases such as Web of Science, JSTOR, CAIRN, or Google Scholar. Despite these constraints, we made an effort to include 12 non-Scopus-indexed papers due to their significant relevance. Similarly, the inclusion and exclusion criteria introduce biases in the sample selection process, a common limitation of systematic literature review methods. To address these issues, future research should consider employing a hybrid literature review methodology that combines systematic and narrative review processes. Lastly, given the insufficient exploration of the contribution of technological tools (e.g., artificial intelligence) to environmental sustainability goals within this paper, it is recommended that academics pursue action research in collaboration with decision-makers and developers. This approach aims to align AI solutions more effectively with specific environmental sustainability challenges.

7. CONCLUSION

This research emphasizes 'Green Port Management's (GPMan)' transition from an optional to an essential practice in enhancing port attractiveness and competitiveness, driven by growing environmental awareness. It highlights the role of 'GPMan' in attracting eco-aware partners and differentiates its methodology from existing environmental models. The study presents a customized evaluation framework for ports, considering their diverse operations, and points out a research void in African ports and energy-demanding sectors, indicating areas for future study. It advocates for the integration of innovative technologies and sustainable practices in line with global environmental conservation trends, suggesting that this interplay will redefine port attractiveness strategies. This is underpinned by the identification of seven 'GPMan' attributes, including environmental sustainability in port activities, incentivizing eco-friendly operations, waste management facilities, publicizing green efforts report, implementing Environmental Management Systems (EMS), renewable energy utilization, and adherence to environmental regulations, demonstrating the study's comprehensive approach to sustainable port management.

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Corresponding author