Intelligent Human Systems Integration (IHSI 2025), Vol. 160, 2025, 21–34
https://doi.org/10.54941/ahfe1005807

Human Systems Integration and Design in Port Terminal Concessions: A Bibliometric Study of End-of-Life Management and Decommissioning Guidelines

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ABSTRACT

This paper addresses the complexities in managing port terminal concessions, focusing on the final asset compensation sub-phase during the pre-biding phase, a critical yet under-researched area in maritime academic literature. The employment of bibliometric analysis revealed four key clusters: (1) Sustainable Concession Strategies in Port Management; (2) Evolving Governance Models in Port Concessions; (3) Sensor-Driven End-of-Life Management in Supply Chains; and (4) End-of-Life Recovery Strategies in Manufacturing Systems. Sixteen decommissioning guidelines are developed: (1) The first eight focus on organizational structures and human factors to establish a structured approach; and (2) The second eight centre on technical integration for enhancing end-of-life management. These guidelines align with Human Systems Integration and Design (HSID) principles to clarify decommissioning and asset recovery processes. The paper highlights the need for early planning and consistent compensation approaches in terminal concession agreements and emphasizes future research to explore the application of HSID in different regional and economic contexts.

Keywords: Port terminal concessions, End-of-life management, Human systems integration and design (HSID), Decommissioning strategies, Bibliometric analysis

INTRODUCTION

Contemporary factors such as globalization, technological advancements, and a shift toward market-oriented public management are stimulating the growing involvement of private entities in seaport services (Brooks and Coolinane, 2007). In response, governments and public Port Authorities are increasingly reducing their direct involvement in port operations, opting for enterprise-driven models that promise greater efficiency, flexibility, and responsiveness to market demands.

Consequently, public–private partnerships have become central to increasing efficiency and competitiveness in port services, driven by a new market-oriented public management philosophy (Debande, 2002). The aforementioned elements of change have resulted in various port governance models, notably those based on the co-existence of public and private entities, such as the landlord governance model. The key constituent of the landlord governance model is the establishment of relationships primarily based on contractual concessions, specifically long-term leases and operating licenses, as defined by the European Commission (Notteboom, 2007). In particular, the concession policy has become a powerful governance tool for port managers. This governance tool enables Port Authorities to retain and maintain a portion of control over the: (1) Organization; and (2) Structure; of the supply side of the port market, delegating operational responsibilities to private entities and fostering a balance between: (1) Public oversight; and (2) Private efficiency (Notteboom et al., 2012).

However, the management of terminal concessions and leases in seaports presents significant complexities for Port Authorities and government agencies in the following two particular aspects: (1) The determination of the most suitable operator for their limited land resources; and (2) Establishing the conditions under which private companies can operate these facilities (PortEconomics, 2023). Furthermore, awarding bodies often face challenges during various phases of the concession process, such as: (1) Selecting the right operators; and (2) Negotiating the terms of operation.

As stated by PortEconomics (2023), a typical terminal awarding procedure consists of three phases: (1) The pre-bidding phase; (2) The awarding phase; and (3) The post-bidding phase. In the stated context, the pre-bidding phase represents a crucial role in ensuring successful concession agreements. One critical sub-phase within the pre-bidding phase is the final asset compensation sub-phase, where key decisions regarding the valuation and compensation for existing assets must be conducted (PortEconomics, 2023). However, the final asset compensation sub-phase in the pre-bidding phase presents two potential problems: (1) Inconsistent compensation approaches; and (2) Lack of early planning. Moreover, Port Authorities often struggle with inconsistent approaches to terminal asset compensation, ranging from: (1) No compensation; (2) Financial reimbursement; and (3) Requiring operators to dismantle superstructures-creating confusion for operators and making long-term investment planning difficult. This issue is further compounded by a lack of early planning during the pre-bidding phase, where failure to clarify asset ownership and compensation expectations can lead to last-minute disputes and operational delays.

Despite being a pivotal aspect of port management and governance, the issue of the final asset compensation sub-phase has received limited attention in academic research, even though it plays a central role in ensuring transparent and fair outcomes in the pre-bidding phase of port concession agreements. In order to bridge the identified gap, this paper conducts a bibliometric analysis methodology to identify the most influential articles within the port terminal concessions design literature. Following this, the identified papers will be evaluated from a Human Systems Integration and

Design (HSID) perspective to develop decommissioning guidelines aimed at improving end-of-life management, specifically addressing the challenges in the final asset compensation sub-phase in port terminal concessions.

BIBLIOMETRIC ANALYSIS METHODOLOGY

Bibliometric analysis is a research methodology that combines quantitative and qualitative methods to assess the impact of scientific literature. The analysis seeks to assess the maturity of the selected research domain by evaluating the scientific quality, interdisciplinarity, network strength, and publication volume of existing studies (Ellegaard and Wallin, 2015). The quantitative aspect of bibliometric analysis is particularly advantageous for science mapping, as it enables the structuring of large volumes of scientific literature and uncovers the dynamics within specific research fields (Aria and Cuccurullo, 2017). The qualitative aspect of bibliometric analysis is beneficial for guided content analysis, allowing researchers to derive contextual meaning from unstructured media—such as texts, images, and symbols—enabling replicable and valid inferences (Aria and Cuccurullo, 2017). Consequently, it is essential for conducting replicable, transparent, and systematic scientific literature reviews, as it enables more reliable and objective scientific analyses (Ellegaard and Wallin, 2015).

Bibliographic Citations Extraction Process

Bibliometric analysis is grounded in the collection of bibliographic citations from the highly esteemed academic database, ISI Web of Science. Table 1 outlines the comprehensive 10-step keyword search process, utilizing Boolean search terms.

Table 1. ISI WoS 10-step keyword search process.

Step	Keywords and Boolean Operators	Number of Articles WoS
1.	(“Human Systems Integration”)	837
2.	(“Human Systems Integration” OR “Human Factor* in Infrastructure*”)	838
3.	((“Human Systems Integration” OR “Human Factor* in Infrastructure*”) OR (“Terminal Concession*”))	862
4.	((“Human Systems Integration” OR “Human Factor* in Infrastructure*”) OR (“Terminal Concession*” OR “End - of - Life Management”))	1484
5.	((“Human Systems Integration” OR “Human Factor* in Infrastructure*”) OR (“Terminal Concession*” OR “End - of - Life Management”) OR (“Sustainable Decommissioning”))	1499
6.	((“Human Systems Integration” OR “Human Factor* in Infrastructure*”) OR (“Terminal Concession*” OR “End - of - Life Management”) OR (“Sustainable Decommissioning”) OR (“Impacts of Decommissioning”))	1516
7.	Exclusion Criteria: WoS Categories	288
8.	Exclusion Criteria: Article(s)	287
9.	Exclusion Criteria: English Language	285
10.	Exclusion Criteria: Article Manual Screening for Inquired Relevance	91

The first section of Table 1 outlines steps one through six, focusing on scientific studies related to Human Systems Integration, Terminal Concessions and End-of-Life Management. The second part filters the search process by filtering specific Web of Science (WoS) categories. The third part filters the search to include only scientific articles, ensuring a higher level of scientific rigour. Part four consists of excluding non-English articles. The final and fifth part involves manually screening and excluding the articles that are either irrelevant to the study's scope or only marginally address Human Systems Integration, Terminal Concessions and End-of-Life Management. The refinement process yielded a bibliometric sample consisting of 91 scientific articles.

RESEARCH CLUSTERS IDENTIFICATION

Research domains consist of the combined individual research clusters, whether they are newly emerging or well-established. In alignment with the preceding sentence, a key-word co-occurrence map is developed to analyse HSID in the context of Port Terminal Concessions; on the basis of bibliographically coupled scientific articles utilizing the VOSviewer software. Bibliographic coupling analysis is a bibliometric technique that links documents citing the same references, enabling the formation of document clusters (Boyack and Klavans, 2010). This suggests that the linked documents likely address a related topic, forming a research cluster. Setting a minimum threshold of five citations per document in VOSviewer reduced the bibliometric sample from 91 to 31 articles, with only these 31 meeting the specified citation criterion. Figure 1 illustrates the four established and interconnected research clusters based on document clustering: (Cluster 1 - Red) Sustainable Concession Strategies in Port Management; (Cluster 2 - Green) Evolving Governance Models in Port Concessions; (Cluster 3 - Blue) Sensor-Driven End-of-Life Management in Supply Chains; and (Cluster 4 - Yellow) End-of-Life Recovery Strategies in Manufacturing Systems.

Figure 1: The four emergent and interconnected research clusters.

VOSviewer is an interactive tool specifically designed for creating and visualizing bibliometric maps (van Eck and Waltman, 2010). The map construction process in VOSviewer functions on two main measurement properties: (1) Total citation; and (2) Total link strength (Jugović et al., 2024). Applying an equal-weighted average to the two main measurement properties in VOSviewer allowed for the identification and selection of 16 key articles in relation to HSID in the context of Port Terminal Concessions, with four articles assigned to each cluster as detailed in Table 2.

Table 2. Identified and selected articles allocated to respective research cluster.

Cluster 1	Cluster 2	Cluster 3	Cluster 4
(Zhang, 2016)	(Notteboom and Haralambides, 2020)	(Ondemir et al., 2012)	(Gungor and Gupta, 1999)
(Yip et al., 2014)	(Cruz and Marques, 2012)	(Ondemir and Gupta, 2014)	(Kuo, 2011)
(Wang et al., 2014)	(Monios and Bergqvist, 2015)	(Capobianco et al., 2021)	(Kwak and Kim, 2010)
(Notteboom et al., 2018)	(Saeed and Larsen, 2010)	(Kuik et al., 2016)	(Bellmann and Khare, 1999)

The 16 key articles identified in relation to HSID in the context of Port Terminal Concessions are subjected to a thorough content analysis, enabling the comprehensive assessment and discussion of the four distinct research clusters.

Sustainable Concession Strategies in Port Management

This research cluster focuses on optimizing port terminal concession agreements by balancing: (1) Economic efficiency; (2) Competitive dynamics; and (3) Risk Management; while incorporating environmental sustainability through tailored contractual and regulatory frameworks.

Zhang (2016) explores how China's quasi-landlord port financing model mirrors international approaches in terms of incentive schemes, yet operates with unique structural complexity involving multiple stakeholders and profit-sharing mechanisms. The scholar reveals that China could align its port financing strategies more closely with efficient international standards and promote sustainability by restructuring the roles of port investment companies to focus on management rather than operations. Yip et al. (2014) state that the introduction of inter-port and intra-port competition by Port Authorities can significantly increase traffic volumes and revenue, providing an optimal strategy to prevent monopolization in terminal concessions. Although terminal operators are incentivized to expand across multiple ports, game-theoretic analysis reveals that excessive competition may lead to a prisoner's dilemma, reducing their overall profitability. Wang et al. (2014) indicate how asymmetric information in cruise port concession contracts creates moral hazard risks that necessitate carefully designed incentive mechanisms to ensure alignment between the profit-driven activities of terminal operators and the managerial objectives of Port Authorities. The scholars refer to the Port of Galveston as a case study to illustrate the effectiveness of using performance guarantees and berth allocation mechanisms to mitigate moral hazard issues and align stakeholder interests in cruse terminal concessions. Notteboom et al. (2018) develop a typology of green instruments that provides Port Authorities with a strategic toolkit to align concession agreements with environmental objectives, though the success of these measures is enhanced by adopting a holistic supply chain approach. The authors state that incorporating green targets into terminal concession agreements can significantly promote environmental sustainability in port management, with certain regulatory instruments, such as information reporting, being particularly feasible for implementation.

Evolving Governance Models in Port Concessions

This cluster focuses on developing flexible, context-specific governance strategies that address the unique economic, social, and environmental challenges faced by modern ports, while emphasizing the need for: (1) Advanced risk management; (2) Efficient public-private partnerships; and (3) Tailored performance and regulatory frameworks; that align with evolving operational realities.

Notteboom and Haralambides (2020) state that modern port governance requires a shift from rigid models to fluid frameworks, enabling ports to adapt to unique and operational challenges through flexible strategies. The authors reveal that as ports navigate increasingly complex global dynamics, adopting tailored governance models that: (1) Enable regional adaptations; and (2) Incorporate advanced performance metrics; is essential for achieving sustainable management. Cruz and Marques (2012) highlight that the success of concession contracts in the seaport sector relies heavily on proper risk allocation between: (1) Concessionaries; and (2) Port Authorities, ensuring that each party assumes risks they are best equipped to manage. Ports must account for increased operational complexity and the need for tailored risk management strategies. Thus, to address the inefficiencies and opportunistic behavior in concession agreements, ports must adopt alternative contract managements that enhance: (1) Transparency; (2) Competition; and (3) Risk allocation, fostering more efficient and sustainable relationships. Monios and Bergqvist (2015) study the World Bank's port reform toolkit, revealing critical deficiencies in intermodal terminal agreements, particularly in areas such as: (1) Performance monitoring; and (2) Open access; highlighting the importance of standardized provisions for improving operational efficiency. The scholars state that further research is essential to refine and expand the proposed toolkit for intermodal terminal concessions, as broader geographical insights are necessary to create globally applicable standards that support both: (1) Public and (2) Private sector interests. Saeed and Larsen (2010) use of the Bertrand competition model in analysing concession contracts and reveal two significant findings: (1) Percentage fee concession contracts prove advantageous for enhancing user welfare, as they distribute additional revenue to port authorities and help prevent terminal operators from charging excessive handling fees; and (2) The cost-benefit analysis highlights that percentage fee contracts generate higher overall benefits compared to fixed fee contracts, making them a preferred option for policymakers aiming to boost competition and user surplus in port operations.

Sensor-Driven End-of-Life Management in Supply Chains

The main focus of this research cluster is on utilizing; (1) Sensor technologies; and (2) RFID tags to enhance decision-making and optimization in end-of-life product recovery, recycling, and disassembly processes, improving sustainability and efficiency in supply chains.

Ondemir et al. (2012) showcase how the integration of: (1) RFID tags; and (2) Sensors; in products facilitates efficient end-of-life product recovery by providing real-time data on product conditions, eliminating the need for: (1) Manual disassembly; and (2) Inspection. The authors propose the Advanced Repair-to-Order and Disassembly-to-Order (ARTODTO) model; which offers an optimized framework for processing end-of-life products, determining the best approach for: (1) Disassembly; (2) Repair; or (3) Recycling; while balancing cost-efficiency and demand fulfillment. By leveraging life-cycle data from RFID tags and sensors, the ARTODTO system enhances decision-making in closed-loop supply chains, enabling better resource utilization and reducing waste in product recovery operations. Ondemir and Gupta (2014) indicate that as the complexity of recovery operations increases with more returned products, research efforts must focus on developing computational models that efficiently address larger-scale end-of-life management challenges. The scholars in this response expand the ARTODTO system, optimized through a multi-criteria Linear Physical Programming model, to allow for efficient processing of end-of-life products by balancing; (1) Cost; (2) Environmental impact; and (3) Customer satisfaction. Capobianco et al. (2021) state that repurposing decommissioned platforms for sustainable ventures, such as: (1) Green energy; and (2) Aquaculture, presents opportunities for economic and social benefits, but legislative and policy alignment is essential to enable these efforts. The authors conclude that the necessity to focus on leveraging: (1) Big data; and (2) Systematic reviews, to explore decommissioning strategies, while identifying synergies and trade-offs through comprehensive PESTLE analysis for more effective decision-making. Kuik et al. (2016) highlight that end-of-life management poses unique challenges due to uncertainties in product condition and quantity, necessitating integrated models that balance: (1) Cost; (2) Waste; and (3) Quality; to optimize recovery processes. The authors introduce a genetic algorithm-based model that enhances decision-making by simultaneously addressing: (1) Recovery cost; (2) Manufacturing lead-time; and (3) Quality; improving overall remanufacturing strategies. By incorporating reuse and rebuild options in addition to recycling, the optimization model helps manufacturers achieve greater recovery value and boost global competitiveness in the circular economy.

End-of-Life Recovery Strategies in Manufacturing Systems

The main focus of this research cluster is on optimizing the: (1) Recovery; (2) Reuse; and (3) Recycling, of end-of-life products by integrating advanced technologies and decision models to address environmental challenges and resource scarcity in manufacturing systems.

Gungor and Gupta (1999) highlight that the effective integration of environmental considerations throughout the entire product lifecycle, as mandated by the ECMPRO (Environmentally Conscious Manufacturing and Product Recovery), plays a pivotal role in minimizing the use of virgin resources and reducing environmental impact. The authors state that for optimal material recovery, automated disassembly systems must be implemented to address inefficiencies and ensure safer processing, compared to traditional manual methods. Additionally, the development of: (1) Specialized decision-making tools; and (2) Global collaboration in research; are critical for advancing ECMPRO practices and supporting sustainable product recovery. Kuo (2011) asserts that optimizing inventory management policies in closed-loop systems plays a pivotal role in remanufacturing infrastructure, ensuring sustainable resource use and minimizing environmental impact. The scholar states that future research should focus on refining closed-loop supply chain models by incorporating: (1) Lean principles; (2) Customer satisfaction factors; and (3) Advanced material planning; to improve both environmental and operational outcomes. (Kwak and Kim, 2010) point out that the use of component sharing in product family design not only enhances profitability, but also optimizes end-of-life management by improving recovery strategies and minimizing material waste. In order to develop more robust frameworks for product family design, future research must address uncertainties by integrating stochastic models that consider both design/manufacturing and end-of-life stages, ensuring optimal recovery and sustainability outcomes. Bellmann and Khare (1999) research that to ensure sustainable recycling practices, life cycle assessments (LCAs) must be conducted to evaluate the environmental benefits, while economic incentives, such as subsidies, can help address market barriers related to recycled materials. The scholars conclude that implementing extended producer responsibility in conjunction with market-oriented financial support is essential for creating accountability and enhancing the efficiency of end-of-life vehicle recycling systems.

GUIDELINES FOR END-OF-LIFE MANAGEMENT AND DECOMISSIONING IN PORT TERMINAL CONCESSIONS

Human Systems Integration and Design encompasses not only technology, but also the integration of organizational structures and human factors (Booher, 2003). Integration must be considered from the start of a system's life cycle and continues through its dismantling. Emphasis should be placed on how people and technology: (1) Interact; (2) Complement each other; and (3) Work together; to fulfil the system's intended purpose (Booher, 2003). HSI&D refers to Human Centered Design processes that concurrently address technological, organizational, and human factors during both the design and operational phases. In adherence to the stated, the bibliometric study conducted revealed four key clusters: (1) Two clusters (Cluster 1 and Cluster 2) focusing on organizational structures and human factors in order to establish an approach; and other (2) Two clusters (Cluster 3 and Cluster 4) centered on technology in order to develop the know-how. The subsequent two subchapters will provide analysis of the approach and know-how elements, as identified per the research clusters.

Organizational Structures and Human Factors in Port Terminal Concessions

Organizational structures and human factors represent a vital role in shaping the decommissioning processes within port terminal concessions. As identified in the research clusters, aligning these elements with Human Systems and Design (HSID) principles is essential to ensure efficient asset management during the end-of-life management phase of terminal concessions. This alignment is particularly crucial in the pre-bidding phase, where decisions regarding the final asset compensation must be carefully structured to prevent operational disruptions and ensure a smooth transition during decommissioning (PortEconomics, 2023).

On basis of the research clusters, eight organizational structures and human factors in port terminal concessions guidelines are identified. These guidelines align HSID principles with effective end-of-life management strategies in port terminal concessions:

1. **Simplifying Organizational Structures for Efficient Decommissioning (Zhang, 2016):** Simplifying the management structure and ensuring a clear division of duties between port investment companies and operators facilitates efficient decommissioning processes. This approach streamlines operations and reduces confusion, ensuring smoother transitions at the end of port terminal concession contracts.
2. **Enhancing Collaboration Between Stakeholders (Yip et al., 2014):** Port Authorities and regulators must play a pivotal role in designing concession agreements that influence decommissioning strategies. Clear coordination between Port Authorities, operators, and regulators is essential to avoid monopolization and ensure that decommissioning aligns with market dynamics.
3. **Incentivizing Responsible End-of-Life Management (Wang et al., 2014):** Incorporating well-designed incentive mechanisms into concession contracts aligns the objectives of Port Authorities and terminal operators, ensuring that responsible end-of-life management and decommissioning practices are maintained throughout the concession period.
4. **Incorporating Green Targets into Concession Agreements (Notteboom et al., 2018):** Integrating sustainability goals, including green targets, into concession agreements ensures that environmentally friendly responsible practices are implemented during the decommissioning phase. A holistic chain approach-incorporating ships, ports, terminals, and inland transport-is essential for realizing these green initiatives.
5. **Adapting Governance Models to Regional Contexts (Notteboom and Haralambides, 2020):** Flexible and adaptive governance models are critical to aligning decommissioning strategies with the specific economic, social, and environmental challenges of each port. These governance models must continuously evolve to address the changing needs and priorities of port terminals.
6. **Allocating Risk Properly for Decommissioning (Cruz and Marques, 2012):** Proper risk allocation between Port Authorities and

concessionaires is essential to ensure that operational, environmental, and maintenance risks are managed efficiently. This helps incentivize responsible end-of-life management, including decommissioning, without compromising social welfare.

7. **Standardizing Hand-back Procedures (Monios and Bergqvist, 2015):** Establishing standardized hand-back and maintenance procedures in concession contracts reduces uncertainties during the decommissioning phase. Consistent performance monitoring provisions prevent delays and disputes, ensuring port terminal assets are well -maintained and ready for hand-back at the end of the concession term.
8. **Designing Concession Contracts to Mitigate Risks (Saeed and Larsen, 2010):** Concession contracts based on optimal fee structures, such as percentage fees, help balance user welfare and operator profits. These contracts also ensure that terminal operators manage assets efficiently, including during the decommission process, by promoting long-term sustainability.

These eight guidelines offer a detailed approach for improving organizational structures and human factors in the decommissioning of assets and end-of-life management processes within port terminal concessions.

Technological Integration and Operational Know–How in Decommissioning

Technological innovations represent a pivotal role in enhancing the decommissioning processes within port terminal concessions. The effective management of port terminals assets during the final asset compensation sub-phase is increasingly dependent on technological advancements. The integration of modern technologies such as sensor systems, RFID tags, and advanced data analytics allows Port Authorities and terminal operators to streamline decommissioning processes, minimize operational disruptions, and enhance sustainability (PortEconomics, 2023) (Ondemir et al., 2012). As identified in the research clusters, integrating these advanced technologies within HSID principles is essential for improving end-of-life management in the pre-bidding phase, where the use of technology can optimize asset monitoring and the final asset compensation process, ensuring a more efficient and sustainable decommissioning approach.

On basis of the research clusters, eight guidelines for technological integration are identified, which align HSID principles with effective end-of-life management strategies in port terminal concessions. These guidelines emphasize the integration of advanced technologies to enhance decommissioning efficiency, sustainability, and asset management:

1. **Embedding RFID Tags and Sensors for Efficient Decommissioning (Ondemir et al., 2012):** RFID tags and sensor-embedded products provide real-time data on component conditions, reducing the need for manual disassembly and inspection during decommissioning processes. This real-time information enhances end-of-life management by optimizing recovery, reuse, and recycling strategies.

2. **Utilizing Life-Cycle Data for Optimized End-of-Life Management (Ondemir and Gupta, 2014):** Integrating life-cycle data from RFID and sensor technologies enables Port Authorities to make informed decisions on the recovery and disposal of terminal assets. Advanced systems like ARTODTO leverage this data to balance financial, environmental, and operational objectives during decommissioning.
3. **Multidisciplinary Collaboration for Sustainable Decommissioning Capobianco et al., 2021):** A multidisciplinary approach involving collaboration among institutions, enterprises, and local communities ensures that decommissioning processes are sustainable. Repurposing decommissioned assets, such as transforming them for green energy use, supports environmental and economic sustainability.
4. **Advanced Decision-Making Models for Efficient Recovery (Kuik et al., 2016):** Integrated decision-making models, such as those using genetic algorithms, allow port operators to balance cost, time, and waste when recovering assets at the end of their life cycle. These models help address uncertainties and improve overall recovery strategies.
5. **Automated Systems for Sustainable Resource Recovery (Gungor and Gupta, 1999):** Automated disassembly systems and specialized decision-making tools are essential for improving the efficiency of end-of-life recovery processes. These tools promote sustainability by minimizing environmental impact and ensuring the efficient recovery of terminal assets.
6. **Closed-Loop Supply Chains for Sustainable Decommissioning (Kuo, 2011):** Incorporating closed-loop supply chains, which include recycling and remanufacturing processes, enhances the sustainability of end-of-life management. Green suppliers and low-pollution materials further support environmentally conscious practices during decommissioning.
7. **Product Family Design for Efficient Decommissioning (Kwak and Kim, 2010):** Designing terminal assets with interchangeable components allows for more efficient and profitable end-of-life management. High levels of component sharing reduce the need for new materials and enhance environmentally conscious asset recovery strategies.
8. **Extended Producer Responsibility in Terminal Decommissioning (Bellmann and Khare, 1999):** Implementing extended producer responsibility encourages manufacturers to design reusable or recyclable terminal assets. This approach supports sustainable decommissioning practices and reduces the environmental footprint of end-of-life management operations.

These eight guidelines provide a detailed approach to integrating technological advancements, such as RFID and sensor systems, into decommissioning and end-of-life management processes, enhancing efficiency and sustainability within port terminal concessions.

CONCLUSION

The management of port terminal concessions presents significant challenges, particularly in determining the most suitable terminal operator due to limited port land resources and establishing conditions under which private companies can operate these facilities. One critical sub-phase within the pre-bidding phase is the final asset compensation sub-phase, where inconsistent approaches and a lack of early planning can lead to operational delays and disputes between the Port Authority and the terminal operator. Despite the importance of the aforementioned sub-phase, this issue has received limited academic attention, even though it represents a central role in ensuring fair and transparent outcomes in port concession agreements. This paper aims to address this gap via employment of bibliometric analysis methodology aimed at identifying influential literature and developing decommissioning guidelines. The bibliometric analysis identified four key clusters within the port terminal concessions design literature: (1) Sustainable Concession Strategies in Port Management; (2) Evolving Governance Models in Port Concessions; (3) Sensor-Driven End-of-Life Management in Supply Chains; and (4) End-of-Life Recovery Strategies in Manufacturing Systems. Furthermore, a total of sixteen decommissioning guidelines have been developed across these clusters, with eight guidelines focusing on: (1) Organizational structures and human factors to establish a structured approach, and the remaining eight guidelines centered on: (2) Technological integration and know-how for optimizing end-of-life management processes. Future research should explore the application of these guidelines across various regional contexts and investigate the long-term effects of integrating Human Systems Integration and Design (HSID) principles into concession agreements to ensure sustainability and efficiency in port terminal asset decommissioning.

ACKNOWLEDGMENT

This research endeavour received financial support from the University of Rijeka under the project line ZIP UNIRI, specifically allocated to the projects titled: (1) “The Influence of “Green” Maritime Policy on the Development of Seaports and Transport Flows” (UNIRI-ZIP-2103-1-22); and (2) “Logistical and Economic Aspects of the Development of Regional Economies in the Coastal Area” (UNIRI-ZIP-2103-5-22).

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