JCBM (2025) 8(S1) 48-61

University of Cape Town

Journal of Construction Business and Management

http://journals.uct.ac.za/index.php/jcbm

Port Efficiency: The Application of Blockchain Technology in the Construction Material Supply Chain

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Received 05 October 2025; received in revised form 19 October 2025, 18 December 2025; accepted 27 December 2025
https://doi.org/10.15641/jcbm.8.S1.1924

Abstract

The Port of Durban has recently experienced operational delays, which have affected its performance. Delays at the Port hinder the timely completion of projects in South Africa's construction sector. Hence, this exploratory research focuses on identifying, through the literature, the suitability and consequences of using blockchain technology to facilitate the supply chain for construction materials. Furthermore, the port productivity of the Port of Durban was compared with that of Rotterdam harbours. The Quantitative Research Approach aligns with this research philosophy and underpinnings. Secondary data are collected from the port website, and the Malmquist Productivity Index is used to determine the enablers of Port Productivity from 2017 to 2023. The heterogeneity of the port cases limits the generalisation of findings. However, policymakers, project managers, investment planners, and operational practitioners will benefit as the possibilities of blockchain technology in enhancing the supply chain of construction materials are discussed. Due to time constraints, the data is limited to the period of 2017-2023. The research findings show that technologies such as Blockchain and artificial intelligence are major drivers of port productivity at the Port of Rotterdam. The application of various customised technologies has improved the Port of Rotterdam's productivity. The construction sector is in dire need of effective, efficient port systems, given the multiple stakeholders and projects. The application of Blockchain technology, especially with smart contracts, provides a degree of flexibility.

Keywords: Blockchain, Construction Material Supply Chain, Efficiency, Productivity, Port of Durban and Rotterdam.

1. Introduction

Operational delays are a recurring phenomenon at Durban Harbour, affecting its performance. According to the World Bank CPPI (2023), the harbours of Cape Town, Durban, and Port Elizabeth in South Africa have been ranked among the world's worst-performing container ports. Griessel (2024) states that along the shores of Durban and Richards Bay in South Africa, almost 100 cargo vessels, laden with fuel, bulk dry goods, containers, and cars, are held up due to delays attributed to a combination of adverse weather conditions and ageing terminal equipment. The implications of port congestion for the construction sector, including the challenges it poses, include a rapid increase in material and labour costs (Griessel, 2024). Delays at the Port can adversely affect the timely completion of construction projects in South Africa (Nemakhavhani & Khafiso, 2024). This is known as time overruns in the construction sector—specifically, delays attributed to the importation of construction materials.

The implications of bottlenecks at the Port have a multiplier effect not only on the Construction sector but also on the South African economy as a whole. One of the significant research gaps that this study seeks to bridge is the fragmentation in the construction supply chain. This exploratory study focuses on identifying, through the literature, the application of blockchain technology (BCT) to facilitate the supply chain for construction materials. Hence, BCT serves as a tool for the seamless flow of information and documentation amongst the stakeholders. Furthermore, the research also focuses on the enablers of port productivity for both the Durban and Rotterdam harbours. Rotterdam harbour is used as a benchmark because of its proven excellence in applying various 4IR Technologies, such as Blockchain. Soni & Smallwood (2023) opine that the construction sector is crucial to South Africa's growth

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and development, contributing to infrastructure development, among other areas. The construction industry creates employment and promotes economic development. As ongoing construction points to environmental and societal dynamism, so too does port efficiency serve as a significant parameter for the successful management of the construction material supply chain (Obasi et al., 2024). Nikjow et al. (2021) also attest that one of the major causes of delays in the procurement of construction materials is inefficient logistics and supply chain. An inefficient port should consider other options, such as Blockchain Technology, to expedite the entire process. Bottlenecks at the Port have a multiplier effect not only on the Construction sector but also on the South African economy as a whole. Leah (2024) further elaborates by citing examples that can affect construction materials supply chains, such as shortages, supply chain disruptions, inflation, and delays due to cumbersome customs procedures. According to Meersman et al. (2012), a Port is congested when it cannot meet the demand of port users at the quayside, crane, yardside, or gate.

Congestion is a significant hindrance to international trade and economic development, particularly during the COVID-19 pandemic (Lin, Zeng, Luo, and Nan, 2022). Yen and Mulley (2023) attest that the more ports understand the importance of efficiency in port operations, the more they can improve their resource allocation and productivity. Vessels laden with containers have their operations expedited in developed economies due to quick clearance times, the adoption of technological architecture, and increased labour output (UNCTAD, 2023). Herein lies the importance of blockchain technology. Blockchain technology can be used to streamline sea-going operations by enhancing customs clearance processes across various shipping containers (Wang et al., 2021). The study is inclined toward the use of secondary data extracted from the respective port websites; hence, a quantitative research design. Kao (2023) states that efficiency is calculated as the proportion of output to input. For this study, inputs include container berths, tug boats, terminals, cranes, port employees, and the length of the quay, whilst the outputs are the number of vessel visits to the harbour and container throughput. Ports are adversely affected by procedural complexities, redundancy, and unintegrated information and document flows, which affect various port users and stakeholders involved in seaport operations (Mthembu & Chasomeris, 2024). According to the USDA Report (2024), South African ports have experienced chronic and acute operational challenges over the years. Analysts estimated that during the peak of the port challenges, the collective economic impact of slowdowns exceeded R124 billion (approximately US$6.5 billion) per day (USDA, 2024). The following are the research objectives of the study:

- Literary thematic identification of the application of a shared distributed digital ledger (BCT) in facilitating the value chain of construction materials.
- Determine the enablers of port productivity for the Durban and Rotterdam harbours.
- Compare the various applications of technology at the Port of Durban and the Port of Rotterdam.

The following is the outline of the paper: Section 2 reviews peer-reviewed journal articles and book chapters; Section 3 examines methodological approaches; Section 4 discusses the results; and Section 5 elaborates on the conclusion and recommendations.

2. Literature Review

The Port has a pivotal role in the Global Supply Chain (Li et al., 2025). Guan *et al*. (2024) note the critical role of ports in promoting global trade and commerce, as well as their adaptability, flexibility, and performance through the lens of 4IR technologies such as artificial intelligence, Blockchain, and the Internet of Things. BCT, also known as a shared, distributed, digital ledger, has gained prominence due to its relevance to the industry (Guan *et al.,* 2024). Blockchain-based approaches could solve the manipulation and fraud issues of export certificates in these areas. In addition, the distributed and immutable ledger can prevent the export of counterfeit or stolen goods (Böhmecke-Schwafert, 2024). This section examines the concepts that underpin this study. These are the construction sector, the Port, port efficiency, the implication of port inefficiency, and the application of a shared distributed digital ledger.

2.1. The Importance of the Construction Industry

No nation can be transformed from a state of development to full development without the effective functioning of its construction sector. According to the Department of Trade, Industry, and Competition (2024), the construction industry is a significant catalyst for socio-economic development because, as a critical employer of labour, it contributes 5.3% and 7.8% of South Africa's formal and informal sector employment, respectively.

2.2. Construction Material Supply Chain

Ghamari et al. (2024) posit that the Construction Material Supply Chain is a network series that shows how construction materials are imported from origin to destination. In this sector, the supply chain manager plays a critical role in strategically planning the consignment from the harbour of origin to the final harbour, the destination. For instance, South Africa imports steel from America and Cement from China. Other imported construction materials include sand, gravel, crushed stone, Plywood, Hardboard, Pine, eucalyptus transmission poles, and Industrial electrical cables (South African Iron and Steel Institute, 2025). South Africa's main trading partners include China, the United States, Germany, and Japan. Steel is a critical material in the construction sector (Putri & Firmansyah, 2020). According to Putri and Firmansyah (2020), Steel is a unique and critical construction material that serves as a raw material for roofing sheets, beams, and columns.

2.3. The Port

The Port is the gateway to any nation's economy, with the port authority serving as the gatekeepers. Tovar and Alan (2024) affirm the importance of Ports, stating that Ports cannot be sidelined in the development of modern economies, as they serve as gateways to hinterlands and hubs and provide specialised services for the energy and cruise-based tourism sectors. This further reiterates that the Port serves as a platform to enhance international trade. The Port is the bedrock for generating domestic and foreign revenue for countries. Peng, Bai, Yang, Yuen, and Wu (2023) affirm that the Ports are central to the maritime supply chain. The implication of this is that without the Port, the maritime supply chain is spineless and scattered. Ayesu and Boateng (2024) posit that Ports are pivotal in facilitating international trade and economic development, hence serving as vital corridors for the movement of goods across the African continent and beyond. Not only are ports of essential value to the global supply chain, but their productivity is also critical. Therefore, seaports and their efficiency remain essential for the success of global international trade (Ayesu, Sakyi & Baidoo, 2024). Mazibuko et al. (2024) assert that a container port's competitiveness depends on the productivity of its container terminal. Continuous monitoring and evaluation of ports ensure risks are mitigated, and crucial decisions are made promptly.

2.3.1. The South African Ports

Over 80% of South Africa's international trade is done by sea (International Trade Administration-ITA, 2024). The South African harbours, including Saldanha, Cape Town, Coega, Mossel Bay, Port Elizabeth, East London, Durban, and Richards Bay, are pivotal to importation and exportation (Transnet, 2024). However, poor infrastructure, a poor maintenance culture, faulty equipment, and wind are major issues plaguing port operations (USDA, 2024).

2.3.2. The Port of Rotterdam

The World Shipping Council (2022) states that the Port of Rotterdam is ranked 10th among the top 60 container ports globally and is the largest Port in Europe. Port of Rotterdam website (2024) asserts that the Port of Rotterdam is deliberate and committed to digitisation and port efficiency. According to Farah et al. (2024), the Port of Rotterdam has used blockchain technology since 2016 to facilitate the tracking and tracing of container shipments of flowers. The service enables a seamless flow of information with customs authorities, thereby allowing exporters to track fully and trace shipments (Farah et al., 2024).

2.3.3. Port Efficiency and Congestion

Yen and Mulley (2023) state that transport efficiency is critical. The evaluation of port performance primarily aims to improve port operations and provide useful information for port development planning and strategies (Suárez-Alemán et al., 2016). When a Port is efficient, it is obvious because there are few delays across its various operational levels. The operational areas include the quayside, crane, yard, and gate operations. A very good parameter to measure port efficiency is the absence of delays at the Port of entry or exit. According to the Port of Rotterdam (2024), an efficient port offers short turnaround and berthing times for vessels, seamless documentation procedures, and high customer satisfaction. According to Pallis and Rodrigue (2022), Port efficiency is multidimensional and describes operational performance, with an emphasis on maximising output and minimising costs. Efficiency drives port competitiveness (Danladi et al., 2024). According to Danladi et al. (2024), various indices, including delays and congestion, indicate that ports are inefficient. On the Durban coastal lines, many vessels are often waiting to berth. The Port is congested and lacks the capacity to handle all vessels. This is a sign of capacity and operational constraints.

2.4. Blockchain Technology (BCT)

According to Farah et al. (2024), Blockchain technology is a credible and essential solution to enhance security, transparency, and efficiency in the maritime industry, where the increasing reliance on digital systems and data is prevalent. According to Monrat et al. (2019), Blockchain has the following features: decentralisation, immutability, transparency, and auditability. These features make transactions more secure and tamper-proof (Monrat, Schelén, and Andersson, 2019). Ziga and Turk (2017) state that the construction value chain includes multiple stakeholders; hence, BCT can provide a trustworthy framework for sharing vital documents, information, and transactions. A predominant feature of the maritime supply chain is a prolonged operational process, structures, and complex data and knowledge generated by multiple stakeholders (Liu et al., 2021). This feature serves as an impetus for the adoption of blockchain technology. The emerging blockchain technology has the characteristics of decentralisation, tamper-proofing, and traceability, which can be correctly applied in the construction material maritime supply chain to promote its transformation and upgrading (Liu et al., 2021).

2.5. Taxonomy of the Significance of Blockchain in the Construction Sector

The search strategy for developing Table 1 (See Appendix 1) used the Google Scholar database for the period 2015-2025. The keywords were "Blockchain Technology Application" and "Construction Sector". The inclusion criteria were articles that demonstrate the importance of blockchain technology in construction. Based on the scoping review search criteria, 20 peer-reviewed articles were selected from the literature to examine the significance of blockchain technology in the construction sector. The table displays the various significance of Blockchain applications in ports.

2.6. Themes

Based on the taxonomy, four major themes are critical to the research gap. Four themes emerged from the review: managing stakeholders in the construction materials supply chain; traceability and transparency; data security; and efficiency and smart contracts.

2.6.1. Managing Stakeholders in Construction Materials Supply Chain

Several stakeholders are involved in the supply chain for construction materials. The stakeholders include the port authority, the freight forwarder, the project management team, and many others. Now, due to the complexity of the entire import and export process, these stakeholders can end up working in silos. Kiu et al. (2020) state that blockchain technology improves loose collaboration amongst the stakeholders. This further fragments the process and increases project costs. Žiga and Klinc (2017) and Okanlawon et al. (2025) purport that blockchain technology improves the construction process.

2.6.2. Traceability and Transparency

Who does what, when, and how is critical in the construction material supply chain. One theme that emerged from scoping the literature review is that Blockchain facilitates traceability and transparency. This is supported by Figueiredo et al. (2024) and Nasih et al. (2024). A container load of construction material can be tracked from the Port of origin to the Port of destination. Elmay et al. (2022) affirm the application of blockchain technology in monitoring the supply chain process.

2.6.3. Data security

The large volume of data being shared amongst stakeholders requires significant trust. Figueiredo et al. (2024) opine on the importance of data security. This is also supported by Akinradewo et al. (2021), who confirm that Blockchain can secure substantial amounts of data and support various types of transactions. Shojaei (2019) argues that, since data is encrypted, it is highly secure.

2.6.4. Efficiency and Smart Contracts

Delays at the ports are indicators of inefficiency. There are several reasons for inefficiencies at the Port. Hargaden et al. (2019) attest that blockchain technology promotes efficiencies. The traditional contractual process comes with many inherent problems. Philipp et al. (2019) and Mahmudnia et al. (2022) advocate that smart contracts provide a solution to the traditional contracting process.

2.7. Theoretical Framework

Two theoretical frameworks are critical to this research: the benchmarking framework and the efficiency theory. The benchmarking theory advocates comparing ports to serve as a basis for learning from one another, in this case, salient truths that can be gleaned from the Port of Rotterdam. According to Wong and Wong (2008), Benchmarking can be applied to the Port of Rotterdam because it serves as a representative of best practices, especially for continuous improvement in blockchain technology. Benchmarking is learning from others and involves leveraging their knowledge and experience to improve the organisation (Lankford, 2002). Optimal inputs that yield the desired outputs, in view of scarcity, are the bedrock of efficiency theory (Camanho et al., 2024). Efficiency is critical because the results from the Malmquist Productivity Index Data Envelopment Analysis (MPI-DEA) show the level of efficiency for the selected ports.

3. Research Methodology

This research adopts the Saunders, Lewis, and Thornhill (2019) Research Onion framework, which is classified into research philosophy, research approach, research strategy, choices, time horizon, techniques, and procedure. The positivist approach was used because the secondary data were collected from the unit of analysis, the selected ports. Positivism emerged from foundationalism and empiricism; positivists value objectivity and the testing of hypotheses (Blackwell, 2018). Deductive reasoning aligns with the numerical data obtained from port stats and is used to determine the port efficiency.

This research employs a multi-method approach, including a scoping review, to examine the application of BCT in the construction materials supply chain. Then, a Quantitative Research Approach was used, drawing on the cases of the Port of Durban and Rotterdam. For calculating efficiency, input and output parameters are required. The inputs are the number of container berths, the number of tug boats, the number of terminals, the number of cranes, the number of port employees, and the length of the quay, whilst the outputs are vessel visits and container throughput. This secondary data for 2017-2023 is sourced from the Port of Rotterdam's and Transnet Port statistics. This data set has been validated by various port information systems, as well as by artificial intelligence and blockchain technology, which provide real-time data. This data set has been confirmed and validated by another source, such as the World Bank CPPI (2023) report. The sampling technique used is purposive sampling, as the Port of Rotterdam is among the few smart ports to have implemented blockchain technology.

This research adopts the Malmquist Productivity Index (MPI) to measure efficiency over time. The Malmquist index (MI) evaluates the efficiency change over time. It is a non-parametric framework measured as the product of catch-up (or recovery) and frontier-shift (or innovation) terms, both derived from DEA technologies (Tone, 2004). Efficiency is measured by the ratio of Output to inputs.

This research uses the Malmquist Productivity Index from data envelopment analysis to evaluate port efficiency and productivity for the Port of Durban and the Port of Rotterdam from 2017 to 2023. The Port of Durban and Rotterdam are the Decision Making Units-DMUs, hence a case study approach. The following shows the importance of the inputs and outputs.

3.1. Inputs

Number of Container Terminals: This is critical as they provide the main infrastructure responsible for loading and unloading the containers full of materials (Martinez-Moya, 2025).

Number of Container Berths: The first point of arrival at the Port is the berth; this is where container terminal offloading and unloading operations begin (Jiang et al., 2024). Hence, to prevent delays, there must be more berths or a process of enhancing the flow of vessels.

Number of Cargo Handling Equipment (Cranes): This is linked to port productivity (Ningrat et al., 2024). **Number of Tugs**: Tugs are important navigational tools for Vessels entering ports (Paulauskas et al., 2021).

Length of Quay: This determines the types and sizes of vessels permitted to berth, and it is crucial to port productivity (Jeong & Kim, 2024).

Port Employees: This has a positive impact on port productivity (Ayesu & Boateng, 2024).

3.2. Outputs

Container Throughput: The number of 20 Ft and 40 Ft containers offloaded or loaded on the vessel. This is very critical for port employment. (Ayesu and Boateng, 2024).

Vessel Visits: Chu et al. (2023) posit that the punctuality of vessel visits or calls is crucial for port operations.

According to Negar and Rostamy-Malkhalifeh (2017), MPI shows the regression and progression of decision-making units, such as ports, over time. The two periods are the efficiency change and the technology change. Negar and Rostamy-Malkhalifeh (2017) state that the MPI indicates that the regression and progress of a unit from one period to the next depend not only on its efficiency changes during these two periods, but also on technological changes in the population or on a boundary shift of the evaluated population in the same period. Equation 1 is the MPI formula. The Pim-Dea V.3.0 software, developed by Emrouznejad and Thanassoulis (2024), is useful for calculating productivity for the selected harbours from 2017 to 2023. The DEA model is input-oriented, and variable returns to scale are assumed.

$$M(Y_{t+1}, X_{t+1}, X_t) = \underbrace{\frac{D^t(Y_{t+1,}X_{t+1})}{D^t(Y_t,X_t)}}_{Efficiency\ change} \quad \underbrace{\frac{D^t(Y_{t+1,}X_{t+1})}{D^{t+1}(Y_{t+1,}X_{t+1})} X \frac{D^t(Y_t,X_t)}{D^{t+1}(Y_t,X_t)}}_{Technology\ change}$$

Equation (1): The MPI

Source: Malmquist (1953)

Negar and Rostamy-Malkhalifeh (2017) state that when the DMU0, MPU0 is greater than 1, progress occurs in the period t+1 ratio to t.; However, if the DMU0, MPU0 is less than 1: A regression occurs in period t+1 ratio to t and when the DMU0, MPU0= 1: No progress or regression occurs in period t+1 ratio to t.

4. Results and Discussion

Three major categories are discussed in this section: the application of BCT on CMSC, the application of Blockchain Technology at the Rotterdam harbour, and the enablers of port productivity for the Durban and Rotterdam Harbours.

4.1. Application of BCT in the Construction Materials Supply Chain(CMSC)

Blockchain technology is well-suited to facilitating the construction material supply chain. Based on a literary search of over 50 articles using keywords like BCT, construction materials supply chain. The Application of Blockchain has been streamlined into four major themes, as depicted in Figure 1. These include smart contracts, track-and-trace, accelerated document flow, and authentication and validation of documentation and stakeholders. Shojaei (2019) posits that the implementation of blockchain technology in the construction industry can also lead to the use of smart contracts, which will reduce administrative burdens and improve the flow of project, material, and service delivery. Elmay et al. (2022) attest that Blockchain accelerates the inefficient shipping process by digitising ownership transfer and process documentation. Wang et al. (2021) posit that Blockchain enables simultaneous auditing and makes real-time optimisation possible for partners and

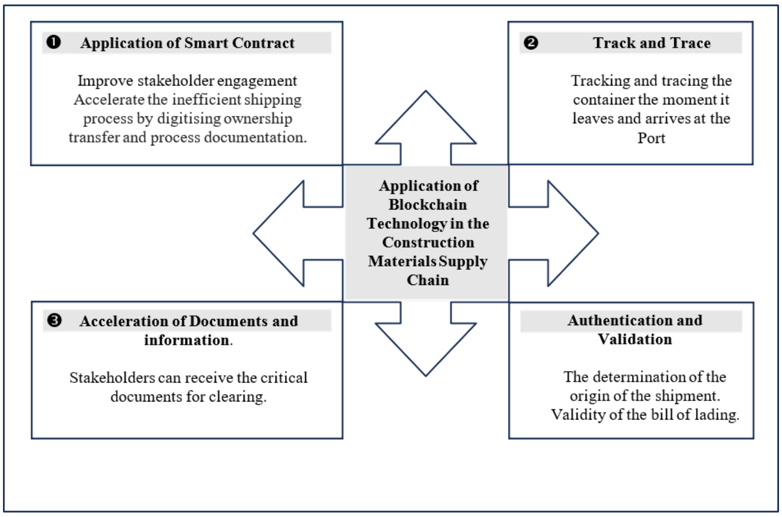

Figure 1: Application of BCT in Construction Material Supply Chain
Source: Author's, 2025

organisations. Nasih et.al. (2024) confirm the use of BCT to improve tracking and tracing services, ensuring data integrity, transparency, and traceability across supply chains.

4.2. Application of Blockchain Technology at the Port of Rotterdam.

Wang et al. (2021) posit that shared distributed digital technology in the maritime industry improves customs clearance efficiency and logistics transparency. Quay Connect was born out of the struggles experienced in importing and exporting between the Netherlands and the UK. It was developed as an independent blockchain platform to facilitate the exportation of shipments from the Netherlands to the United Kingdom (Port of Rotterdam, 2025). The benefit of this application is the automatic exchange of information with the customs authorities at ports in the United Kingdom (Farah et al., 2024). The implication is that exporters from the Netherlands can digitise and streamline the export and customs process. This results in a 30% savings on the cost of each customs clearance (Port of Rotterdam, 2025).

4.3. The enablers of port productivity for the Durban and Rotterdam Harbour

Productivity measures for ports are important for port stakeholders (Gonzalez, 2022). The port productivity of both the Port of Rotterdam and the Port of Durban is analysed from 2017 to 2023. The results of these analyses are categorised into efficiency change and technology change. The product of efficiency changes and technological progress makes up the Malmquist Productivity Index. The Pim-Dea V.3.0 software developed by Emrouznejad and Thanassoulis (2024) calculates the efficiency change for the selected ports from 2017 to 2023.

4.3.1. Efficiency Change

The efficiency change component measures how well a firm, in this case the Durban and Rotterdam harbours, uses its resources to produce a given level of output. Both the Port of Durban and Rotterdam make optimal use of their resources, as indicated by level 1. Figure 2

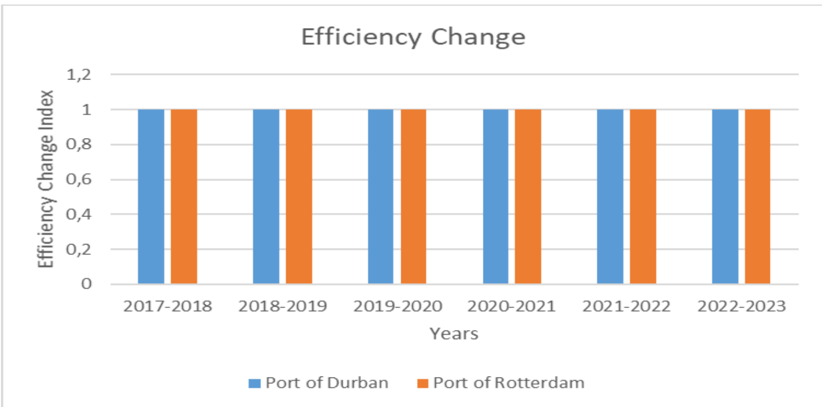

Figure 2: Efficiency Change
Source: Author's Compilation, 2024

and Table 2 show that efficiency has been consistent throughout the years examined.

of productivity. This is confirmed by Van Den Bosch et al. (2011) and Osundiran and Makgopa (2025).

Table 2: Numerical DEA-MPI

Port	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Technology Change						
Port of Rotterdam	3,16	1	2,98	3,34	2,87	3,31
Port of Durban	1,1	0,94	0,88	1,03	0,97	0,99
Port	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Efficiency Change						
Port of Rotterdam	1	1	1	1	1	1
Port of Durban	1	1	1	1	1	1
Malmquist Productivity Index						
Port	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Port of Rotterdam	3,16	1	2,98	3,34	2,87	3,31
Port of Durban	1,1	0,94	0,88	1,03	0,97	0,99

Source: Author,2024

4.3.2. Technology Change

Technological change measures the shift in the production frontier over time. As the frontier shifts upward, more outputs can be obtained from the same level of inputs. Technology is a major driver of productivity. In Figure 3 and Table 2, there is a clear-

Nevertheless, Rotterdam's higher MPI is not necessarily attributable solely to blockchain technology but to other factors, such as artificial intelligence, geographic positioning, and operational efficiencies (Fani, 2025).

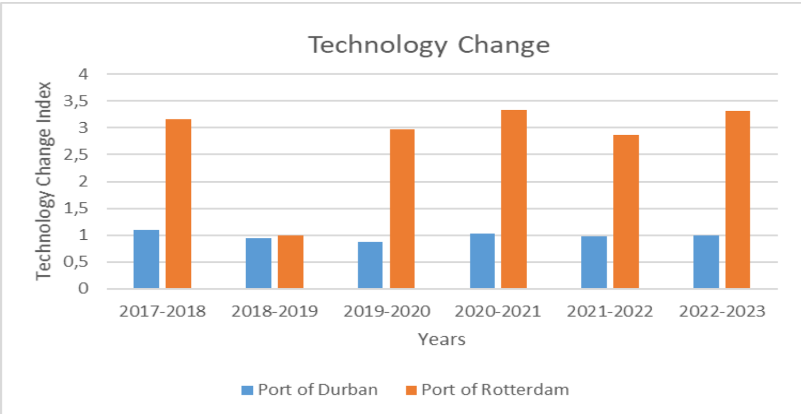

Figure 3: Technology Change
Source: Author's Compilation, 2025

cut demarcation of the impact of technology on port productivity for the Port of Rotterdam. The Port of Durban still has much room for improvement in the application of suitable, customised technology to improve port performance. The point of inflexion for the Port of Durban in 2018-2019 was due to operational inefficiencies (Dlamuka, 2022). Throughout the examination period, Rotterdam maintained a high level

4.3.3. The Malmquist Productivity Index

From Figure 4 and Table 2, the Rotterdam harbour has a greater Malmquist Productivity Index than the Port of Durban. The Technology factor plays a crucial role in the Port of Rotterdam's performance. Figure 4 shows the impact of technology on productivity at the Rotterdam port. Over the years examined except for 2018-2019. The Port of Rotterdam has improved

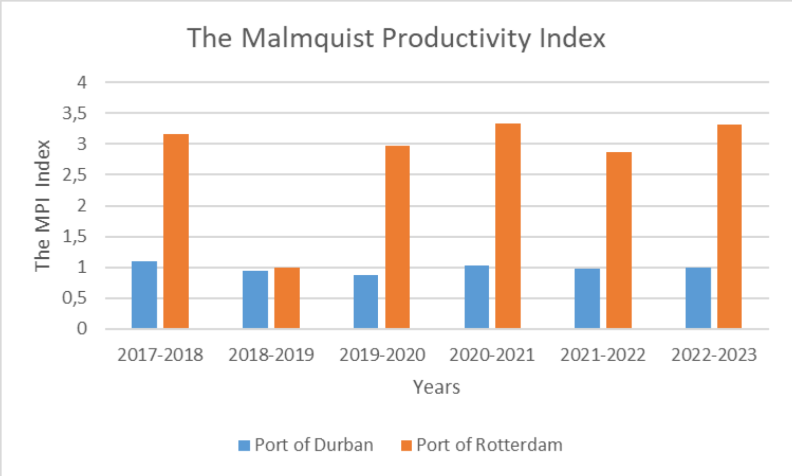

Figure 4: The Malmquist Productivity Index
Source: Author's Compilation, 2024

productivity through technology.

Table 2 shows the numerical breakdown of the results for the Ports of Durban and Rotterdam for 2017-2023. It captures the technological and efficiency changes, then presents the Malmquist Productivity Index result.

4.4. Compare the various applications of technology at the Durban and Rotterdam Harbours

This section compares the Port of Rotterdam with the Port of Durban using several parameters. Elhussieny (2025) posits that the Port of Rotterdam is ranked highly in Europe and globally. However, World Bank CPPI (2023) indicates that the Port of Durban is struggling in terms of its performance. Table 3 shows the various parameters used to compare.

5. Conclusion and Further Research

Port congestion is associated with vessels lining up along the Port's shores. Leading to delays, queuing, and extra time for the voyage and the docking of ships and cargo at the Port. This research was conducted due to the persistent delays that importers of construction materials experience at the Port of Durban. The research further used the Port of Rotterdam as a basis for comparison, as it is not only a smart port but has also used Blockchain Technology. This study identified various applications of blockchain technology to

Table 3: The Application of Technology at the Selected Ports

Parameter	Ports		Comments on the Port of Rotterdam	Comments on the Port of Durban
	Port of Rotterdam	Port of Durban		
Type of Port	Smart	Traditional	Smart because of the adoption of the latest and relevant technology.	Very traditional in its operations
Technology Type	Blockchain (Quay Connect) HAMIS- Haven Management Information System Artificial Intelligence Twin Digitalisation.	Navis Sparcs N4 Electronic Data Interchange General Cargo Operating System AVEVA Software to reduce the risk of load shedding	Partners with several Universities and Software Companies	There is a need for more stakeholder engagement.
The Role of Technology	The existing technology that is being used in Rotterdam is crucial to facilitating the construction materials supplychain.	The technology used is not adequate to mitigate the current operational risks and delays experienced at the Port of Durban.	Proven track record in handling efficiency issues.	There is need to upgrade the current technology mix to improve efficiency at the Port of Durban.

Source: Authors, 2025

facilitate the supply chain for construction materials. This lends credence to the importance of Blockchain in the areas of smart contracts, shipment tracking and tracing, accelerated document flow, and authentication and validation of documentation among stakeholders. The study demonstrated that technology can be a major driver of port productivity.

Furthermore, the enormous gap in port productivity, as shown in Figure 4, underscores the importance of innovation and technology in the Port of Rotterdam, as noted by Osundiran and Makgopa (2025). Finally, the study compares the various applications of technology at the Port of Durban and Rotterdam. The research also notes that, even though the Port of Rotterdam is more productive and digital, blockchain technology is not the only causal factor.

This research suggests that the port authority, construction companies, and other stakeholders recognise the benefits of Blockchain in facilitating the construction material supply chain. For instance, Quay Connect is the collaboration between the Port of Rotterdam, Brexit and Importers and Exporters. This customised BCT was developed to address the challenges of import-export between European nations. Particularly since BCT provides a way forward for addressing port inefficiencies, for instance, Smart contracts can activate real-time actions or transactions as soon as the predefined contractual clauses and rules are fulfilled (Phillip et al., 2019). Furthermore, the Port of Rotterdam engages its stakeholders in a way that ensures the technology used in the port is well-suited to meet the needs of the Port and its stakeholders. Therefore, this study recommends that a customised Blockchain be adopted between the construction companies and the South African Port.

The study's limitations include focusing on two sets of DMUs, omitting variables such as hinterland infrastructure, and having a short timeline. The study does not empirically test the impact of BCT in Durban, and the policy recommendation is based on analogy and literature rather than intervention evidence.

Further research can be conducted on the efficiency of ports after the adoption of Blockchain Technology in subsequent years to determine whether there is an improvement or a further decline in port efficiency.

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Appendix 1

Table1: Significance of Blockchain Technology in Construction

S/N	Authors	Significance of Blockchain Technology in Construction
1	Kim, K., Lee, G. & Kim, S. A. (2020)	Reduces and Manages Project Cost; enhances the process of change Management; Assists in Contract Bidding and Formation, and fosters procurement evaluation.
2	Žiga Turk, Robert Klinc (2017)	When building information modelling (BIM) is used, Blockchain can complement by managing and assigning roles and responsibilities.
3	Shojaei, Alireza. (2019).	Data is encrypted, hence secured.
4	Philipp, et al., (2019)	Smart Contracts
5	San et al., (2019)	The construction industry should adopt blockchain technology because other technologies used across various project life-cycle stages have limitations.
6	Mahmudnia, D., Arashpour, M. and Yang, R., (2022)	Solve problems related to traditional contract forms.
7	Adel et al., (2022)	BCT secures access control for electronic records and the IT system
8	Elmay, Salah, Yaqoob, Jayaraman, Battah, & Maleh, (2022.)	The application of blockchain technology guarantees the full traceability of containers and goods in the Port.
9	Rahimi et al.,(2020)	Blockchain provides an authentication mechanism that enables secure communication for a wireless communications-assisted UAV sensing system for maritime IoT critical applications, by deploying a private Blockchain network connected to a fusion centre (FC) in the terrestrial area.
10	Nasih, et.al.,(2024).	The use of BCT improves tracking and tracing services, ensuring data integrity, transparency, and traceability across supply chains.
11	Xu, Xu & Yang, Yanbin. (2024).	Aids in improving visibility across the global supply chains.
12	Zhang & Zhang (2025).	BCT stands as an unconventional strategy
13	Hargaden et al., (2019)	Promotes the efficiency of processes
14	Kiu et al., (2020)	Blockchain technology can tackle the issue of loose collaboration among stakeholders in the construction industry.
15	Akinradewo et al. (2021)	The ability of blockchain technologies to record, enable and secure large amounts and types of transactions
16	Okanlawon et al. (2025).	Improve the construction process.
17	Figueiredo et al., (2024)	Blockchain ensures data security, integrity, and transparency.
18	Khalifa and Marzouk (2025)	Integration of Blockchain technology with others, like Digital Twin technologies
19	Waqar et al. (2024).	Enhances the sustainability of projects
20	Basheer, et al. (2024)	Applicable for integrating systems to manage construction materials and inventory to enhance the traceability and transparency of shared supply chain material information.

Source: Compiled by Authors, 2025