Journal of Transport and Supply Chain Management
ISSN: (Online) 1995-5235, (Print) 2310-8789

An assessment of the capacity and the performance of marine services in South Africa's ports

Authors:
Sphiwe E. Mthembu[1]
Mihalis G. Chasomeris[1]

Affiliations:
[1]Graduate School of Business, College of Law and Management, University of KwaZulu-Natal, Durban, South Africa

Corresponding author:
Sphiwe Mthembu,
sphiwe.mthembu@transnet.net

Dates:
Received: 06 Dec. 2022
Accepted: 28 Mar. 2023
Published: 29 May 2023

How to cite this article:
Mthembu, S.E. & Chasomeris, M.G., 2023, 'An assessment of the capacity and the performance of marine services in South Africa's ports', *Journal of Transport and Supply Chain Management* 17(0), a879. https://doi.org/10.4102/jtscm.v17i0.879

Background: With about 80% of world trade being seaborne, seaports' capacity, efficiency and associated services are vital to ensure seamless, sustainable global supply chains. A lack of investment in marine services capacity and performance in South African ports remains a concern for port users and supply chain practitioners.

Objectives: This study examines the capacity and performance of marine services in South Africa's ports. The primary example examines marine services performance data for the Port of Durban.

Method: This study uses Transnet National Ports Authority (TNPA) data and descriptive statistics to analyse marine fleet performance, bollard pulls and human capacity in South Africa's ports to identify causes of shipping delays in the Port of Durban from 2014 to 2021.

Results: The 8 years analysis show five most prominent sources of shipping delays in Ports as; tugboats occupied, shift changes, shipping movements, tugs out of commission and adverse weather conditions. Other factors identified were pilot-boat availability, overbooking slots, port meetings, etc. The performance of marine services are impacted by outdated wet infrastructure and a shortage of marine crafts and critical skills.

Conclusion: There is a clear and justified need to increase physical and human capital investment in the provision of marine services and improve maintenance spending on critical infrastructure to reduce shipping delays and costs of conducting trade in South African (SA) ports.

Contribution: The study compiles, analyses and provides a contextual understanding of the number of marine crafts, average bollard pulls, human resources capacity and causes of shipping delays in Republic of South Africa (RSA) ports.

Keywords: marine; performance; pilotage; towage; mooring; anchorage; seaports; logistics.

Introduction

Ports are gateways to international markets with maritime transport accounting for more than 80% of global trade (UNCTAD 2021). Ports facilitate international trade by connecting global supply chains. Ports present opportunities for shippers to build shipping volume buffers, consolidate cargo and perform transhipments. Port operation efficiencies are increasingly becoming an important influence towards attracting international shipping (Xu, Mao & Jin 2012). Shippers aim to reduce logistics costs as they search for ways to improve efficiencies in the logistics supply chains (Rodrigue, Comtois & Slack 2016). Shipping business, the transport sector and ports are crucial economic growth enablers that create cities' employment (Dwarakish & Salim 2015) and contribute to a country's economic outlook. The governance of the ports, pricing and ownership structures varies from one country to another, forming a source of competitive advantage for the ports (Meyiwa & Chasomeris 2020; Mthembu & Chasomeris 2021).

South Africa has eight commercial ports along its coastline and Transnet National Ports Authority (TNPA), a division of Transnet SOE Ltd, is the landlord and sole provider of marine services in each of these ports. Consequently, there is economic regulation of TNPA prices (tariffs). Gumede and Chasomeris (2018) examine the TNPA tariff structure imbalances and cross-subsidisation between commodities and different port users. Vessel charges are below the benchmarked mean, and the required revenues (RRs) are raised largely from cargo dues that are charged to cargo owners. The Ports Regulator of South Africa (PRSA) (2021) 'Global' port pricing benchmarking study (actually a sample of 25 container ports) shows that whereas terminal handling charges and cargo dues are 55% and 166% above the average, marine services are 44% below the benchmarked average. The relatively low prices for marine services may exacerbate the lack of investment and maintenance in marine services.

Since 2009 and 2010, the PRSA has allowed a rate of return pricing methodology referred to as the RR model. The RR model, however, created perverse incentives and did not appropriately incentivise port performance and capital expenditure (investment) in infrastructure and marine services (Chasomeris 2015; Grater & Chasomeris 2022; Gumede & Chasomeris 2017). In attempts to measure and improve port performance, TNPA implemented port performance standards such as Marine Operations Performance Standards, Terminal Operator Performance Standards and Rail Operator Performance Standards and Haulier Operator performance standards.

Furthermore, in an attempt to incentivise improved port performance, the PRSA allowed the inclusion of a Weighted Efficiency Gains from Operations (WEGO) variable into the calculation of the RR model. Weighted Efficiency Gains from Operations allowed TNPA to earn up to an additional 5% profit for a 10% increase in five key performance indicators. Alternatively, a reduction in port performance could reduce profits by up to 5%. The World Bank et al. (2022) ranked 370 competent container handling facilities in 2021. Despite the initiatives to improve port performance, South African ports were ranked towards the bottom with the Port of Port Elizabeth ranked at position 312, Ngqura ranked at position 363, the Port of Durban ranked at 364 and Cape Town ranked at 365.

The mandate for port authorities is to improve the performance of ports to satisfy the needs of port users (The World Bank et al. 2022). Transnet National Ports Authority is mandated to provide port infrastructure and marine services in the eight commercial ports. Despite introducing measures like the WEGO into the RR model, port capital expenditure has significantly declined from ZAR 2.96 billion in the financial year (FY) 2015–2016 to a mere ZAR 684 million in FY2020–2021 (Grater & Chasomeris 2022). According to the Ports Regulator of South Africa (2016), the provision of marine services in South Africa's ports has inadequately evolved to meet the needs of shipping demands. Identification and classification of ship delays at anchorage have proven to be difficult. Various factors can influence the time ships spend waiting at anchorage; these are related to scheduling problems, ships missing berthing windows, documentation, cargo surveying, terminal readiness and terminal performance.

This study examines the capacity and performance of marine services in South Africa's ports. The primary example examines marine services performance data for the Port of Durban. It explores the capacity and performance of marine and nautical services and contributes to a better understanding of their impact on the overall performance of ports. This paper uses descriptive research design to collect, analyse and present the research results (Mertler 2021; Siedlecki 2020). The Port of Durban handles about two-thirds of the total value of cargo passing through the country's eight ports. In addition, it is the main container port and handles the largest number of ships, about 34% of the total port calls (Chasomeris & Gumede 2022). Because of the demand concentration and technological developments in the Port of Durban, the ship delay data were gathered and analysed for the Port of Durban for the period 2014–2021. The study employs a quantitative descriptive statistics approach to perform marine and nautical performance data analyses. The fleet data analysis of marine crafts, average bollard pulls and human capacity was conducted at the national level including all of the eight South African ports, but shipping delay analyses focused on the Port of Durban. The results show the capacity constraints and inadequacies in the provision of marine services in the port system that consequently inhibits the overall productivity of ports.

Port users and the PRSA should continue to exact pressure on the TNPA and provide appropriate incentives to improve the investment, capacity, pricing and performance of marine services in South Africa's ports. The article consists of a literature review, research methodology, results, discussion and conclusions.

Literature review

Marine services in port

Marine and nautical services in South Africa's ports commence as the ship crosses the port boundary (*National Ports Act* 2005). The ship announces its arrival to vessel traffic control as it crosses the port boundary and is allocated an appropriate position inside the port limits area that could mean either anchoring, drifting, waiting for berth availability or proceeding to the port entrance to receive the pilot (Sasa, Mitsui & Tamura 2018). All commercial ships visiting South African ports must be allocated local pilots, harbour tugboats and mooring gangs to facilitate the safe docking of the ships in the ports (*National Ports Act* 2005). Once the cargo operation has been completed, the ship agent must request marine and nautical services from the port authority (pilot, tugboats and mooring crews) to undock the ship in readiness to proceed to the next port of call. This is a common practice observed in most ports around the world. Marine services institutions are mandated to safeguard ships, reducing the risk of collision in ports (Zhen et al. 2018). The harbour master's office is tasked with the duty of ensuring the safety of ships and the environment within the port limits (*National Ports Act* 2005). The harbour master has the jurisdiction to impose regulatory rules in ports to safeguard ships and port infrastructure (Hershman 2017). The harbour master must establish port emergency preparedness and disaster management plans (Zhen et al. 2018). The port authority, through the office of the harbour master, maintains the safety of navigation by means of providing vessel traffic control services, aids to navigation, hydrographic survey, appointments of pilots and provision of towage services (Ugboma et al. 2007). According to Gans and King (2003), it is the general practice in ports for the private sector to provide the majority of marine services. In contrast, TNPA, through its integrated port management structure, provides all marine services in South Africa's ports (Mthembu &

Chasomeris 2021; Wayne 2017). In recent years, ports experienced the introduction of the private sector in functions such as maintenance dredging, bunkering services, shipbuilding and rescue services (Mthembu & Chasomeris 2021; Wayne 2017).

Pilotage operation

Ships are in great danger when navigating close to shore and in narrow port channels as compared to sailing at open sea (Constable & Wild 2017). Ship collision risk is much higher in the congested and confined areas of the ports. The probability of ship-grounding and collision heightens as the ship approaches and transits a congested anchorage area through to shallow waters of the ports Georgescu et al. (2010). According to Sahin and Yip (2020), about 85% of marine incidents occur as a result of human error because of the dominant role of judgement in piloting and the hazards associated with in-shore navigation. The international ship regulation stipulates ship manning to ensure sufficient human intervention to avoid maritime incidents (MacDonald 2006). The ship's crew consists of the ship's captain, the commander of the ship, navigating officer in charge of executing navigational plans, the officer of the watch tasked with filtering shipping situations that may hinder execution to the navigating officer, the assistant to the navigating officer who works with navigational chart-work, blind-safety officer, who oversees and monitors the ship's position using blind piloting techniques to ensure the ship's safety, yeoman, who is tasked with recording the wheel and engine orders and echo sounder operator, who provides the standard reports (Stefan et al. 2010).

Most countries' navigational policies call for local pilots to navigate the ship in ports (Eriksen & Lützen 2022). Navigating the ship safely in port is the responsibility of the port authority, which is exercised through the group of skilled mariners (harbour master, pilots, tug masters, chief engineers, coxswains, berthing masters and general-purpose ratings). According to Sahin and Yip (2020), pilotage is performed by mariners who have local knowledge of the ports. They provide advice to the ship master as the ship transits port channels. The responsibility to provide pilotage, towage and mooring resides with the National Ports Authority (NPA). The harbour master determines and specifies pilots' qualifications, authorising personnel to operate as pilots (*National Ports Act* 2005). Pilot transfer operations are the most critical part of pilotage. The pilot is transported by helicopter or pilot-boat six miles at sea to board a moving commercial ship or taken off the sailing ship while transiting the port channel. According to Wang and Li (2022), a pilot-boat is the big water taxi that transfers pilots to and from commercial ships. The pilot-boat must race out to meet the ship at the designated area and transfer the pilot without delaying the ship's progress. While in transit, the pilot-boat master advises the ship's captain on the course and speed to maintain and the ship side (port or starboard) to which the pilot ladder should be deployed. The transfer takes place while both ships are in motion moving at an average speed of nine knots (Wang & Li 2022).

Towage operation

Ship docking is an important operation in the shipping business and greatly impacts port and terminal performance (Miletić, Debelić & Rathman 2015). Pilots require the assistance of tugboats to dock the ship safely in ports, an operation also known as a towage operation (Chou, Wen & Huang 2020; Miletić et al. 2015). Tugboats are small compact ships used to assist big commercial vessels in navigating narrow port channels in ports around the world. Tugboats have greater manoeuvring capabilities than the ship they assist; their manoeuvring is flexible and equipped with powerful diesel engines. Tugboats provide protection for ships in port, as they play an essential role in reducing the risk to ships in ports (Chou et al. 2020). There are several factors determining the number of tug-boat requirements in ports. These are shipping demand in ports, the number of births, the availability of mariners, policies and/or regulatory laws and the weather conditions in the region or country.

There are three types of tugboats in existence around the world. These are the conventional tugs, azimuth stern drive tugs and tractor tugs. Conventional tugs are the oldest model of tugs. These tugboats are still in existence in some parts of the world. They are especially found in developing countries. Conventional tugboats have manoeuvring capability limitations with their amidships positioned towing winch, making them susceptible to girting (Jong & Krishnan 2011) The azimuth stern drive tugboat is highly manoeuvrable with its powerful nozzle propulsion units originally placed on the stern. The new generation azimuth tugboat consists of two nozzle propulsion units positioned alongside the tug. They are popularly known as Z-type tugboats because of the shape of the nozzle. The mooring windlass is located at the bow, increasing the turning lever and, therefore, increasing manoeuvring capabilities (Jong & Krishnan, 2011). Lastly, tractor tugs, these tugboats that represent a completely new and opposite concept of propulsion order when compared to conventional and azimuth tugboats. These tugs are seldom used because they are very expensive. The tug concept is based on two built-in multi-directional propulsion systems that work in a cycle of 360° on the principle of two vertical built propulsion mechanisms with rotating wings below the tug bridge, providing excellent manoeuvring capability to the tractor tug (Cui & Notteboom 2017; Jong & Krishnan 2011). Usually, two tugs are required during the operation of docking the ship to its designated berth. Berth allocation is the process of planning a berth for an incoming ship and allocating marine resources to assist the ship to its allocated berth. Tug-boat assignment is described as a task of finding the best tug assignment and schedule sequence of ships to minimise ship turnaround time (Wang et al. 2014). Ships have developed, growing bigger in size and possessing improved technology. The number of ships visiting ports has also increased as

international trade grows (Wang et al. 2014). Due to the growth in ship size and the number of ships visiting the ports, ship safety and efficient docking have become a priority in ports. Ships, in general, need greater water room to turn because of their size and propulsion system. For them to navigate narrow channels and shallow water of the ports and risk running aground, they need the assistance of tugboats in pulling and pushing the ships around the ports.

According to the International Transport Forum (2014), frequently, during ship arrivals in ports, berths are rarely available for ships to dock immediately. Ships have to be diverted to the anchorage and, as a result, become congested in port's anchorage areas. Immediately when berths become available, the allocation of pilots, tugboats and mooring gangs is activated (Xu et al. 2012). According to Xu et al. (2012), a single tug-boat operator usually enjoys a monopoly in ports in most countries. According to Haider et al. (2014), the customers for tug-boat services are shipping lines requiring ship towage during the docking and sailing of their ships. Özbaş and Or (2007) suggest that one of the important goals for the port authority is to ensure that tugboats do not deter shippers from utilising the port. Consequently, harbour towage has been the subject of performance surveillance in most ports in South Africa and other ports in developing countries. The *National Ports Act* (2005) mandates the port authority to ensure efficient port operations in all eight South African ports to reduce turnaround time for ships. The International Transport Forum (2014) suggests that there should be an optimal deployment level for tugboats as their performance has a direct impact on the ship's turnaround time. Beckman (2007) proposes the performance measurement for tugboats in ports to include the availability of tugs per hour and the sum deployed gradually.

Vessel traffic services in ports

A technological innovation introduced into the maritime industry was the Automated Information System (AIS) and electronic charts displayed into one navigational system. Automated Information System has improved the productivity of the maritime industry (Praetorius, Hollnagel & Dahlman 2015). According to Kim and Lee (2018), the introduction of vessel traffic system (VTS) in ports complementing AIS aimed at reducing maritime incidents, increasing efficiencies and reducing the risk of damage to the environment. Vessel traffic system monitors the traffic within port boundaries, assists ship navigate anchorage areas and provides ships with information pertaining to geographic factors. According to Praetorius, Hollnagel and Dahlman (2015), the system is delivered at three different levels: information service (INS), traffic organisation services (TOS) and navigational assistance services (NAS). Information service broadcasts information to all ships within the VTS zone. The system provides information about the ship position, provides ships with the intentions of other ships and provides geographic information on the navigational lanes. Traffic organisation services aids the management of traffic movements within VTS zones, thereby facilitating the prevention of port disasters and avoiding congestion. Navigational assistance services facilitates decision-making on-board ships and provides confirmation on very high frequency radio (VHF). The purpose of vessel traffic control is to lessen overall business risk within a port boundary or VTS zone (Kim & Lee 2018). According to Shakhnov et al. (2023), the VTS is a service implemented by a competent port authority intended to improve the safety and efficiency of the movement of ships within the port boundary and protect the environment. Hsu (2012) proposes that the operator should have capabilities to interact with marine traffic and respond to traffic situations developing in the VTS range. Traffic is organised and regulated to minimise the risk of vessel collisions (Hsu 2015). A passive VTS provides information regarding traffic movements and other matters of interest to port users. The main components of a good VTS station include building for control operatives, radar-tracking system, communication system and data handling capability (Transnet National Ports Authority 2017).

Procedure for receiving ships in ports

Ports provide a safe shelter for ships and seafarers, and they are a place for loading and unloading of cargo (Wayne 2017). In almost all ports around the world, there are port-specific procedures for accepting ships visiting the ports. These berthing procedures are aimed at avoiding port incidents pertaining to vessel collisions, infrastructure damage and avoidance of ships from running aground in shallow port waters. In South Africa's ports, such procedures are detailed in the berthing guidelines as published by the office of the Harbour Master. Berthing procedures are a common practice in most ports around the world. The procedure begins with ship sending 72 h notification to the port authority of its intention to call in at the port. This document is known as estimated time of arrival (ETA) (*National Ports Act* 2005).

The ship agent further notifies the port authority and the terminal 48 h before the expected berthing time of the intention to berth the ship. Once the ship arrives at the port limits, the ship captain notifies the vessel traffic control of the ships crossing of port limits, which is 12 miles at sea in South Africa's case. The captain reports again the position of the ship while crossing six miles away from the port entry. Depending on the availability of berth, marine resources and weather conditions, the ship will be instructed accordingly. Vessel traffic control liaises with the captain and directs the ship to either proceed to anchorage or towards the fairway-buoy where the ship will meet with the pilot. If a berth is not available, the ship will be given a position at an anchorage area where it will hold while awaiting the availability of berthing space. If the ship is to dock on arrival, the pilot, tugboats and berthing gangs are allocated to assist the ship with navigating to the designated cargo berth (Cui & Notteboom 2017). The pilot proceeds to board the vessel four miles off the port entrance channel. The pilot is transferred

to the moving ship through the pilot boat or a helicopter. Once the pilot has boarded the ship, the pilot meets the ship's captain and shares essential information pertaining to the ship's capability, ship's dynamics, ship draft and gross tonnage. The pilot shares information regarding the tugs in position, berthing arrangement and conditions of the port (Cokgormusler 2021). The pilot takes charge and navigates the ship approaching the port, passing breakwaters into the port entrance channel where tugs are in standby position to assist the ship. When the ship enters the channel, tugs quickly connect their towing line to the ship and report to the pilot, then await further instructions. The ship is piloted or navigated by the team including ship's captain, pilot, tug masters and berthing masters. The role of petty officer is to assist the pilot count down the distance between the ship and quay as the ship approaches the berth. Once the ship is alongside, the petty officer assists the pilot to position the ship according to the bollard allocation and supervises berthing gangs to secure the ship in position using the ship's ropes, generally known as ship's lines. The petty officer informs the pilot as soon as all lines are fastened onto the bollards. Now that the ship is safely fastened alongside, the pilot releases the tugboat and berthing gangs to attend to other ships. The ship's captain further conducts an inspection and releases the pilot. The pilot proceeds to disembark the ship and attend to the next ship in line. The entire procedure takes about one and a half hours, on average, depending on whether it is an incoming ship or a sailing ship.

Four hours before the expected time of departure (ETD), ship agent and terminal operator notify the port authority of intention to sail the ship. Two hours before ETD, the vessel agent confirms with port authority of intention to sail the ship and again 30 min before ETD. Vessel traffic control proceeds to allocate marine resources (pilot, tugs and berthing gangs) to assist the ship to sail (Cui & Notteboom 2017). The inverse of the incoming procedure is then executed by the marine services team during the sailing of the ship. Depending on the location of the berth, sailings on average take approximately 45 min to complete (Transnet National Ports Authority 2016). Figure 1 summarises and illustrates the process flow for receiving ships in South African ports.

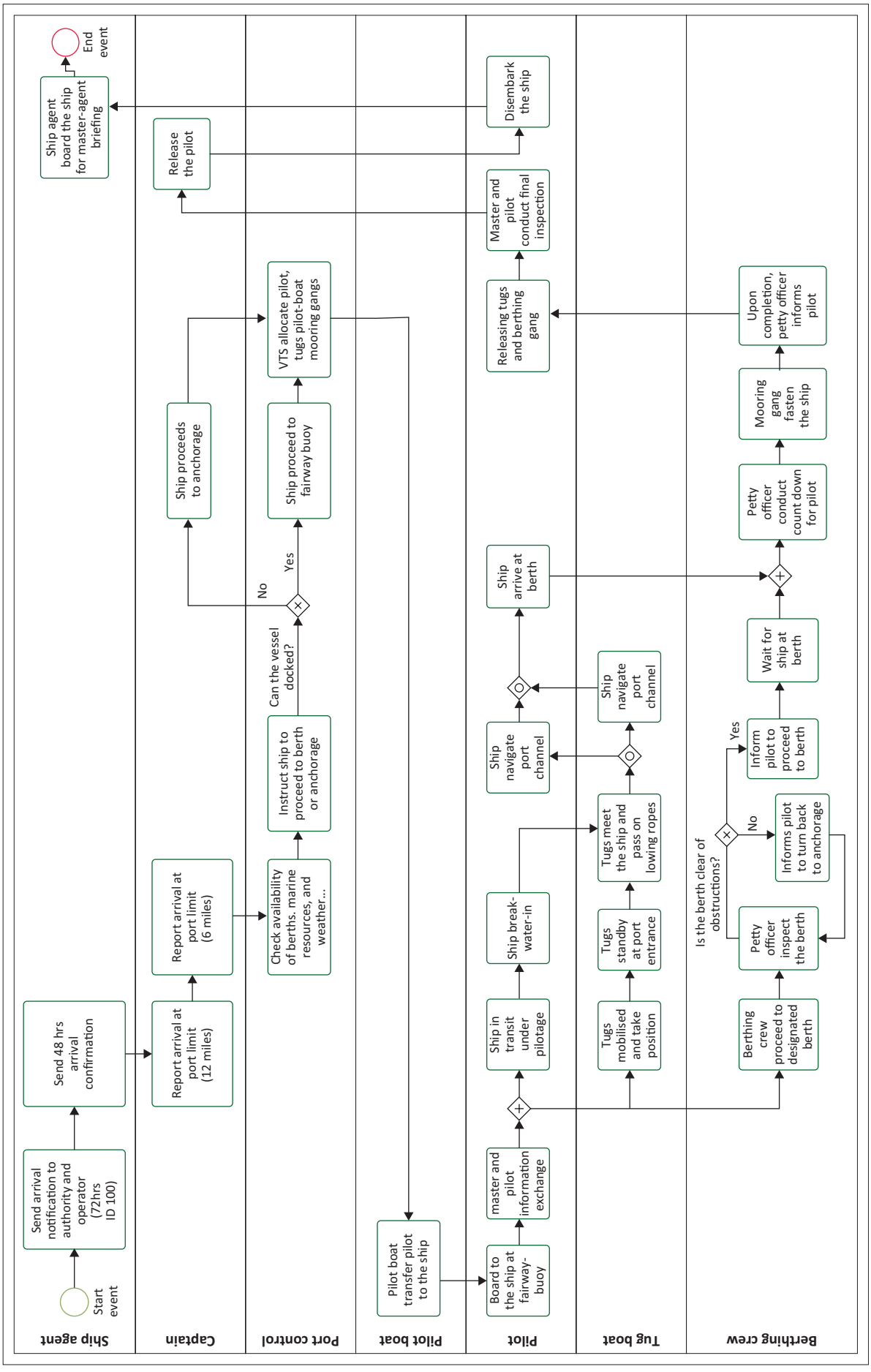
The procedure above is applicate to South African ports while it is also relevant and largely applicable to other ports around the world. By virtue of maritime logistics being an essential factor of global seaborn trade, port productivity is fundamental to the seamless flow of cargo through to the hinterland (Elbert & Scharf 2018). The above procedure of accepting vessels in port is designed to enhance productivity of the ports and avert maritime incidents (Wang et al. 2014). The efficiencies in the provision of marine services are the key responsibility of the harbour master assisted by port management. The port operation policies and procedures are enablers to the speed at which services are rendered to ships. The capacity challenges and availability of needed resources are foundation to the flow of cargo and shipping movement reducing congestion in ports anchorage areas (Elbert & Scharf 2018). The paper will contribute to the literature on the capacity and the performance of marine services in ports.

Research methodology

The study employs a quantitative descriptive research design to analyse the productivity and performance of marine services in ports along with a review of the impact of marine services on shipping in ports. The main aim is to study productivity and efficiencies in the provision of marine services in South African ports' systems. This quantitative study uses descriptive statistics to analyse, evaluate and present marine services performance and resource capacity. The results are presented in the form of tables, graphs and figures (Matthews & Marzec 2012). The aim is to gather understanding of the level of shipping delays, capacity requirement versus shipping demand and assess the impact of marine services on the overall port performance. Tables, figures and graphs are used to aid readers' understanding of marine services productivity performance and highlight areas of underperformance in the provision of marine services in South Africa's ports.

The study samples marine services performance data from 2014 to 2021. The study assimilates a tendency associated with longitudinal research design where data are collected on multiple occasions. The first sample was collected in 2018, studying marine performance between 2014 and 2018, and results were presented as a conference paper at the International Association of Maritime Economists conference in Greece in 2019. The second sample was collected in 2021, studying marine services performance between 2018 and 2021. This study compiles and analyses the data for the 8 years from 2014 to 2021. Secondary data pertaining to provision of marine services performance and capacity requirements were obtained from Transnet libraries. The data gathered from the Transnet database were reviewed, compiled analysed and presented as graphs, figures and tables that help to identify trends and provide evidence that supports the results, conclusions and recommendations.

This study benefited from a reductionist approach imbedded in the quantitative research design. Moreover, quantitative descriptive statistics design allows the researcher to analyse and present complex phenomena in a simple and easy to comprehend format (Matthews & Marzec 2012). A descriptive research approach can respond to questions of what, where and how, using a wide variety of quantitative research tools that identifies characteristics, tendencies, frequencies, trends and categories (Amis 2011). Central tendencies, frequencies, trends and categories are employed to aid a better understanding of the performance of marine services in South Africa's ports and assess the impact on the overall performance of the ports. According to the author's knowledge, there is little research conducted that evaluates the provision of marine services and their



Source: Adapted from National Ports Act, 2005, *National Ports Act No. 12 of 2005*, vol. 482, no. 27863, Government Gazette, Cape Town, viewed 18 March 2023, from https://www.transport.gov.za/documents/11623/114625/National_Ports+Act_a12_051.pdf/4f9f271c-3c79-44f8-be7a-e5e0fdbe76d7. and Transnet National Ports Authority, 2016, *Berthing policy*, viewed March 2019, from www.transnet.net

FIGURE 1: Process flow for receiving ships in ports.

impact on shipping movements in ports. Attention has been focused on shipbuilding, terminal planning, maritime logistics, maritime policies and marine emissions (Pallis, Vitsounis & De Langen 2010). The Port of Durban handles the most containers in Southern Africa and is referred to as the gateway to Africa. Chasomeris and Gumede (2022) explain that the:

> Port of Durban is the busiest multipurpose port in Africa and, in 2017, it handled total cargoes of about 42 million tons, more than 455 thousand vehicles, and about 2.7 million TEUs. Cargo volumes flowing through the Port of Durban are estimated to be about two-thirds of the total value of cargo through the country's ports. (p. 55)

The Port of Durban was selected for this exercise, considering its size, trade value and volume handled, number of ship calls, its position of national strategic importance and other complexities faced, as opposed to other ports. In addition, it employs about one third of the marine fleet available to service South Africa's eight commercial ports. The fleet data analysis of marine crafts, average bollard pulls and human capacity, was conducted at the national level including all of the eight South African ports, but shipping delay analyses focused on the Port of Durban. The study contributes to an understanding and appreciation of marine services' capacity and productivity and its impact on supply chain performance to assist policymakers, the port community and port managers in better collaborating and achieving efficiencies and optimisation.

Ethical considerations

Ethical clearance to conduct this study was obtained from the University of KwaZulu-Natal Research Ethics Committee (no. 00002007).

Results and discussion

The functions of TNPA are to ensure equal access to ports' facilities and provision of port services to multiple port users (*National Ports Act* 2005). Transnet National Ports Authority must ensure safe navigation of ships within the ports' limits and provide security within port boundaries through the provision of navigational aids, ship berthing resources and port parameter fencing to comply with the ISPS Code (beacons, buoys, breakwaters, sufficient channel depth, vessel traffic services, pilotage, tugboats, mooring facilities, berths, water transfer facilities and dry-docking facilities) to circumvent marine and security incidents (Ports Regulator of South Africa 2015). According to the Ports Regulator of South Africa (2016) and the author's own assessment, the provision of marine services in South Africa's ports has inadequately evolved to meet the needs of shipping demands. Identification and classification of ship delays at anchorage have proven to be an overwhelming exercise. Various factors can influence the time ships spend waiting at anchorage; these are related to scheduling problems, ships missing berthing windows, documentation, cargo surveying terminal readiness and terminal performance (Ha et al. 2017).

The assessment of resources and equipment required for the provision of marine services in ports revealed a massive national deficiency that has continued to restrict performances at a broadly national scale. The assessment of tugboats, pilot-boats, workboats, floating cranes, launches and manning levels, dependent on availability of critical skills required to support maritime industry in ports, has proven to be inadequate for the size of South African ports. This phenomenon has had negative impacts on the provision of marine-related services and sparked huge concerns for managers of the marine industry. The situation impedes on the performance of ports, limiting volume throughput and snowballing into poor performance of the hinterland supply chains and increasing the cost of doing business.

Table 1 shows fleet deployment as per port and provides a national view of the fleet composition in all eight commercial ports in South Africa.

Nationwide TNPA owns 31 tugboats, 7 workboats, 9 pilot boats, 9 work launches, 4 helicopters, 2 floating cranes, 4 dry docks and 2 slipways, all intended to support the maritime industry in South Africa. Tugboats, workboats and pilot-boats are meant to assist with the transfer of pilots, tugging and towing of ships inside confined narrow waters of the ports and remain available as standby in case of emergencies relating to grounding, fire and man-overboard. Helicopters, on the other hand, fall under the aviation department but provide services to ships by transferring pilots to board the incoming vessels. Work launches assist with running of lines, especially for the tanker industry, while floating cranes assist shipping customers with heavy lifting of out of gauge cargo (Transnet National Ports Authority 2017). Regrettably at a national level, all eight commercial ports marine services provision are under-capacitated and operate below required capacity. Assessment craft requirements for three major ports in South Africa: the port of Richards Bay, the port of Durban and the port of Cape Town confirmed major concerns from port users pertaining to the shortage of marine crafts. According to TNPA Fleet Replacement Plan (2019), port of Richards Bay requires five tugboats versus three operational tugboats, two pilot-boats versus one currently operational and two helicopters versus one operational. The port of Durban requires eight tugboats versus five currently operational, two pilot-boats versus one currently operational and two helicopters versus one operational at this stage.

TABLE 1: Marine fleet at South Africa's ports.

Port	Tugs	Work boats	Pilot boats	Launches	Helicopter	Floating crane	Total crafts per port
Richards Bay	5	1	1	0	2	0	9
Durban	10	0	2	5	2	1	20
East London	2	1	0	0	0	0	3
Ngqura	3	0	1	0	0	0	4
Port Elizabeth	2	1	1	0	0	0	4
Mossel Bay	0	1	0	1	0	0	2
Cape Town	5	2	3	2	0	1	13
Saldanha	4	1	1	0	0	0	6
Total	**31**	**7**	**9**	**9**	**4**	**2**	**61**

Source: Transnet National Ports Authority, 2021, *Transnet National Ports Authority marine services performance data*, viewed June 2022, from www.transnet.net

The port of Cape Town requires five tugboats compared to three operational, two pilot-boats versus one operational and two helicopters versus zero helicopter operational in the port currently. This tendency of under capacitation is evident throughout all eight commercial ports in South Africa. Tug bollards pull available in ports plays a key role in determining the capacity of the port to handle deep-drafted new generation ships. A major concern by maritime industry stakeholders is the ageing fleet as well as the available combined tug bollard pull power in ports.

Table 2 illustrates the average age and combined bollard pull power available per port in South Africa.

Assessment of national fleet age and bollard pull power available in ports illuminated the challenge confronted by ports and legitimatised concerns tabled by the South African Association of Ship Operators and Agents (SAASOA) and other port users regarding marine fleet delays. This phenomenon emphasises a lack of investment into marine floating crafts by TNPA (evident in Table 2), especially in the Port of Mossel Bay and the Port of East London, where the fleet is much older than 35 years of age. Most tugboats are between 16 and 30 years old, with only eight tugs out of 31 being below 10 years old. According to Marcon International report (2021), the worldwide average age of tugs in ports is 23 years - 35 years for sea-going tugs. In the latter part of the analysis, the number of tugs in port was reported as insufficient. In this section, the assessment identifies age as problematic for two ports. The examination of tug bollard pull indicates variance in bollard pull across the ports system. The average bollard pull required in port is 65 tonnes bollard pull compared with the average 54 tonnes pull in South African ports – an 11 tonnes bollard pull power deficit. The port with sufficient average bollard pulls power are the Port of Ngqura, the Port of Port Elizabeth and the Port of Saldanha. The busiest port, the Port of Durban, remains under-capacitated. This is supported by Paulauskas et al. (2021) assertion of the international benchmark for tug bollard pulls ranging from 55 to 100 tonnes bollards pull. The smaller ports operate with 50 tonnes bollard pull tugboats rendering these ports redundant for ships such as E/G class container vessels, SUEZMAX and/or bigger tankers capsize and/or bigger bulkers and other ships that require bigger tugs to berth safely.

The reviewed workforce and skills availability on paper and in practice revealed huge shortages in crew requirements in South Africa's port systems. Crew shortages, competency levels and inadequate planning processes remain a challenge for ports. The lack of technology to manage these complex processes was identified as a major challenge as this could be a main contributor to the incidents experienced in ports. There is a general lack of pilots, tug masters and engineers in South African ports that are skills essential for docking of ships and reducing risk to navigation. The trend in many ports around the world, including canals, is to have a greater number of pilots rather than fully crewed tugboats. In South Africa, according to the tariff book, there is one pilot per two tugboats while in the ports of developed countries, the ratio is one pilot per half a tugboat (Özbaş & Or 2007). Observations of marine operations in other developing countries suggest a 50/50 split (one pilot per one tugboat). These ratios of pilot to tug-boat attendance to ship calling into ports reflect the cost paid by shipping lines for the provision of marine services. It suffices to say that port users pay for an additional number of tugs per ship size in South African ports compared to other ports around the world. Costs (but not the tariff charged) to operate a tugboat in South African is greater compared with other countries because of extra manning levels and additional tug-boats requirement per ship. Navigational risk varies from port to port because of conditions associated with port layout, channel width, regulations, skills and other factors associated with local climate.

Table 3 exhibits the challenge relating to workforce availability in South Africa's ports.

South Africa's ports are confronted by the growing need for seafarers to operate TNPA marine crafts (tugboats, pilot-boats, workboats, floating cranes and launches). The gap is widening between required skilled mariners and the marine workforce. There is a general shortage of master mariners, pilots, marine engineers and general-purpose ratings in the port system. Table 3 shows the problem faced by the national system with a total shortage of 75 personnel. This translates into a 20% shortage on pilots, a 26% shortage on tug masters and a 24% shortage on marine engineers (Transnet National Ports Authority 2018). The bleak picture is made worse by a lack of maritime training in the country. The lack (absence) of ships registered under the South African flag exacerbates the problem as those training towards being pilots, masters and engineers do not receive berth time to qualify as master mariners and chief engineers. The available capacity of marine crafts and workforce is evidently inadequate to meet the need of the South African maritime industry. There are justifiable concerns raised by the industry that relate to delays caused by a shortage of marine resources.

To further analyse the impact of marine services on South Africa's ports, the authors conducted a desktop descriptive statistics analysis of ship delays to assess the impact on the overall port performance, using a sample taken for the Port of Durban. The analyses are aimed at contributing to understanding the impact of marine services on the overall port performance, drawing attention to inefficiencies

TABLE 2: Transnet National Ports Authority fleet average age and bollard pull analysis.

Criteria	Richards Bay	Durban	East London	Ngqura	Port Elizabeth	Mossel Bay	Cape Town	Saldanha
Average fleet age	16	21	44	12	10	36	21	17
Average bollard pull	58	50	43	70	70	19	56	64

Source: Adapted from Transnet National Ports Authority, 2019, *National fleet plan*, viewed July 2021, from www.transnet.net

TABLE 3: Marine services critical skills requirement vs available skills.

Ports & Grades	Critical skills analysis																								Total Variance
	Richards Bay			Durban			East London			Ngqura			Port Elizabeth			Mossel Bay			Cape Town			Saldanha			
	Req	Avail	Var	Req	Avail	Var	Req	Avail	Var	Req	Avail	Var	Req	Avail	Var	Req	Avail	Var	Req	Avail	Var	Req	Avail	Var	
Pilots	20	15	-5	31	24	-7	3	2	-1	10	6	-4	10	8	-2	1	1	0	19	19	0	11	9	-2	-21
Tug masters	20	14	-6	36	28	-8	5	3	-2	10	7	-3	10	7	-3	0	0	0	18	15	-3	10	7	-3	-28
Chief engineers	20	13	-7	36	29	-7	5	5	-1	10	8	-2	10	8	-2	0	0	0	18	14	-4	10	7	-3	-26

Source: Adapted from Transnet National Ports Authority, 2021, *Transnet National Ports Authority marine services performance data*, viewed June 2022, from www.transnet.net

Req, Required; Avail, Available; Var, Variance.

pertaining to marine operations and further highlighting the need for investment in marine equipment and infrastructure. Table 4 shows the 15 topmost prominent marine services delays in ports and calculates their percentage contribution to the overall delays over the period of eight years from 2014 to 2021.

Table 4 shows the 15 topmost eminent causes of marine services delays in South African ports. It illustrates the total hours per category of marine services delays annually and shows the percentage contribution of each delay to the total shipping delays at the port. Delays range from tug occupied, shipping movements, tugs out of commission, shift change, weather delays, pilot-boat out of commission, berthing crew delays, terminal delays and tidal vessel delays.

The mean of the eight years analysed shows that the top five categories of delays contribute to over 70% of shipping delays in the Port of Durban. These delays include tugboat occupied (29%), shipping movements (22%), tugboat out of commission (10%), adverse weather (5%) and terminal delays (4%). The top three shipping delays point to problems of capacity. The top three delays relate to tug-boat shortages, ships waiting on anchorage and awaiting the availability of tugboats. Tugboat out of commission can be addressed through better planning and a good maintenance regime while tug occupied, and shipping movement reflects a lack of investment to increase the number of tugboats. The top three categories of delays (tugboat occupied, shipping movements and tugboat out of commission) account for roughly 61% of the port delays. Tugboat occupation suggests limitations in the number of tugs in ports. An increase in capacity could have a major impact on reducing shipping delays. Analysis of the 8-year financial period shows a steady decline in shipping delays from 2313 h in 2014 to 896 h in 2020. In 2020, because of the coronavirus disease 2019 (COVID-19) pandemic, South Africa imposed a strict lockdown that resulted in a 6.4% decline in real Gross Domestic Product (GDP), and annual container trade volumes declined from about 4.59 million TEUs in 2019 to 4.02 million in 2020 (Statistics South Africa 2022; UNCTAD 2022). Unfortunately, with a return to higher port volumes in 2021, there appears to be an increase in the annual total hours of ships delayed to 1153 h.

Table 5 quantifies the impact of shipping delays, as it shows the total number of ships visiting the port, the number of ships delayed, the percentage of ships delayed, the total hours of delay and the average hours of delay per delayed ship. The evidence points to a decline in shipping movements in ports from 3023 ships in 2014 to 2176 ships in 2021. This decline in the number of ships could partly be a consequence of shipping lines consolidating cargo into larger vessel sizes (Grater & Chasomeris 2022) While the number of ships visiting ports has declined over the period, the ports have achieved a steady decline in the number of ships delayed from 40% in 2014 to 25% in 2020, a 15-percentage point decline in marine services delays. However, the port experienced a sharp increase in marine services delays in

TABLE 4: Analysis of ship delays, 2014–2021.

Category	Year 1: 2014		Year 2: 2015		Year 3: 2016		Year 4: 2017		Year 5: 2018		Year 6: 2019		Year 7: 2020		Year 8: 2021		Avrg 8-Years	
	Hrs	%	Hrs	%	Hrs	%	Hrs	%	Hrs	%	Hrs	%	Hrs	%	Hrs	%	Avrg Hrs	Avrg %
Tug occupied	786.42	34	668.1	34	600.84	36	485.76	33	485.94	39	317.13	29.7	327.69	36	331.08	29	425.12	29
Shipping movements	531.99	23	451.95	23	358	21	382.72	26	224.28	18	225.06	21	228.39	25	224.28	20	330.83	22
Tug OOC	208.17	9	176.85	9	116.83	7	137.28	9	74.76	6	112.53	11	139.02	1.6	168	15	141.68	10
Shift change	47	2	39.3	2	16.69	1	44.16	3	37.38	3	30.69	2.9	19.86	2	21.36	1.9	32.1	2
Adverse weather	115.65	5	98.25	5	124.26	7	88.32	6	74.76	6	61.38	5.7	29.79	3	53.4	4.6	73	5
Pilot Boat OOC	44	1,9	37	1.9	16.69	1	44.16	4	37.38	3	30.69	2.9	19.86	2	10.68	0.9	30	2
Slot over booking	92.52	4	81	4.1	62	3.7	44.16	4	37.38	3	30.69	2.9	19.86	2	0	0	46	3
Reasons not captured	93	4	78.6	4	92	6	83	6	74.76	6	48	4.5	9.93	1	0	0	60	4
Berthing staff occupied	43	1.9	39.3	2	23	1	16	1	25.62	2	5.12	0.5	29.79	3	32.04	2.8	27	2
Port meetings	48	2	58.95	3	61	3.7	23	1.6	49.55	3.9	8	0.7	9.93	1	42.72	3.7	37.6	2.6
Pilot occupied	49	2	19.65	1	68	4	58	4	74.76	6	9	0.8	29.79	3	38	3.3	43.3	3
Terminal delays	92.52	4	78.6	4	72	4	29.44	2	12.46	1	79	7.4	59.58	7	51	4.4	59.3	4
Wind delays	94	4	98.25	5	18	1.1	13	0.9	24.92	2	29.91	2.8	59.58	7	53.4	4.6	49	3.3
Tidal vessel	46	1.9	21	1	16.69	1	12	0.8	8.32	0.7	30.69	3	19.86	3	31.36	2.7	23.4	2
Day light shipping	21.73	0.94	18	0.9	23	1.4	11	0.7	3.738	0.3	5.115	0.5	9.93	1	10.68	0.9	13	1
Annual total hours ships delayed	**2313**		**1965**		**1669**		**1472**		**1246**		**1068**		**896**		**1153**			

Source: Adapted from Transnet Information used is from 2014–2021, *Transnet National Ports Authority marine services performance data*, viewed June 2022, from www.transnet.net
OOC, Out of Commission Reports; Avrg, average; Hrs, hours.

TABLE 5: Ship delays analysis 2014–2021.

Years	2014	2015	2016	2017	2018	2019	2020	2021
Total ships	3023	2922	2707	2567	2386	2505	2596	2176
Number of ships delayed	1216	1123	952	886	704	592	642	823
% of ships delayed	40	38	35	34	29	24	25	35
Total hours delays	2313	1965	1669	1472	1246	1068	896	1153
Average hours delay per delayed ship (h)	1.90	1.75	1.75	1.66	1.77	1.80	1.4	1.4

Source: Adapted from Transnet National Ports Authority, 2021, *Transnet National Ports Authority marine services performance data*, viewed June 2022, from www.transnet.net

2021 with 35% of ships experiencing a delay, but the average hour per delayed vessel remained at 1.4 h.

It is evident that critical skills shortages, the inadequate number of craft in ports and the age of equipment are causing major bottlenecks in shipping in South Africa's ports (Ports Regulator of South Africa 2016; South African Maritime Safety Authority 2017). Greater attention and resources are required to build human capacity and upgrade equipment and infrastructure to improve marine services and their impact on overall port performance in South Africa. The age of marine crafts contributes immensely to tug out of commission delays because of the amount of time tugs spend in dry-dock undergoing repairs. There are minor delays relating to adverse weather conditions, pilot unavailability, tidal vessels, berthing staff and pilot-boat being occupied but in the main, delays are as a result of inadequate capacity. It is noted, with appreciation, that South Africa's ports are showing a greater improvement in ship turnaround time over the period of analyses from 2014 to 2021. Newer tug models with weather-predictive technologies would further reduce marine incidents.

Further discussion

Superb execution of maritime services is the groundwork for enhanced port productivity and the key ingredient for ships manoeuvrability in narrow channels of the ports (Xu et al. 2012). The deficiencies in the marine systems (Floating crafts, Navigational Aids, Wet Infrastructure and Expertise) have a negative impact on the overall performance of the port supply chain. Bureaucratic systems of regulations stifle agility in the execution of marine services in ports resulting in delays in shipping (Chou et al. 2020). The port regulatory environment promotes under-recovery of operating costs resulting in slow investment into marine equipment, infrastructure and human capacity. The government's preferential procurement policy (PFMA) has created hindrances to the execution of maintenance in marine operation environments. The Ports Regulator of South Africa regulates pricing as mandated by the *National Ports Acts* (2005); the outcome is below the globally benchmarked average tariff for marine services in ports, and this negatively affects productivity and effectiveness in the provision of marine services. This phenomenon has a negative impact on the performance and investment flow towards building marine capabilities. The TNPA performance initiatives, the implementation of Terminal Operations Performance Standards and Marine Operations Performance Standards, have seen improvement in the provision of services and provision of oversight to the terminals; however, the performance gap remains noticeable as the ports continue to underperform and dropping the World Bank et al. (2022) container ports global rankings. The performance initiatives continue to play a critical role during the tariff's application process while the PRSA

reviews TNPA performance during quarterly performance reviews. The WEGO was aimed at providing incentives for marine services to improve performance, yet WEGO received criticism from port users who cite insufficient motivation for the TNPA to improve productivity as the authority passes costs to port users (Gumede & Chasomeris 2015). Internally, the TNPA introduced a balance scorecard that is aimed at increasing staff motivation while providing incentives for improved performance, a great step towards improving productivity of the ports. Further research is required to investigate the potential to privatise the provision of marine services and to examine its impact on the overall port's economic activities.

The PRSA, TNPA and port stakeholders are presently (in March 2023) reviewing proposals on how to improve the pricing of marine services that should result in the prices moving closer to the ideals of user pays and cost-based pricing principles. In addition, there are proposed revisions to the WEGO that aim to further connect TNPA profits with port performance indicators. Such initiatives should help to better incentivise enhancements to capacity and improvements to port performance.

Conclusions and recommendations

Marine services constrain shipping movements in ports as a consequence of the unavailability of marine floating crafts, the limited number of marine pilots, the shortage of tug-boat crews and challenges relating to the availability of maintenance spares as the source for spares resides with international suppliers. The main industry concerns have been the shortage of port tugboats, resulting in ships staying longer than expected at anchorage. The number of crafts, ageing infrastructure and availability of skilled workforce are fundamental structural problems constraining the ports' mission of providing maritime services to maritime customers. The safety of ships in ports has been compromised because of a lack of investment in marine infrastructure, equipment and critical skills. To draw near to the industry requirements, TNPA must accelerate investment in much-needed resources to support and satisfy industry demands. Policies pertaining to maritime traffic are available in the form of port rules, berthing policy and the *National Ports Act* (2005). The need to invest in capacity creation is supported by problems such as 60% of ship delays are related to shortages of capacity in the ports system. Although there was a steady decline in marine delays between 2014 and 2020, the ageing fleet in ports remains a risk in the long run. The average of 2 h per ship delayed may be considered less insignificant, but the cumulative effect affects the port performance and cost of the supply chain in South Africa's ports through increased shipping costs. Transnet National Ports Authority needs to address critical skills capacity through building programmes ensuring continuous generation of marine services knowledge and foster partnerships with institutions of higher learning. Such initiatives will help reduce levels of unemployment and ultimately reduce societal problems. Long lead times in the procurement of spares were observed as a major challenge because of the unavailability of local suppliers' competencies to provide reliable marine spares for TNPA floating crafts in ports. A prerequisite and essential factor for operation of a reliable fleet is a good maintenance regime. The composition of crafts between the new generation tugs versus ageing crafts was noted as a major contributor to tug out of commission delays. The trend of under-deployment of tugs emerges throughout South Africa's ports' system as a challenge associated with a lack of investment in port infrastructure that affects the total performance of the ports. A simulation of activities from anchorage through to berths and vice versa will assist in enhancing understanding of the process and creating an appreciation for additional resource requirements necessary to improve the provision of marine services in ports. Forming a cross-functional team that includes private sector participation, like the South African Association of SAASOA, should be considered as part of a turnaround strategy for enhancing port marine services in South Africa.

Acknowledgements

The authors give special thanks to the almighty God for his grace. The authors would like to thank Transnet Executive for allowing access to Transnet important business data. A special thanks goes to Lorelle Royeppen for thoroughly editing this article. Great appreciation to all Transnet specialists who have endorsed the work done in this paper.

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

S.E.M. conducted this research through acquiring gatekeeping and ethical clearance. S.E.M. further conducted the research analysing information from Transnet Marine Services and putting together the research introduction, conducting literature review, compiling discussion and conclusion. M.G.C. supervised the research and provided guidance on the purpose, research methodology, data analyses and interpretation of data. He is also responsible for the co-conceptualisation of the article and editorial input. M.G.C. funded the page fees through my research account.

Funding information

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Data availability

The data that support the findings of this study are available on request from the corresponding author, S.M.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

References

Amis, J., 2011, 'Book Review: Amis: Denzin, N. K., & Lincoln, Y. S. (Eds.). (2008). The landscape of qualitative research. Thousand Oaks, CA: Sage', *Organizational Research Methods* 14(1), 239–242. https://doi.org/10.1177/1094428109332198

Beckman, R.C., 2007, 'PSSAs and transit passage – Australia's pilotage system in the Torres Strait challenges the IMO and UNCLOS', *Ocean Development & International Law* 38(4), 325–357. https://doi.org/10.1080/00908320701641552

Chasomeris, M.G., 2015, 'Port infrastructure pricing: A critique of the revenue required methodology', *International Journal of Transport Economics* 42(2), 153–170.

Chasomeris, M. & Gumede, S., 2022, 'Regulation, governance and infrastructure pricing in South Africa's ports sector', *Palgrave Studies in Maritime Economics*, 53-67. https://doi.org/10.1007/978-3-030-83985-7_4

Chou, C., Wen, C. & Huang, Y., 2020, 'Analysis of tugboat operation and towage fees in a Taiwanese port and alternatives for improving tugboat operation by the Delphi method', *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment* 235(1), 176–187. https://doi.org/10.1177/1475090220927246

Constable, K., & Wild, R., 2017, Pilotage. Encyclopedia of Maritime and Offshore Engineering, (Eds). Carlton, J. Jukes, P., ans Choo, Y.S. pp. 1–10. https://doi.org/10.1002/9781118476406.emoe051

Cokgormusler, N., 2021, 'The situational awareness & the port pilotage services', *Journal of ETA Maritime Science* 9(2), 154–155. https://doi.org/10.4274/jems.2021.80217

Cui, H. & Notteboom, T., 2017, 'Modelling emission control taxes in port areas and port privatization levels in port competition and co-operation sub-games', *Transportation Research Part D: Transport and Environment* 56, 110–128. https://doi.org/10.1016/j.trd.2017.07.030

Jong, G. D., & Krishnan, U., 2011, 'Regulatory developments and their practical implementation in today's rapidly developing OSV & TUG markets', *4th International Conference on Technology and Operation of Offshore Support Vessels*. https://doi.org/10.3850/978-981-08-9731-4_osv2011-07

Dwarakish, G.S. & Salim, A.M., 2015, 'Review on the role of ports in the development of a nation', *Aquatic Procedia* 4(4), 295–301. https://doi.org/10.1016/j.aqpro.2015.02.040

Elbert, R. & Scharf, K., 2018, 'Analysis of the choice behavior for container transport services in the maritime hinterland', in *Dynamics in logistics*, pp. 199–203, Springer, Cham.

Eriksen, S. & Lützen, M., 2022, 'Manning the unmanned ship: Is safe manning legislation a bottleneck in the development of autonomous ships?', *Autonomous ships 2022*, 37–46, https://doi.org/10.3940/rina.as.2022.05

Gans, J.S. & King, S.P., 2003, 'Contestability, complementary inputs and contracting: The case of harbour towage', *Australian Economic Review* 36(4), 415–427. https://doi.org/10.1111/j.1467-8462.2003.00298.x

Georgescu, S., Georgiana, S. & Acomi, N., 2010, 'Execution of maritime pilotage', *Constanta Maritime University Annals* 14(2), 31–34, viewed 24 March 2021, from https://EconPapers.repec.org/RePEc:cmc:annals:v:14:y:2010:i:2:p:31-34.

Grater, S. & Chasomeris, M.G., 2022, 'Analysing the impact of COVID-19 trade disruptions on port authority pricing and container shipping in South Africa', *Journal of Transport and Supply Chain Management* 16, a772. https://doi.org/10.4102/jtscm.v16i0.772

Gumede, S. & Chasomeris, M., 2015, 'Maritime port pricing and governance in South Africa and stakeholder comments', *Journal of Economic and Financial Sciences* 8(1), 47–62. https://doi.org/10.4102/jef.v8i1.83

Gumede, S. & Chasomeris, M., 2017, 'A critique of South Africa's National Ports Authority's revenue required pricing methodology', *International Journal of Transport Economics* 44(4), 611–632. https://doi.org/10.19272/201706704006

Gumede, S. & Chasomeris, M., 2018, 'Pricing strategy and tariff structure for a port authority: A case study of South Africa', *Maritime Policy & Management* 45(2), 1–14. https://doi.org/10.1080/03088839.2018.1446103

Ha, M.H., Yang, Z., Notteboom, T., Ng, A.K. & Heo, M.W., 2017, 'Revisiting port performance measurement: A hybrid multi-stakeholder framework for the modelling of port performance indicators', *Transportation Research Part E: Logistics and Transportation Review* 103, 1–16. https://doi.org/10.1016/j.tre.2017.04.008

Haider, J., Pettit, S.J., Mitroussi, K., & Katsogiannis, G., 2014, 'The emergence of eco-ships: inevitable market segmentation?', *Transport Newsletter* 64, 11. https://arca.cardriff.ac.uk/id/eprint/72835.

Hershman, M.J., 2017, 'Harbor management: A new role for the public port', *Urban ports and harbor management*, pp. 3–22, Routledge, London.

Hsu, W.K.K., 2012, 'Ports' service attributes for ship navigation safety', *Safety Science* 50(2), 244–252. https://doi.org/10.1016/j.ssci.2011.08.057

Hsu, W.K.K., 2015, 'Assessing the safety factors of ship berthing operations', *The Journal of Navigation* 68(3), 576–588. https://doi.org/10.1017/S0373463314000861

International Transport Forum, 2014, *The competition of ports in emerging countries: The case of Durban, South Africa*, OECD/ITF, Durban.

Kim, K.I. & Lee, K.M., 2018, 'Deep learning-based caution area traffic prediction with automatic identification system sensor data', *Sensors* 18(9), 3172. https://doi.org/10.3390/s18093172

MacDonald, R., 2006, 'Safe manning of ships-yesterday, today and tomorrow', *Journal of Maritime Affairs* 5(2), 143–151. https://doi.org/10.1007/BF03195101

Marcon International, Inc, 2021, *Vessels and barges for sale or charter worldwide*, Tugboat Market Report, viewed 25 September 2021, from www.marcon.com.

Matthews, R.L. & Marzec, P.E., 2012, 'Social capital, a theory for operations management: A systematic review of the evidence', *International Journal of Production Research* 50(24), 7081–7099. https://doi.org/10.1080/00207543.2011.617395

Mertler, Craig A., 2021, *Introduction to Educational Research*, SAGE Publications, Thousand Oaks.

Meyiwa, A. & Chasomeris, M., 2020, 'South Africa's port doctrine: Dilemmas and the way forward', *Maritime Studies* 19(2), 179–191. https://doi.org/10.1007/s40152-020-00166-2

Miletić, P., Debelić, B. & Rathman, D., 2015, 'Port towage as a factor of port service integrity and efficiency', *Pomorski zbornik* 49(1), 305–318. https://doi.org/10.18048/2015.49-50.305

Mthembu, S.E. & Chasomeris, M., 2021, 'An evaluation of the governance structure of marine services in South Africa's Ports System', Paper presented at the 29th Conference of the International Association of Maritime Economists (IAME), Rotterdam, 25, 26 and 27 November 2021.

National Ports Act, 2005, *National Ports Act No. 12 of 2005*, vol. 482, no. 27863, Government Gazette, Cape Town, viewed 18 March 2023, from https://www.transport.gov.za/documents/11623/114625/National_Ports+Act_a12_051.pdf/4f9f271c-3c79-44f8-be7a-e5e0fdbe76d7.

Özbaş, B. & Or, I., 2007, 'Analysis and control of maritime transit traffic through the İstanbul channel: A simulation approach', *Central European Journal of Operations Research* 15(3), 235–252. https://doi.org/10.1007/s10100-007-0028-9

Pallis, A.A., Vitsounis, T.K. & De Langen, P.W., 2010, 'Port economics, policy and management: Review of an emerging research field', *Transport Reviews* 30(1), 115–161. https://doi.org/10.1080/01441640902843208

Paulauskas, V., Simutis, M., Plačiene, B., Barzdžiukas, R., Jonkus, M. & Paulauskas, D., 2021, 'The influence of port tugs on improving the navigational safety of the port', *Journal of Marine Science and Engineering* 9(3), 342. https://doi.org/10.3390/jmse9030342

Ports Regulator of South Africa, 2016, *Global price comparator study*, viewed 12 May 2021, from https://portsregulatororg-my.sharepoint.com/:b:/g/personal/webcomments_portsregulator_org/Eccy9qJnaGBMuU3kwM-RE9cBML_Fw4-wR9NGuT6A17eSHg?e=dBuJDf.

Ports Regulator of South Africa, 2021, *Global pricing comparator study 2020/21. Port tariffs. Benchmarking South African port administered prices against a sample of international ports. Report No. 9*, viewed 26 March 2021, from https://ports.isitehosting.co.za/doc/Global-Pricing-Comparator-Study-2020_21.pdf.

Praetorius, G., Hollnagel, E. & Dahlman, J., 2015, 'Modelling Vessel Traffic Service to understand resilience in everyday operations', *Reliability Engineering & System Safety* 141(2), 10–21. https://doi.org/10.1016/j.ress.2015.03.020

Rodrigue, J.P., Comtois, C. & Slack, B., 2016, *The geography of transport systems*, Taylor & Francis Group, London.

Sahin, B. & Yip, T.L., 2020, 'Analysis of root causes for maritime accidents originated from human factor', Paper presented at the International Association of Maritime Economist (IAME) Annual Conference, Paper ID 440, Hong Kong, 10–13 June.

Sasa, K., Mitsui, M. & Tamura, M., 2018, 'Survey and analysis on safety of ship mooring operations in Japanese ports facing open seas', in *International Conference on Offshore Mechanics and Arctic Engineering*, vol. 51258, p. V006T05A011, June, American Society of Mechanical Engineers.

Siedlecki, S., 2020, 'Understanding descriptive research designs and methods', *Clinical Nurse Specialist CNS* 34(1), 8–12. https://doi.org/10.1097/NUR.0000000000000493

Shakhnov, S., Karetnikov, V., Butsanets, A. & Sazonov, A., 2023, 'The concept of introducing a decision support system into the structure of the vessel traffic management system', *Transportation Research Procedia* 68, 363–371. https://doi.org/10.1016/j.trpro.2023.02.049

Statistics South Africa, 2022, *Gross domestic product, fourth quarter 2021. Statistical release P0441*, viewed 06 April 2022, from https://www.statssa.gov.za/publications/P0441/P04414thQuarter2021.pdf.

The World Bank, Humphreys, R.M., Biju, N.O., Tan, H., Ashley, G.N.M., Guillot, D. et al., 2022, *The container port performance index 2021: A comparable assessment of container port performance*, Washington, DC.

Transnet National Ports Authority, 2014, *Marine services performance data*, viewed 23 February 2019, from www.transnet.intranet.net.

Transnet National Ports Authority, 2016, *Berthing policy*, viewed 24 March 2019, from www.transnet.net.

Transnet National Ports Authority, 2017, *Marine services performance report*, viewed 23 February 2019, from www.transnet.intranet.

Transnet National Ports Authority, 2018, *Marine services performance data*, viewed 23 February 2019, from www.transnet.net.

Transnet National Ports Authority, 2019, *National fleet plan*, viewed 17 July 2021, from www.transnet.net.

Transnet National Ports Authority, 2021, *Transnet National Ports Authority marine services performance data*, viewed 04 June 2022, from www.transnet.net.

Ugboma, C., Ogwude, I.C., Ugboma, O. & Nnadi, K., 2007, 'Service quality and satisfaction measurements in Nigerian ports: An exploration', *Maritime Policy & Management* 34(4), 331–346. https://doi.org/10.1080/03088830701539073

UNCTAD, 2021, *COVID-19 and maritime transport: Impact and responses*, Transport and trade facilitation, series 15, viewed 25 January 2022, from https://unctad.org/system/files/official-document/dtltlb2021d1_en.pdf.

UNCTAD, 2022, *United Nations Conference on Trade and Development, container port throughput*, viewed 06 April 2022, from https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=13321.

Wang, L.P., Yin, M.M. & Dong, B.X., 2014a, 'Total factor productivity and convergence of port logistics with Tianjin Port', *Advanced Materials Research* 998–999, 1653–1656. https://doi.org/10.4028/www.scientific.net/AMR.998-999.1653

Wang, S., Zhu, M., Kaku, I., Chen, G. & Wang, M., 2014b, 'An improved discrete PSO for Tugboat assignment problem under a hybrid scheduling rule in container terminal', *Mathematical Problems in Engineering* 2014, 714832. https://doi.org/10.1155/2014/714832

Wang, W. & Li, D., 2022, 'Research on key elements of ship safety pilotage evaluation in complex channel environment', in *2022 IEEE 10th Joint International Information Technology and Artificial Intelligence Conference (ITAIC)*, vol. 10, pp. 1–4, June, IEEE.

Wayne, K.T., 2017, 'Port governance, privatization, concessions and public-private partnerships', *Port economics*, pp. 181–192, Routledge, London.

Xu, Q., Mao, J. & Jin, Z., 2012, 'Simulated annealing-based ant colony algorithm for tugboat scheduling optimization', *Mathematical Problems in Engineering* 2012(11), 246978. https://doi.org/10.1155/2012/246978

Zhen, L., Wang, K., Wang, S. & Qu, X., 2018, 'Tug scheduling for hinterland barge transport: A branch-and-price approach', *European Journal of Operational Research* 265(1), 119–132. https://doi.org/10.1016/j.ejor.2017.07.063