Sustainability through Technology & Collaboration

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Abstract
The Paris Agreement requires emissions to be reduced by 50% by 2050. Alternative fuels will play a major role this achieving this target, although their widespread adoption is still some years away. Noting the recommendation from the United Nations Conference on Trade and Development 2023 Review of Maritime Transport that "beyond cleaner fuels, the industry needs to move faster towards digital solutions…to improve efficiency as well as sustainability", there are opportunities for ports to actively contribute to emissions avoidance through digital technologies.
A study published in 2024 by the World Bank found that around 60% of a ship's time in port is attributed to cargo operations, with 30% accounting for arrival time and 10% idling time. This means there is a significant amount of wasted time, leading to excess fuel burn and emissions (World Bank 2024). Port turnaround times are the responsibility of both the vessel and the port so both need to work in tandem to achieve the desired results. A ship that spends less time in port will burn less fuel, reduce its emissions, and achieve more optimal arrivals. Improving the efficiency with a coordinated approach to shipping is estimated to reduce fuel use of the current fleet by around 20% (Global Maritime Forum 2023). Coupling this with enhancing the efficiency of each individual transit through digitalization, IoT, and Big Data is a proven and immediately available opportunity to reduce shipping related emissions.
This paper will present a case study highlighting how a Port Authority has applied digital technologies to increase the efficiency of its port operations, and quantify the emissions reductions realised. Furthermore, the application of the technology has extended to the Port's customer, enabling that customer to optimize their own shipping operations and reduce emissions.

Keywords: Technology, Sustainability, Emissions Reductions, Optimisation.

1. Introduction

Ports play a critical role in Australia's trade-driven economy, serving as vital nodes in global and domestic supply chains. As the volume and complexity of maritime logistics continue to grow, Australian ports are increasingly turning to digital technologies to enhance operational efficiency, resilience, and sustainability. The integration of advanced digital solutions—ranging from real-time data analytics and automation to artificial intelligence and Internet of Things (IoT) systems—offers significant opportunities to optimise port operations, improve decision-making, and reduce environmental impacts.
The UNCTAD Review of Maritime Transport 2024 (UNCTAD 2024) states "achieving more robust, reliable and resilient maritime chokepoints requires maritime transport and logistics to embrace green technologies, digitalization and greater international cooperation." This paper provides a case study from the Port of Fremantle that highlights the application of digital technologies and collaboration between stakeholders to yield significant sustainability outcomes.

2. United Nations Sustainable Development Goals

The International Maritime Organization (IMO) acknowledges that a sustainable transport sector is essential for achieving the United Nations 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) (IMO, 2020; United Nations, 2015).

The SDGs constitute a comprehensive framework aimed at promoting peace and prosperity for people and the planet. They encompass a wide range of global priorities, from the eradication of poverty and hunger to the advancement of clean energy and sustainable urban development (United Nations, 2015).

In 2017, with support from strategic partners, the International Association of Ports and Harbors (IAPH) launched the World Ports Sustainability Program (WPSP). The WPSP categorizes the UNSDGs across six key areas:

- Digitalization
- Infrastructure
- Health Safety and Security
- Environmental Care
- Community Building
- Climate and Energy

Among these, the themes of Digitalization and Infrastructure are most relevant for this paper. The focus of these themes is on innovative digital applications, smart port initiatives, port call optimisation, optimizing use of existing port capacity, handling increasing ship sizes, and sustainable dredging, with an emphasis on SDG 9 (Industry, Innovation and Infrastructure) and SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals).

For SDG 9, the IMO emphasizes that technological innovation in ports is central to building resilient infrastructure and ensuring the efficient operation of the global transport system. A collaborative, technology-enabled shipping and port ecosystem plays a key role in fostering global stability and sustainable development. Investment and growth in the maritime sector are strong indicators of both current prosperity and future readiness (IMO, 2020).

Regarding SDG 13, the IMO asserts that climate change is among the most pressing challenges of our era, requiring ambitious yet realistic measures to reduce emissions and minimize the environmental footprint of international shipping (IMO, 2020).

SDG 17 underscores the importance of inclusive partnerships based on shared principles and values to promote sustainable development. Specific to this case study is multi-stakeholder collaboration and technology sharing to achieve more sustainable operations.

Operational efficiency has become increasingly topical, and proven digital technologies are now playing a vital role in enabling sustainable practices across the maritime sector.

3. Port of Fremantle

The Port of Fremantle is Western Australia's principal general cargo port and a critical gateway for international trade, handling $3.6m worth every hour. Located at the mouth of the Swan River, approximately 20 kilometres southwest of Perth. Fremantle Port comprises an Inner Habour which services the containers and also provides facilities for livestock exports, motor vehicle imports, other general cargo trades, cruise ships and visiting naval vessels. The Outer Harbour, about 22km to the south at Kwinana, handles grain, petroleum, liquid petroleum gas, alumina, mineral sands, fertilisers, coal, sulphur, iron ore and other bulk commodities.
In 2023/24 the Port had 1,444 vessel visits, 856,000 TEU, and total trade of 29.7m tonnes comprising 51% imports and 49% exports. Approximately 23.4m tonnes was dry, liquid and break bulk cargo, with, including 4.4m tonnes of refined petroleum imports.

The navigation approach to Fremantle comprises a number of maintained channels. These are:

- Deepwater Channel (-17.7m CD);
- Inner Harbour (-14.7m CD)
- Success & Parmelia (-14.7m CD)
- Calista (-11.6m CD)
- Stirling & Kwinana Bulk Terminal (-11.6m CD).

The tidal range is 1.4m and the port can be exposed to large, long period swells arriving from the Indian Ocean. These conditions can add complexity to the scheduling of vessels, and optimisation of throughput.

4. Digital Technologies

Fremantle Ports runs a comprehensive suite of real-time met-ocean instrumentation including 8 tide gauges and 7 wave instruments. This met-ocean information, along with AI enhanced forecasts, AIS and regular bathymetric survey data is integrated into a digital model of the port operations. This system, DUKC®, incorporates all berths, manoeuvres and transit options. DUKC® is used by the port to maximise the sailing windows and drafts considering each vessel’s unique parameters and stability, the details specific to the transit such as speed, course and rates of turn, and the environmental conditions encountered during the voyage. The modelling of transits, and compliance with transit parameters can be validated using real-time data feeds.

DUKC® enables the port to safely sail ships deeper than they otherwise could utilising their static UKC rule. Similarly, for any given draft, a vessel can sail with less tide using DUKC® than it could using the static UKC rule. Requiring less tide increases the available sailing windows, thereby improving channel accessibility, port capacity and efficiency.

The Port of Fremantle was the second port globally to implement advanced under keel clearance management technology, and the first port to use it for tankers, container vessels, and inbound transits. A long term analysis indicates that the increase in draft available with DUKC® at the port averages at 0.50m, with some vessels achieving more than 1.0m additional draft.

5. Stakeholder Collaboration

Fremantle Ports, as the regulator authority for the port, has carriage over the decisions at which vessels can transit the port's waters, and they use DUKC® for all deep draft vessels to ensure safe UKC requirements are maintained, and to optimise sailing windows and drafts. However, they are not in a position to advise on arrival drafts as this is a decision for each individual shipper based on a range of criteria specific to their unique operations.

OMC and Fremantle Ports recognised an opportunity to improve this position, ultimately resulting in OMC collaborating with one of the port's key customers. The aim of this collaboration is to provide advice as to the optimal arrival draft for inbound tankers, accounting for potential variations in environmental conditions at the time of transit, and uncertainty in the expected date that the vessel would arrive at port.

Noting that decisions about the draft of the ship are made months ahead of the vessel calling the Port of Fremantle, a novel approach was required. This involved providing a long range planning tool (DUKC® Voyage Planner) configured specifically to meet the requirements of the shipper. Using the DUKC® in simulation mode enables determination of the expected sailing windows for any given draft, with a level of certainty defined by the shipper.

When the shipper is chartering a vessel, they provide the vessel class and expected laycan, and are provided with detailed analysis of the available sailing windows at a range of drafts. The shipper can then load to a draft, confident that the vessel with have a window when it arrives at Fremantle.

6. Emissions Reductions

By increasing the cargo carried per voyage, the emissions on a CO_2 per tonne-km basis are reduced. To quantify the emissions reduction achieved through increasing sailing drafts, the approach adopted is based on the work of Psaraftis and Kontovas (2009). In their model, the CO_2 emissions are calculated from fuel consumption information on a per ship basis used directly as an input. The model then determines CO_2 emissions on a tonne-km basis per ship class, accounting for the following variables:

- Deadweight (DWT) (tonnes)
- Payload Capacity W (tonnes)
- Average Cargo Capacity Utilization w ($0<w<1$)
- Speed of ship at sea V (km/day)
- Percentage of total operational time that ships spend at sea, s ($0 \le s \le 1$)
- Total Fuel Consumption at sea, including fuel that is used by Maine Engine and Auxiliaries, F (tonnes/day)
- Total Fuel Consumption in port, including fuel that is used by Maine Engine and Auxiliaries, G (tonnes/day)
- Operational days per year, D (days) ($D \le 365$)
- Sea days in a year: sD
- Port days in a year: pD

The key equations utilised in the analysis are:

$$\text{Sea kilometres per year } (km) = sDV \quad (1)$$

$$\text{Total fuel consumption per year (tonnes)} = (sF + pG)D \quad (2)$$

$$\text{Total } CO_2 \text{ in a year (tonnes)} = 3.17(sF + pG)D \quad (3a)$$
$$= 3.17[s(F\text{-}D)+G]D \quad (3b)$$

$$\text{Total tonne-km in a year} = (wW)(sDV) \quad (4)$$

$$CO_2 \text{ per tonne-km} = 3.17[F+(p/s)G]/wWv \quad (5)$$

A flowchart describing the calculation of CO_2 emissions per tonne-km as determined by Psaraftis and Kontovas is provided in Figure 1.

Their analysis utilised the world fleet database sourced from Lloyds Fairplay, and included 648 vessels of relevance for this case study, concluding that the CO_2 emissions could be approximated at 5.7 grams per tonne-km for an Aframax tanker.

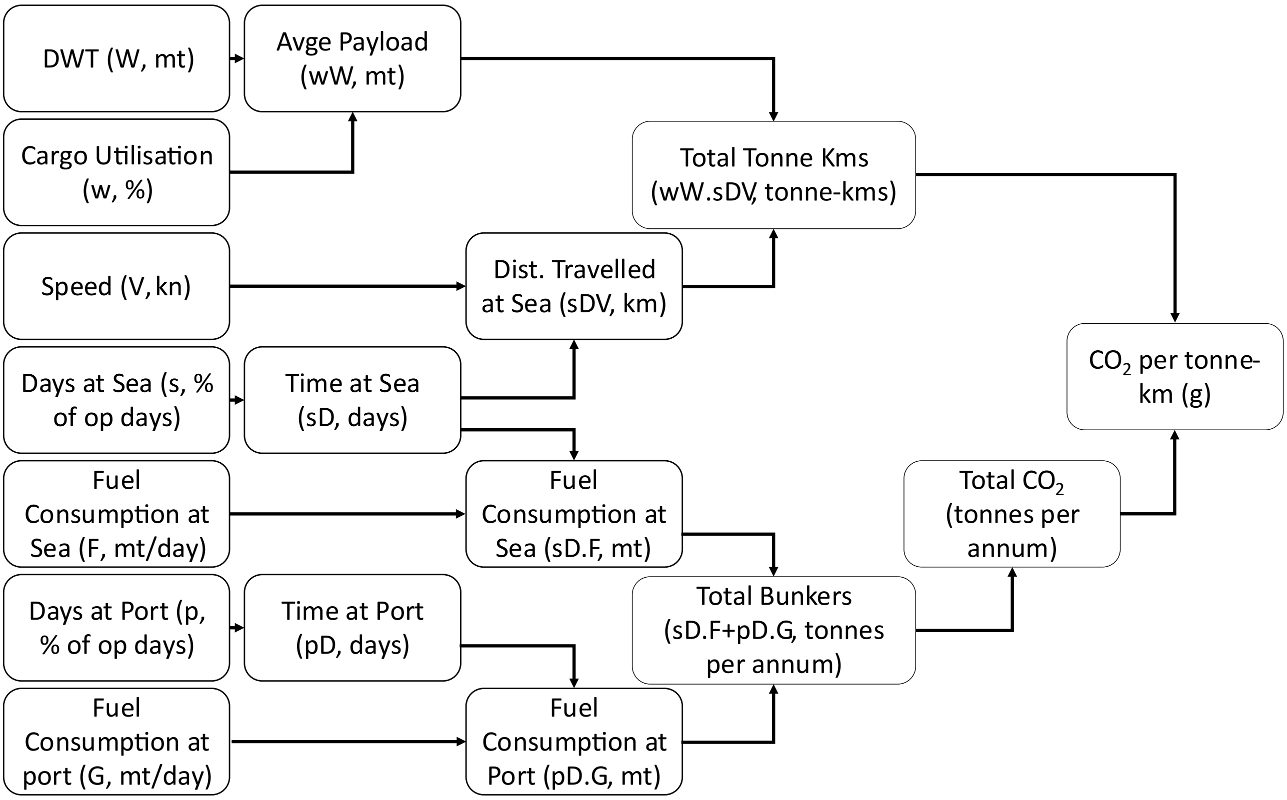

Figure 1 CO_2 emissions calculation flow chart highlights to process to determine the aggregate grams CO_2 per tonnes-km that is used to estimated emissions savings for any voyage. Adapted from Psaraftis and Kontovas (2009).

7. Results

Considering a single, one way voyage from Singapore to Fremantle, by increasing the cargo utilization with a higher draft, the shipper was able to reduce their CO_2 emissions through the application of DUKC® Voyage Planning. In this example, the emissions avoided were ~243 tonnes CO_2 (Greenhouse Gas Equivalencies Calculator | US EPA, 2025).

To provide some context, this is equivalent to the CO_2 emissions from driving a Toyota Prado around Australia 69 times. Furthermore, this analysis has ignored any sustainability benefits achieved with DUKC® resulting from wider sailing windows which reduce delays and facilitate just in time arrivals. With more than 1,400 vessel visits per annum, achieving incremental optimisations can result in significant emissions reductions.

8. Summary

This paper has provided a case study for the Port of Fremantle, highlighting the integration of leading digital technologies to enhance operational efficiency and reduce carbon emissions. Whilst technologies have been applied, and evolved, at the port for many years, this case study has focused on collaborative efforts to avoid significant emissions.

The results seen here are not an isolated example. Similar results have been achieved at other ports in Australia and internationally. However, the views of the author are that there are still significant unrealised benefits that could be achieved with the existing technologies through enhanced collaboration. Furthermore, DUKC® can be applied to any draft restricted port or waterway to enhance capacity, efficiency, safety, and reduce emissions.

Through the adoption of advanced data analytics, real-time vessel tracking, and digital port optimisation and risk management systems, Fremantle Ports and the port users have realised enhanced vessel utilisation, and these innovations have led to measurable reductions in fuel consumption and CO_2 emissions. The case of Fremantle Ports underscores the critical role of digital transformation in achieving sustainability goals, and demonstrates that collaboration can further amplify the environmental benefits already being realised.

9. References

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Relevant UN SDGs (https://sdgs.un.org/goals)

9, 13, 17.