ENHANCING PORT EFFICIENCY THROUGH TECHNOLOGY: A CO_2 EMISSIONS REDUCTION CASE STUDY

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Summary

Saqr Port in Ras Al Khaimah implemented DUKC® in January 2020, with the aims of offering increased sailing drafts to their customers, and enhancing port efficiency. The benefits were immediate, with the first vessel to sail achieving an increase in draft of 0.58m, equating to approximately 4,000 tonnes additional cargo. Since then, Saqr Port has set multiple records for sailing drafts and throughput.

Aside from the benefits to the port and its customers of increased throughput, there is a climate benefit by enhancing shipping efficiency. This paper set out to quantify the reduction in shipping related CO_2 emissions achieved by improving vessel utilisation with DUKC®. An analysis of every DUKC® transit from Saqr Port over a two year period was performed, considering the destination port, voyage distance, and duration. Using a peer reviewed approach to determine CO_2 emissions on a tonne-km basis per ship class, the reduction in CO_2 emissions resulting from DUKC® was estimated to exceed 100,000 tonnes.

The implementation of DUKC® has been recognised by the IAPH World Port Sustainability Program, and RAK Ports was awarded the 2020 Intelligent Shipping Seatrade Award for the successful integration of digital technologies into their operations.

1. INTRODUCTION

Ports and shipping channels are critical components of many nations' transport infrastructure, and make a significant contribution to the economy. With volatile and disrupted global trade comes further pressure on ports to be adaptive and resilient. This is occurring against a backdrop of increasing regulatory and environmental requirements, and social expectations, as well as a changing climate that is presenting more frequent and severe weather events.

Safety and efficiency are often considered to be competing ideals, but that is not necessarily accurate. Digitalisation has driven access to more data, in real-time, and with greater precision. With the right tools, this data can lead to deeper insights into port and shipping operations, and be leveraged to identify opportunities to enhance safety and improve efficiency.

This paper addresses the Congress theme of 'Shaping for a better, safer future' through the case study of Saqr Port's implementation of the digital port optimization and risk management technology, DUKC®. In the first study of its kind, a detailed analysis of the impacts the technology has had on port operations is presented based on 2 years of actual shipping data. Specifically, the contribution of the technology towards reducing shipping related CO_2 emissions is evaluated. The paper provides an overview of Saqr Port and its operations, and details the implementation of the technology and the benefits that have been realised. Ultimately, the case study demonstrates that ports can facilitate a material reduction in shipping related CO_2 emissions through technology, and that this can be done cost effectively whilst managing navigational risk.

2. SAQR PORT

Saqr Port in Ras Al Khaimah is one of five ports operated by the Ras Al Khaimah Port Authority (RAK Ports). Saqr is one of the Middle East's leading centres of maritime and industrial commerce. Strategically located near the Strait of Hormuz, it is one of the major hubs in the regional industrial supply chain, supplying construction materials for the majority of world-renowned real estate projects in UAE, and beyond.

Saqr Port is comprised of an Inner Harbour with 12 berths, and a Deep Water Bulk Terminals that has capacity to berth two Capesize or three Panamax vessels. At a depth of 12.2m, the Inner Harbour caters to vessels from Handymax to Baby Cape size, although draft restricted. The mean spring tidal range is 2.0m and 1.0m at neaps. With a cargo handling capacity of over 100 million tonnes annually, Saqr is the region's largest dry bulk port.

The main trades are limestone and aggregate exports, and coal imports, although the port also handles clinker, cement, gypsum, and general cargo.

Figure 1 Saqr Port

3. CLIMATE CHANGE AND THE SUSTAINABLE DEVELOPMENT GOALS

Whilst shipping is the most efficient mode of transport on a CO_2 per tonne-km basis [1], greenhouse gas emissions (GHG) from maritime transport are estimated to exceed one billion tonnes per annum, representing around 3% of global anthropogenic GHG emissions [2]. International shipping accounts for approximately 87% of total shipping related CO_2 emissions [3]. Despite improvements in engine technologies, fuel quality and operational practices such as slow steaming aimed at improving vessels' fuel efficiencies, the total shipping related GHG emissions have continued to climb, largely due to the increase in shipping [3]).

The Paris Agreement requires emissions to be reduced by 50% by 2050 [4]. Sustainability is, therefore, an ever present and increasingly important consideration for ports. To achieve these results will take new innovations in the areas of ship and engine design, and alternative fuels. However, there are technologies available now that can be implemented easily and cost effectively to facilitate an immediate reduction in CO_2 emissions.

In 2015, 193 countries adopted the United Nation's 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) [5]. The IMO recognizes that most of the elements of the 2030 Agenda will only be realized with a sustainable transport sector supporting world trade and facilitating global economy, and is actively working towards the SDGs. Ports, as critical nodes in the global supply chain, must respond to worldwide, regional and local challenges such as climate change and digitalization.

The United Nation's Sustainable Development Goals are far reaching, with the intention that they provide a framework for peace and prosperity for people and the planet. They incorporate concepts from the elimination of poverty and hunger through to clean energy and sustainable cities.

In 2017, with the support of strategic partners, the International Association of Ports and Harbors established the World Ports Sustainability Program. As part of the IAPH's World Ports Sustainability Program, the SDGs were grouped into specific themes that align with the areas in which ports operate. The five themes are:

- Climate and Energy
- Community outreach and port-city dialogue
- Resilient Infrastructure
- Governance and Ethics; and
- Safety and Security

Of these themes, the focus of this study is Resilient Infrastructure, and in particular, two SDGs which it encapsulates: #9 Industry, Innovation and Infrastructure, and #13 Climate Action.

In relation to SDG #9, Industry, Innovation and Infrastructure, the IMO states that technological advances in the port sector are key to building resilient infrastructure and central to the effective functioning of the whole transportation sector [5]. A more efficient shipping, working in partnership with the port sector, will be a major driver towards global stability and sustainable development for the good of all people. Furthermore, investment, growth and improvement in the shipping and ports sectors are clear indications of a country or region that is enjoying success in the present and planning for future success.

On #13 Climate Action, the IMO's position (refence needed) is that responding to climate change is one of the greatest challenges of our era, and requires appropriate, ambitious and realistic solutions to minimise shipping's contribution to air pollution and its impact on climate change.

4. DIGITALISATION

Digitalisation is not a panacea for maritime challenges. However, digitalisation does drive access to more data, in real-time, and with greater precision. Forward thinking ports are finding ways to leverage these developments to deliver operational efficiencies and enhance safety. The digitalisation trend has been underway for some time, but is now more prevalent than ever. The United Nations Conference on Trade and Development (UNCTAD) Review of Maritime Transport 2020 proposes that "adopting technological solutions and keeping abreast of the most recent advances in the field will become a requisite, no longer an option" for the maritime industry [6].

Enabling and enhancing data capture is one area in which digitalisation can deliver immediate benefits. In their Maritime Digitalisation Playbook [8], the Maritime and Port Authority of Singapore highlight the global trend of port operators to harness data to improve port efficiency, and provide greater visibility of operations. UNCTAD [6] found that enhanced digital data exchange across port stakeholders enables better collaboration and decision-making. In the International Association of Ports and Harbour (IAPH) led and IMO endorsed call to action entitled “Accelerating digitalisation of maritime trade and logistics” [7], released in June 2020, the authors note that while some ports had “seized the opportunities of the fourth industrial revolution”, transitioning towards smart ports, many others have “barely grasped the essentials of digitalisation”.

The digital port optimisation technologies discussed herein capture and transform historic, real-time and forecast data, and integrate it into the port’s operations, enabling better, faster, more transparent decision making. The result is more a more efficient port.

5. DYNAMIC UNDER KEEL CLEARANCE (DUKC®)

With the ambition of enhancing their operational efficiency, RAK Ports commissioned OMC International to implement its Dynamic Under Keel Clearance System (DUKC®). This project was unique as Saqr Port was the first in the MENA region to implement this type of innovative technology.

DUKC® is a comprehensive digital solution for UKC management, underpinned by detailed modelling of port operations, numerical analysis of ship motions, hydro-dynamic models, channel survey data, and the AI assisted assimilation of real-time and forecast environmental conditions. Connecting advanced calculation engines with the port's available IoT devices and digital data sources, DUKC® allows the sailing draft of every vessel to be safely maximised.

The DUKC® functionality allows the port and its customers to evaluate what the maximum sailing drafts will be for future tides. DUKC® calculates these maximum sailing drafts based on the specific vessel, its unique stability characteristics for that voyage based on the cargo and how it is loaded, and the prevailing environmental conditions during the transit.

6. RESULTS

DUKC® was commissioned for use on January 1st 2020 and the benefits for the port and its customers were immediate and significant, as DUKC® allowed vessels to sail with deeper drafts and more cargo.

The first vessel to load with DUKC® was the LMZ Phoebe on January 9th 2020. It sailed at a record draft of 12.76m with an additional 3,000t of cargo than it would otherwise have achieved. That record was short lived as on January 20th, the

Ganga K sailed at a draft of 12.83m. The next day, the Elbabe again set a record with a draft of 12.85m.

On August 20th 2020 the MV Soho Mandate became the first vessel to exceed 13m from the Inner Harbour, at a draft of 13.02m. This equates to an additional 7,000t of cargo.

On October 15th 2020, the Asia Ruby I sailed at a draft of 13.10m. In October 2021, the Star Crios sailed at a draft of 13.25m. Since the implementation of DUKC®, there have been 87 transits at drafts in excess of 13.0m. In March 2022, Saqr Port set a record for the highest monthly tonnage of 6.1m..

The average draft achieved with DUKC® is 12.75m, a benefit of 0.75m per vessel.

7. CO_2 EMISSIONS REDUCTIONS

Increasing sailing drafts with DUKC® allows vessels to carry more cargo. This reduces the number of voyages to transport the equivalent volume of cargo. Fewer voyages results in reduced fuel usage which ultimately leads to a reduction in greenhouse gas and carbon dioxide emissions. The aim of this study was to quantify the emission reductions achieved through the implementation of DUKC® at Saqr Port. The method employed was to evaluate the increase in vessel utilisation in the context of a CO_2 emission per tonne-km.

There are several methods typically employed to derive fuel and emission related estimates for shipping [1]. Danish Shipping [9] has developed a calculator designed to determine emissions for a specific vessel including its type and size, payload capacity, rate of utilisation and speed, with the ability to manually adjust a number of parameters such as engine and fuel types. Without knowledge of the specifics of each individual vessel and voyage, an aggregate approach can be taken. An aggregate approach can broadly take one of two forms: top down, or bottom up.

A top down approach is to determine fuel usage based on reported marine bunker sales. Concerns of this approach are largely centred around the reliability of bunker fuel statistics, given different reporting requirements globally, and the known occurrences of misallocation of fuel types or industry sectors [1].

The approach adopted herewith, based on the work of Psaraftis and Kontovas [1], can be considered a bottom up approach. 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 ($0 \leq s \leq 1$)

- 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≤365)
- Sea days in a year: sD

  Port days in a year: pD

A flowchart describing the calculation of CO2 emissions per tonne-km as determined by Psaraftis and Kontovas is provided in .

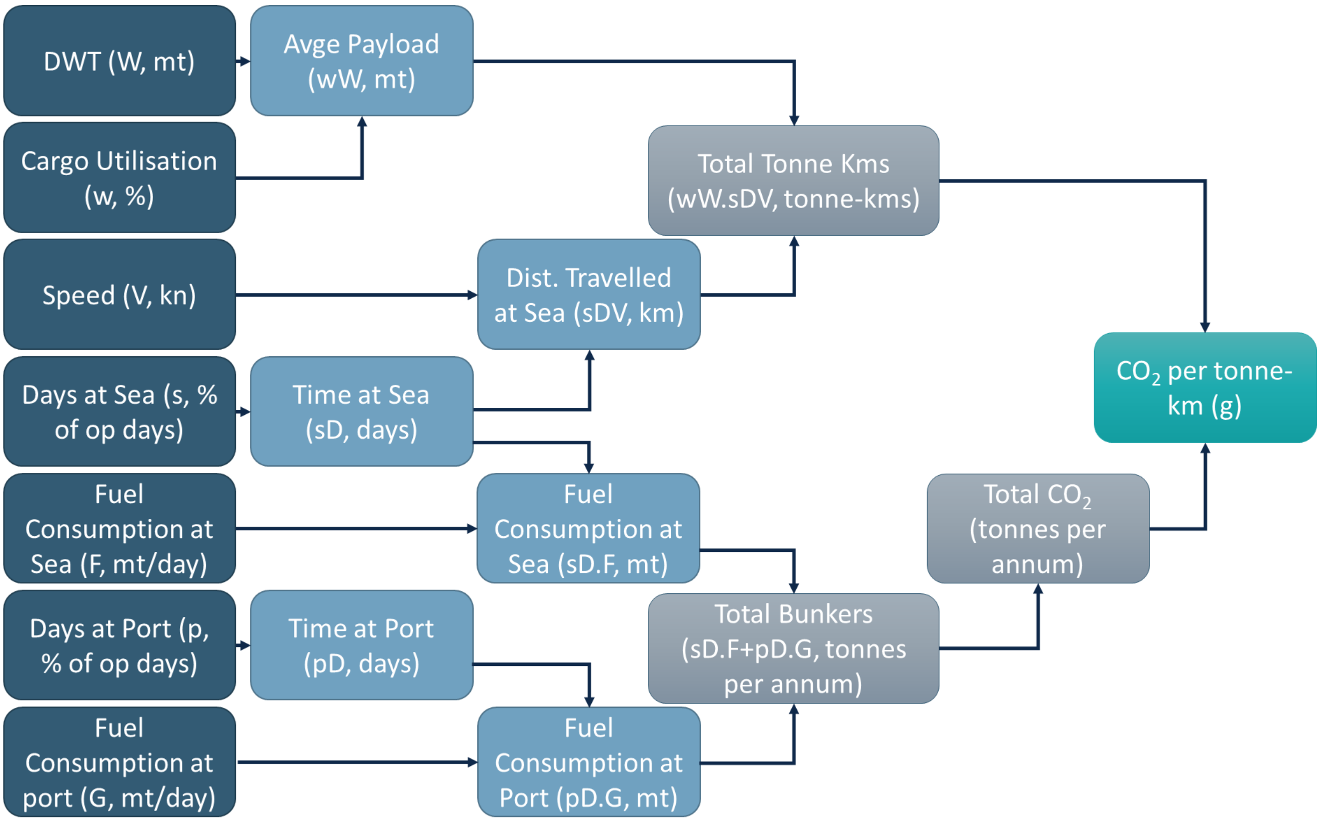

Figure 2 CO_2 emissions calculation flow chart highlights to process to determine the aggregate grams CO_2 per tonnes-km that is used to estimated emissions savings for any voyage. Adapted from Psaraftis and Kontovas [1].

The key equations utilised in the analysis are:

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

Total fuel consumption per year (tonnes)

$$= sDF + pDG \quad (2)$$

Total CO_2 in a year (tonnes)

$$= 3.17(sDF + pDG) \quad (3)$$

Total tonne-km in a year

$$= (wW)(sDV) \quad (4)$$

CO_2 per tonne-km

$$= 3.17[F+(pD/sD)G]/wWV \quad (5)$$

Their analysis utilised the world fleet database sourced from Lloyds Fairplay, and included 1,732 vessels of relevance for Saqr Port, and concluded that the CO_2 emissions could be approximated at 6.3 grams per tonne-km for this vessel class (35,000 to 65,000 DWT).

With an understanding of the average gram of CO_2 produced per tonne-km of shipping, the impact of DUKC® in reducing shipping related CO_2 emissions is estimated by determining the additional tonnage that is carried to each port, and the associated distances. Given the marginal percentage increase in the overall displacement of each individual vessel, it is assumed that the implication of the additional tonnes is negligible in terms of fuel requirements.

For every vessel entered into the DUKC®, the system records the sailing draft, and the draft benefit achieved. The destination port for the vessel is manually entered. The available dataset spans from January 1st 2020 to December 22nd 2021 and contains 369 transits. Transits where the destination port was not listed were removed. The dataset contained 8 entries where the discharge port was listed only as India. In these instances, the distance for the purpose of CO_2 emissions calculations has been assumed as the average of the known Indian discharge ports. Distances between ports were calculated using the sea route distance calculator available at http://ports.com/sea-route/.

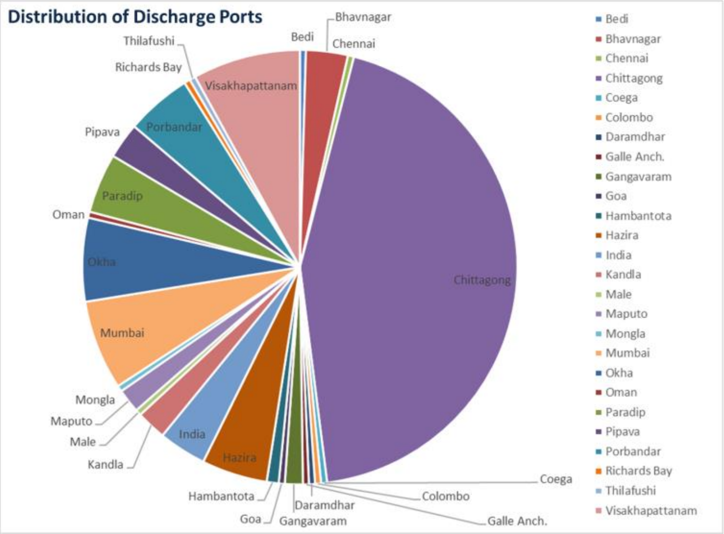

Figure 3 Distribution of discharge ports.

The average increase in draft achieved with DUKC® was 0.68m. Of the 225 transits, there were 27 unique destinations. Of these 27 ports, 12 had only a single transit. Chittagong was the most frequented port with 186 transits. It also has one of the longest distances as well as the highest average benefits in terms of increased draft (0.73m) and tonnage (4,394t).

Taking into consideration the increased tonnage and distance for every DUKC® transit, and applying the CO_2 emissions per tonne km value of 6.3g, the reduction in CO_2 resulting from the efficiencies achieved with DUKC® is estimated at 100,617 tonnes.

To assess the impact of these CO2 reductions, the equivalency calculator developed by the US Environmental Protection Agency is used (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator). Some example equivalents include:

- Emissions from the use of 37,414,223 litres of diesel
- Emissions from 399,603,323 kms driven by an average petrol passenger vehicle
- Emissions from 19,578 homes' electricity use for 1 year
- Emissions reductions achieved from 27.3 wind turbines running for 1 year
- CO_2 sequestered by 1,663,711 seedlings grown for 10 years

8. CONCLUSIONS

There is a global imperative for industry to reduce shipping related CO_2 emissions, and this is evidenced through the United Nations' Sustainability Development Goals, endorsed by the IMO. Whilst the challenge remains large and will take multiple and significant innovations to resolve, there are solutions that can be implemented now, with immediate and significant benefits.

This paper has presented a case study for DUKC®, a digital port optimisation technology that allows ships to sail with more cargo and reduced risk. By increasing the tonnes lifted by every vessel, the per tonne-km CO_2 emissions are reduced. Essentially, fewer voyages are required to transport the same volume, therefore fuel use is reduced with a corresponding reduction in GHG emissions.
In this example, the 24 months' analysis shows a reduction in CO_2 emissions of more than 100,000 tonnes. Although this may be small in percentage terms relative to the global shipping related emissions, it is significant when viewed in the context of sequestering the same level of CO_2. Importantly, it is expected that similar benefits could be replicated at any port where vessels are draft constrained, thereby enabling ports with a focus on sustainability to realise CO_2 emissions reductions through DUKC®.

RAK Ports was the first in the MENA region to adopt DUKC®, thereby giving its customers the opportunity to improve their environmental footprint, and demonstrating how digital technologies such as DUKC® can contribute towards achieving Sustainable Development Goals.

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