Practical Applications of Digitalising Port Operations to Enhance Safety, Efficiency, Resilience & Sustainability

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Summary
The objective of this paper is to examine some of the recent advancements in digitalisation of ports and shipping. The paper analyses several case studies where ports have implemented new digital technologies. For each example, an overview of the port operations and the application of digital technologies is provided. Furthermore, the improvements to safety and efficiency that they have delivered are evaluated.
The study found that the advancement of technology is enabling all ports, regardless of size or geographic region, to benefit by adopting proven solutions that are most applicable to their operations.

Keywords: Digitalisation, Port Optimisation, eNavigation, Sustainability.

1. Introduction

There are a lot of buzz words around digitalisation – IoT, Big Data, Machine Learning, Artificial Intelligence – and the maritime industry is part of this everchanging operational environment. There are significant investments in R&D in these areas by the industry's big players and start-ups alike, and pressure is on ports to plan for the evolving landscape whilst continuing their day to day business of safely facilitating trade. This is occurring against a backdrop of increasing regulatory, environmental, and social requirements for the shipping industry. The IMO2020 sulphur regulations, and the imperative for the industry to minimise emissions in accordance with the IMO's 2050 Goals are two clear examples driving the need for improved efficiencies.

Whilst there have been, and will continue to be, step changes in technology (autonomous ships immediately come to mind) there are also incremental digital developments that can already be leveraged by forward thinking ports to deliver genuine and immediate safety and efficiency improvements.

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. When applied correctly, this data can be used to identify opportunities for operational improvements and benchmark performance whilst simultaneously enhancing safety. Recent, practical examples include:

- Realising an additional 100m tonnes per annum of port capacity through digital modelling;
- Reducing yearly CO_2 emissions by 1.2m tonnes and fuel costs by USD$130 by optimising sailing drafts;
- Facilitating the arrivals of the deepest ever container vessels into an Australian port;
- Reducing dredging volumes, costs, and associated environmental impacts through digital channel optimisation.
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Ports at the forefront of innovation are leveraging data to understand their operations more comprehensively leading to improved safety and efficiency outcomes. Importantly, with the advancement of technology, it is easier and cheaper than ever for ports to progress their digital transformation processes. This allows all ports, regardless of size or geographic region, to benefit by adopting proven solutions that are most applicable to their operations.

Drawing from a number of recent case studies, this paper will:

- Discuss the application of digital technologies and data analytics to port operations;
- Evaluate the improvements to safety and efficiency that they have delivered; and
- Highlight how these technologies can be adopted by any port and aligned to their business strategy.

2. Operational Context

During periods of 2022, an estimated 14% of the world's shipping capacity was unutilised due to congestion[1]. Data from Sea-Intelligence [1] indicates that it stands at approximately 8%, with vessels spending 5% to 9% of their time waiting to enter port [2]. Maritime transport is estimated to emit one billion tonnes of greenhouse gas (GHG) emissions annually, representing ~3% of the total global emissions [3].

The Paris Agreement requires emissions to be reduced by 50% by 2050, and the IMO's 2018 Initial Strategy for Reduction of GHG Emissions from Ships [6] has an objective to achieve a 40% reduction of CO_2 emissions per transport work by 2030 (compared to 2008 values as an average across international shipping).

However, recent data suggests shipping related GHG emissions continue to climb, with research from Simpson Spence Young [4] indicating a 4.9% CO_2 emissions increase from 2020 to 2021.

In addition to emissions reductions targets, the IMO recognizes that a sustainable transport sector is critical for the realization of the United Nation's 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) [5].

The UNSDGs 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, Resilient Infrastructure, and in particular, two SDGs which it encapsulates: #9 Industry, Innovation and Infrastructure, and #13 Climate Action, are of key relevance.

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. 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.

The ability to enhance operational efficiencies is extremely topical, and there are proven digital technologies that are enabling this.

The United Nations Conference on Trade and Development (UNCTAD) Review of Maritime Transport 2022 [6] highlights a number of priority action areas that are relevant to this discussion. They include the following:

- Improve port performance and productivity;
- Adopt smart and green trade logistics systems;
- Coordinate efforts, enhance collaboration, share information and prepare for coordinated solutions.
- Employ real-time, digital platforms.
- Help developing countries expand the use of digitalization…and adopt smart maritime logistics.

3. Digitalisation

The IAPH [7] states "The port sector needs to embrace innovation as part of its own transformation. Ports face multiple challenges, in a constantly-changing economic context, and must adapt to both new international and national regulatory requirements, strong international competition, accelerated digitalization and major climate and environmental challenges. An innovation strategy makes it possible for ports to adapt and reinvent themselves in what has now become a highly competitive and uncertain environment."

Digitalisation and technology will not, in and of themselves, address all these 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 in focus for some time, noting that UNCTAD 2020 [8] stated 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. UNCTAD 2022 [6] provides an update to the 2020 position, stating "much of maritime transport industry is putting more priority on customer relations, managing risks, stronger planning, preparedness, resilience and digitalization."

The Sustainable Smart Ports project (UNCTAD 2023) is aimed at raising awareness among ports and national authorities about the strategic importance of competing on a level playing field. Sustainable Smart Ports "take advantage of the new data environments… artificial intelligence, and green technology-based solutions to enhance port operational efficiency."[10] UNCTAD (2023) also highlights that "technologies such as AI, cloud computing, and IoT can also help the economies become greener – while also accelerating progress for all 17 SDGs."

At its most fundamental level, digitalisation and digitisation facilitate access to data. This in turn, allows people to review and challenge the way in which things have always been done, and identify opportunities for improvement supported by the data.
In his 2020 presentation The Future of Maritime Risk, Dr. Shuo Ma, professor of shipping and port management and Vice President at the World Maritime University, highlighted that risk stems from uncertainty, where uncertainty results from not only lack of data and information, but more importantly the unknown relationships between data. Data acquisition is essential to managing risks, and right decisions are always made on adequate information.

The technologies available today are not only allowing enhanced data capture through digitalisation, but also improving the ability to understand the relationships between data.

4. Case Studies

The first case study examines the use of a stand-alone IoT vessel motion sensor. Designed by OMC International specifically for the purpose of measuring vessel wave response, the iHeave2 unit enables easy and cost effective real-time data capture of vessel motions both in-transit and at berth. The application has significant benefits, but the most immediate is the ability to cease reliance on models and simulations that do not capture the full complexity of a real world operation.

A recent application of the technology was for a capital city port in Australia. The pilots at the port were aware of a phenomenon whereby inbound container vessels would experience a 'corkscrew' wave response motion with the swells approaching the stern. An iHeave2 measurement campaign allowed the port to capture the actual wave response of numerous vessels. The data comprehensively demonstrated that the UKC management system being used by the port to manage transit safety was accurately predicting the vessel motions.

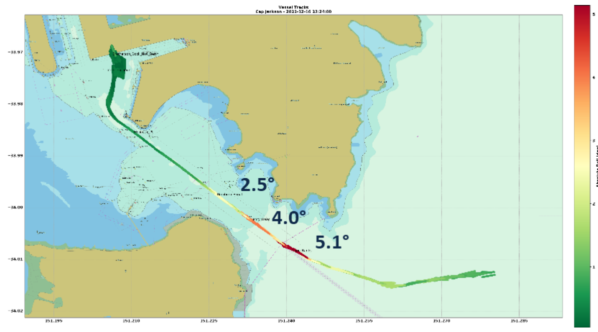

Figure 1: iHeave2 measures vessel motions in real-time. This allows quick and easy validation of vessel motion predictions and UKC. This technology gave the port and pilots the confidence to bring in vessels at record drafts.

The confidence that the real-time vessel motion measurements delivered to the port and pilots has allowed the port to accommodate the deepest draft container vessels ever into Australia, twice breaking the previous draft records. The first occasion was the MSC Asya, with a sailing draft of 14.8m in October 2021 [11], and the latter being the MSC Tokyo at a draft of 15.1m in March 2022 [12].

The second case study examines the use of a data analytics system to prevent a grounding.

In 2015, the container ship Maersk Garonne grounded at the Port of Fremantle after being taken outside the shipping channel in an attempt to delay the transit due to concern that tugs would not be ready for the entrance manoeuvre.

A subsequent Australian Transport Safety Board (ATSB) investigation [13] identified that the pilot had conducted the ship along a route to the east of both the planned track on the ship's chart, and his own intended transit on the MPX form. Further, the port's operational parameters stated that a deep draft vessel like the container ship should not exceed 13 knots in the Deep Water Channel, and the master's passage plan for pilotage anticipated a speed of 12 knots departing the DWC and less than 8 knots for the entrance channel. The Maersk Garonne actually transited DWC at around 16 knots, The ship's speed as the pilot started the turn towards the entrance channel was 14.5 knots.

While various recommendations were by the ATSB, a contributing factor identified was that deviations from the publicly available passage plan were routine. Considering this fact, the accident could potentially have been anticipated. An analysis of the previous 2 months of tracks of similar sized vessels (more than 40), revealed that while all tracks were within the port approved transit corridor (Figure 2), none of the tracks were consistent with published waypoint list. In other words, a clear trend of vessels deviating from the published way points existed prior to the accident.

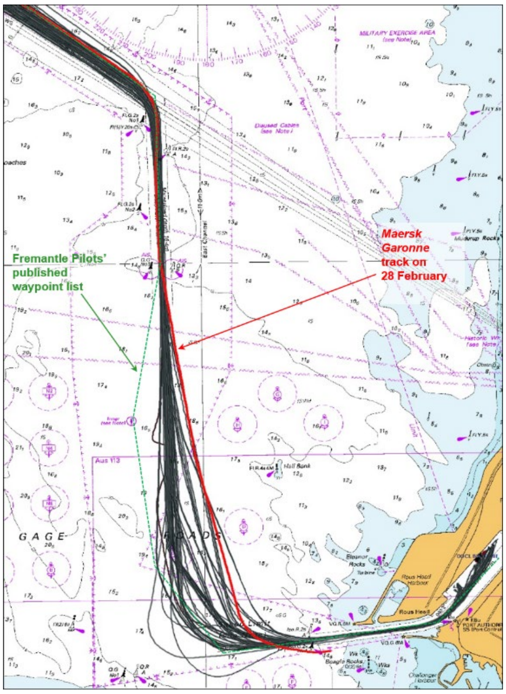

Figure 2: Analysis by ATSB showing similar vessel tracks in months prior to the accident. The trend in deviation from planned routes is apparent. Prior awareness of this trend may have avoided the grounding.

The findings from the ATSB could be reproduced from publicly available AIS data. Therefore, the warning signs of a potential incident were available, but had not been recognised. Anecdotally other maritime accidents follow a similar trend, where warning signs of variations from port guidance are missed, are not corrected and ultimately an accident occurs. In essence such an accident could be deemed preventable in the sense that warning signs were available but not detected.

Recently developed digital technology is being adopted by New Zealand and Australia ports to reduce the number of such preventable accidents. Taking a lead from the Aviation industry these ports are implementing Quality Assurance on their Marine operations. Using TransitAnalyst, transits are being continuously monitored and compared against predefined parameters and outliers identified for further analysis by the Marine Operations team. An example of the output of an operational TransitAnalyst is shown in Figure 3, highlighting occasions the frequency of vessels exceeding pre-defined limits.

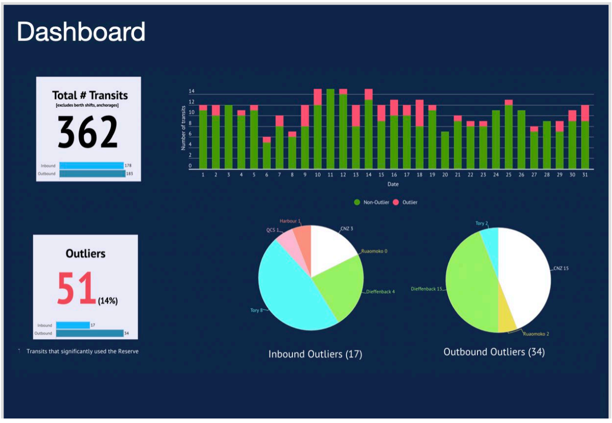

Figure 3: Example of dashboard output from TransitAnalyst. Identification of trends and transits of concern is simple. This allows for further investigation and rectification measures if required.

Implementations of TransitAnalyst in at least five New Zealand and Australian ports have all highlighted deviations in shipping operations from the norms defined by the Marine Operations team. By identifying such deviations through routine Quality Assurance, it is expected that potentially dangerous trends will be detected ahead of time and accidents such as the Maersk Garonne avoided.

The last case study examines an Australian bulk port. The port handles approximately 30m tonnes per annum and has channel approach of ~1.5km.

The port implemented an advanced risk management and optimisation solution that resulted in ships being able to safely sail at deeper drafts, and therefore, carry additional cargo. Furthermore, this technology, Dynamic Under Keel Clearance (DUKC®), increased the available sailing windows. This means that berth occupancy is increased and wait times for vessels at anchor are reduced. DUKC® achieves this through the integration of real-time IoT data feeds, AI enhanced forecasts, sophisticated environmental modelling, and advanced computational analysis of vessel motions.

The additional draft resulting from the application of digital transit planning was 0.73m. This equates to an available 9,000 tonnes for every vessel. Enhancing the utilisation of each vessel reduces the CO_2 emissions on a per tonne-km basis. For this case study, the estimate CO_2 reductions are 140,000 tonnes, equivalent to [14]:

- Emissions from 52,058,709 litres of diesel;
- Emissions from 70,260,229 kilograms of coal burned;
- Emissions from 27,240 homes' electricity use for one year;
- Carbon sequestered by 2,314,912 tree seedlings grown for 10 years.

In terms of enhancing channel capacity and efficiency, the digital innovation increased the available sailing windows by a mean of 28 hours, and a median of 7 hours.

These achievements were realised with minimal port infrastructure. The data requirements from the port were limited to an AIS feed, a single tide gauge, and wave buoy, and bathymetric survey data. This is hardware and data that many ports already have access to, or that can be implemented cost effectively. The value delivered to the operations by integrating existing data into a digital twin to allow data driven decision making was significant.

This case study in not a unique or isolated example. The technology is available to any port or terminal interested in enhancing efficiency and reducing its carbon footprint, and the application is entirely consistent with the PIANC Declaration on Climate Change [15].

Conclusion

Digital twin technologies integrating real-time data, AI enhanced forecasts, and advanced ship motion models are delivering operational decision support systems. These systems are delivering enormous value and reducing CO_2 emissions.

As ports face the challenges of congestion and delays, larger vessels, and more frequent and severe weather events, decision support technologies such as those presented herein are allowing Harbour Masters, Pilots, Terminal Operators, and Shippers to maximise efficiency whilst ensuring navigational safety and enhancing port resilience. The case studies highlight specific examples, but it is expected that any port, regardless of size or geographic region, could benefit by adopting proven solutions that are most applicable to their operations.

The benefits can be realised with minimal hardware requirements. Often, ports will already have access to the necessary data feeds. If not, instrumentation can be obtained and deployed more cost effectively than ever before.

Any port can progress towards enhanced efficiency, resilience, safety and sustainability through incremental digitalisation programmes that build on data already available. With the latest generation technologies, cost is no longer a barrier.

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