A Digital Gateway to the Hunter

An action plan for the digitalisation of the Port of Newcastle

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Executive summary

The adoption of digital technologies and digitalisation, a CSIRO megatrend, holds the potential for substantive impact and transformation of ports. Through the use **of Digital Port Scheduling Tools**, **Internet of Things (IoT)**, **Digital Twins** and **Blockchain** the Port of Newcastle (PoN) is poised to become a more efficient, environmentally sustainable and secure port. Progressive Digital Consulting (PDC) presents this report, which through analysis, literature review and case studies, demonstrates how these complementing technologies can benefit the PoN's operational efficiency, competitive edge, supply chain stability, sustainability and safety.

The introduction of Digital Port Scheduling Tools is crucial to bring about efficiency enhancements, reduced vessel turnaround times, and increased business opportunities for the PoN. Real-time visibility and optimisation capabilities offer the potential to minimise delays and promote sustainability, aligning with environmental, social and governance (ESG) goals.

The integration of IoT into the PoN's clean energy precinct and condition monitoring systems will not only reinforce sustainability but also lead to cost savings and operational efficiency gains. Digital Twins provide valuable insights into asset management, safety improvements, and environmental sustainability, they should be viewed as a strategic long-term investment.

Blockchain technology presents exciting possibilities for improving transactional transparency, security, and efficiency, particularly in the supply chain. PDC believes that although the benefits of implementing Blockchain are realised with greater adoption by industry participants, it remains a technology to watch for the PoN's future digital strategies.

The action plan outlined in this report emphasises the significance of aligning digital strategies with the PoN's long-term vision, engaging stakeholders, identifying pain points, and adopting an agile approach to manage risks. Fostering a culture of change is pivotal to the successful implementation and sustainability of digital transformations.

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Smart Ports & the Digital Economy

A tide of change

Ports are vital to the global economy, requiring the coordination of a multitude of stakeholders, vessels and business interests in a dynamic environment, affected by weather, economics and politics. A port that can thrive in this system is already smart! Progressive Digital Consulting (PDC) believes these successful ports can still leverage innovative technologies and data-driven solutions to enhance operational efficiency, safety, and sustainability (Rahman, 2023).

Ports are not alone as they **'Dive into Digital'**, taking advantage of the rapidly growing digital and data economy. In fact, this has been identified as a CSIRO Global Megatrend with Industry 4.0 technologies and associated digital innovations anticipated to generate $10 - $15 trillion globally (Naughtin, et al., 2022).

The most efficient ports around the globe have implemented or are implementing digital technology. Well established waterways and ports that operate near 100% capacity realise the greatest benefits from digital technology, e.g. The Panama Canal, Rotterdam, Antwerp, Hamburg and Singapore. They are hence the greatest innovators in this space:

The **Panama Canal Authority** began implementing a digital scheduling system in 2017, realising considerable benefit within a year. A key benefit for the authority was in adapting to unforeseen changes in their program from weather disruptions. "For example, if there is a delay in ship availability or fog disrupts operations, then planners can use their own information and experience to move vessel schedules and then use our system optimiser to move all the vessel schedules around this." (Wingrave, 2023).

The **Port of Rotterdam** maintains extensive digital dashboards monitoring sensors to capture a vast array of information for the real time monitoring of asset conditions, vessel movements, tidal and port depth conditions (Port of Rotterdam, 2023). This IoT platform was implemented in 2019, incorporating a water/weather (hydro/meteo) system measuring the height of tide, tidal stream, salinity, wind speed, wind direction and visibility data via a combination of 44 sensors in the port. The output of predictive models, data from the Ministry of Infrastructure and Water Management and astronomical calculations are also synthesised

with the sensor output (Port of Rotterdam, 2019). The information gained from this allows for optimisation of port movements, efficient maintenance planning activities leading to reduction in operational costs (Aita, 2022). The combination of port scheduling, internet of things and digital twinning leads to safer vessel navigation and ultimately optimised port performance (Bills, 2023).

The **Seaport of Antwerp** is implementing a blockchain initiative as part of a broader smart port project aiming to make the Belgian city a European IoT leader. The solution concerns container release where truck drivers picking up containers need to identify themselves. The blockchain solution removes the need to manually generate a pin code for authentication, instead relying on an app with the additional security of geofencing (the driver must be within a location to receive the pin). Similar projects exist in other 'smart ports' such as Hamburg, Singapore and Rotterdam (I-Scoop, 2023). These projects required significant engagement from external stakeholders.

The examples above were researched at the suggestion of representatives of the Port of Newcastle (PoN) following several extensive positive interactions. Based on the research and the perspective of the PoN representative, PDC believes that Digital Port Scheduling Tools, an IoT and Digital Twins are the technologies that stand to deliver the biggest medium-long term benefit to the PoN. Implementation of Blockchain technology should be reviewed in the medium term and assessed in collaboration with PoN's various stakeholders.

The Port of Newcastle

A harbour of intelligence

The Port of Newcastle is situated at the mouth of the Hunter River in New South Wales, Australia. Currently the Port of Newcastle is the third largest in Australia by trade volume and well placed to contribute to the expected doubling of Australian freight over the next 20 years. The PoN is the commercial manager of Newcastle Port with a 98-year lease from the NSW Government, which commenced in 2014. The core functions of the business are trade and port development, management of port land, wharf and berth service, maintenance of major port assets, vessel scheduling and dredging and survey services (Port of Newcastle Operations Pty Limited, 2018).

In the ‘Port Master Plan 2040’ (Port of Newcastle Operations Pty Limited, 2018)., the Port of Newcastle identifies five key strategic development opportunities and how to attain them, these are to:

- Promote the capacity of the Port and the supply chain to support the economy.
- Utilise the existing road and rail transport assets to improve freight efficiency.
- Facilitate new trades and supply chains.
- Support the development of new facilities and enabling infrastructure.
- Protect the Port and transport corridors from urban encroachment.

The land assets of the Port of Newcastle are significant covering four major precincts; Carrington, Mayfield, Kooragang and Walsh Point (Figure 1). All precincts are well connected by rail and three by road with ample capacity. The Mayfield site represents the largest vacant Port land site on the eastern seaboard, with direct Channel frontage and potential for deep water berthing (Port of Newcastle Operations Pty Limited, 2018). The Port of Newcastle has ample capacity for growth and has identified five key developments:

- The Newcastle Container Terminal in Mayfield;
- The Newcastle Bulk Terminal in Walsh Point;
- A specialised Automotive and Ro-Ro Hub;
- Supporting the Maritime Precinct in Carrington; and
- Construction of the Newcastle Cruise Terminal in Carrington.

Additionally, a 220-hectare parcel of marginal land has been earmarked for a new Clean Energy Precinct which will act as a production, storage and export hub for future clean energy products and technologies including hydrogen and green ammonia (Port of Newcastle Operations Pty Limited, 2023).

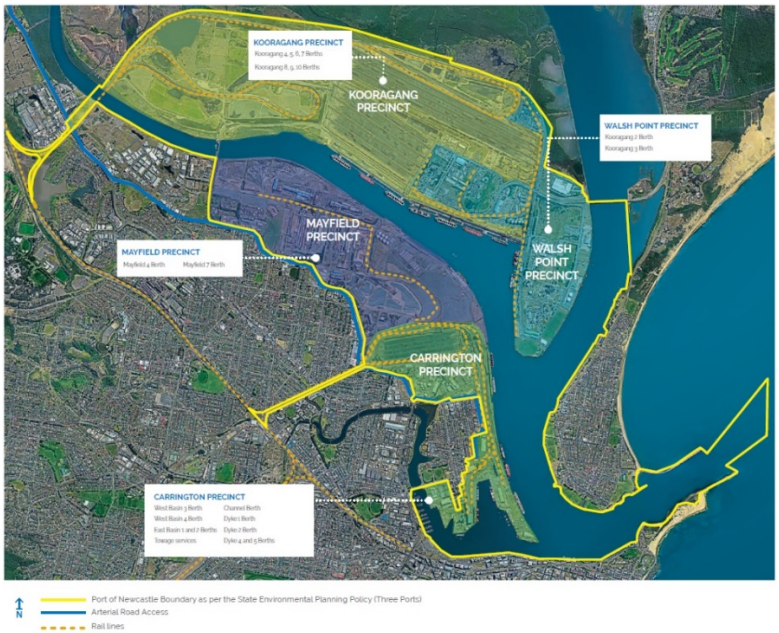

Figure 1 Map of the Port of Newcastle precincts (Port of Newcastle Operations Pty Limited, 2018).

As discussed in the previous section, established ports that have reached physical capacity look to digital solutions to enhance their efficiency and improve their profitability. However, there is no need to wait until the decision is forced to begin realising the benefits of a smart port, through accelerating adoption of digital technologies and its associated gains (CSIRO, 2022). In crossover with other identified megatrends (**Adapting to a changing climate** and **Leaner, cleaner, greener**), these technologies also provide opportunity for the PoN to achieve its ESG goals.

The PoN has ample capacity, including land assets, transport connections and human resources, to achieve its identified strategic opportunities and development plans. However, PDC believes that transforming the digital capabilities of the port should also be seen as a strategic opportunity and development goal. This document is a rallying call and a plan of action to see our beautiful harbour become a smart port for our united future.

Live Port Scheduling

Ships in the night

A Digital Port Scheduling Tool streamlines and optimises the complex operations involved in managing maritime traffic, cargo handling, and resource allocation. Historically, port management has been characterised by extensive coordination among stakeholders from vessel operators to cargo owners, and port authorities. The emergence of Digital Port Scheduling Tools has revolutionised this process by automating and optimising key operations. These tools facilitate real-time communication, data sharing, and collaboration among all involved parties, eliminating the inefficiencies of manual coordination (Port Technology Team, 2021). Moreover, they provide a centralised platform for information exchange, enabling stakeholders to make well-informed decisions promptly. As maritime trade evolves, adopting intelligent systems are a necessity for ports to thrive in a competitive global landscape (Port of Rotterdam, 2023).

Real-Time Visibility: Minimising Delays and Enhancing Sustainability

The dynamic nature of vessel arrivals, departures, and cargo movements presents a formidable challenge for port management. Digital scheduling tools offer real-time visibility that would give the PoN the power to navigate these complexities with precision. Even though the PoN right now has an excess of capacity in overall vessel movements, a digital

technology like a port scheduling tool could reduce the turn around times for the vessels that visit the port, having a significant impact on costs for port users in areas like vessel demurrage. This can cost approximately $30,000 per day (Legchekov, 2023). Reducing these costs would, in turn, make the PoN more attractive for vessel operators knowing the turn around times of their vessels are being optimised for their benefit. This enhances the port's reputation, attracting more business and promoting long-term growth.

Digital port scheduling's ripple effects on environmental sustainability are enormous, a critical concern in the maritime industry. The minimised waiting times for vessels and efficient resource utilisation lead to a reduction in emissions and energy consumption (Li, 2021). As the world shifts its focus toward achieving sustainability goals, digital port scheduling is emerging as a powerful tool to ensure that port operations contribute to, rather than detract from, these efforts.

Scalability and Integration: Future-Ready and ESG-Compliant

Modern port operations have two pivotal aspects that have emerged as paramount considerations: scalability and integration, both aligned with the principles of ESG compliance. As ports stand as critical meeting places of global trade and transportation, the efficiency and sustainability of their operations are of huge importance. In this context, the concept of digital port scheduling emerges as a game changing solution, embodying the ideals of scalability and integration, while fostering ESG-compliant practices.

The main benefits of digital port scheduling lie in its forward-looking approach, accommodating the ever increasing demands placed upon ports in our interconnected world. A digital port scheduling system is a single point of contact for data, providing the groundwork for future growth, making ports more agile and responsive. With the expected amount of change and expansion planned for the PoN in the coming decades, a scheduling tool designed with scalability in mind is crucial.

However, the digital port scheduling tool is more than operational efficiency alone. By aligning with ESG principles, the tool can help improve and add a positive change. It can address pressing environmental concerns by optimising shipping routes and minimising energy consumption (Dávila de León, Lalla-Ruiz, Melián-Batista, & Moreno-Vega, 2017). This relationship between technological advancement and ethical considerations is the

cornerstone of future-ready and ESG-compliant port operations. Some potential savings worldwide have been stated as having the potential to reduce emissions by 200M tonnes of CO2 and $50 billion in fuel costs annually by optimising port efficiency (Safety4sea, 2023).

Adaptability for Resilient Operations: Handling Unforeseen Challenges

Digital port scheduling has become an indispensable asset in ensuring resilient operations within the dynamic realm of port management. Scheduling tools deployed in modern port systems showcase a remarkable capacity to address unexpected events, ranging from inclement weather to sudden equipment malfunctions (DHI Worldwide, 2020).

One of the key strengths of these digital scheduling tools lies in their real-time dynamic rescheduling capabilities. When faced with adverse weather conditions, for instance, the system can swiftly reorganise the port activities, redistributing resources and vessels to mitigate potential disruptions. Similarly, in the event of equipment failures, the scheduling tool can allocate alternative resources and readjust timelines to minimise operational downtime.

Newcastle is a tidal port through which the Hunter River flows to sea. The allowable draught for a vessel can change according to the tide and can change rapidly after major weather events in the river catchment. With many different types of port users and highly variable draught heights, there is significant complexity in moving vessels in and out of the harbour (Port authority of NSW, 2023). A Digital Port Scheduling tool can take all of this information into account and consistently output the most efficient vessel schedule in a very small space of time. A sandbox mode is also available to allow Vessel Schedulers to compare different scenarios and make an informed decision on the best path forward.

All of these benefits, combined with a relative low cost make a Digital Port Scheduling Tool an attractive prospect for the PoN. The benefits of this tool are also realised almost immediately. It is PDC's strongest recommendation that the PoN look to invest in a Digital Port Scheduling Tool as a top priority.

The Internet of Things

Making Waves in The Digital Sea

The Internet of Things (IoT), is essentially a network of devices and systems from which data is gathered, exchanged, and analysed. It has significant implications for port management which often faces challenges related to operational efficiency and environmental sustainability. IoT technology offers a promising solution to address these challenges by providing real-time data, improving decision-making capabilities.

IoT and Environmental Sustainability

PoN is committed to aligning its sustainability commitment with the principles of the United Nations Sustainability Development Goals (SDGs) (Port of Newcastle, 2022). The integration of IoT Technology allows for real-time monitoring which helps ports identify areas for improvement and implement more sustainable practices. The PoN has already put IoT technology into practice, utilising tidal sensors to provide improved navigational passage and safety and visibility through the port, enabling analysis of usage profiles, network leakage and identification of main breaks (Port of Newcastle, 2022). They have also installed smart energy meters to access detailed, real-time information of electricity consumption.

IoT can also be used to identify air quality and emission hazards. The Port of Rotterdam utilises an ‘e-nose’ system, an array of sensors in static locations and mounted on vehicles that detects changes in the composition of air and transmits the information to a central server via a wireless connection (Port of Rotterdam, 2023). Another recent implementation of IoT at a port is in Indonesia where researchers have developed an advanced ship emission monitoring system utilising a multi-gas (SOx, NOx, COx, and particulate matter) sensing drone (Yusri, 2023) The gas monitoring conducted by drones provides real-time data accessible through a designated website developed by the research team.

IoT Technology emission monitoring is a powerful tool for ports seeking to enhance environmental sustainability, improve regulatory compliance and reduce the environmental impacts of their operations.

IoT Technology and Condition Monitoring

Condition monitoring is the process of monitoring a parameter of condition in machinery (vibration, temperature etc.), in order to identify a significant change which is indicative of a developing fault. Port equipment is exposed to extreme environmental conditions such as salt water, high winds, strong sunlight and sand. Unforeseen breakdowns are traditionally avoided through routine maintenance. The integration of the IoT into condition monitoring system can greatly improve the way port manages asset health through more cost effective predictive maintenance (Durlik, et al., 2023). Condition monitoring's financial benefit is around 2.7% of the revenue as yearly steady state net value. This will give a payback of around two years and a return on investment by year five of 126% (Ericsson, 2021).

The revenue and ROI benefits come from:	
Reduction in maintenance Labor	53%
Reduction in the cost of monitoring	40%
Decrease in the cost of maintenance materials	7%

Figure 2: The revenue of ROI benefits via using condition monitoring (Ericsson, 2021)

IoT implementation in Clean Energy Precinct

PoN is regenerating a 220-hectare parcel of industrial wasteland into a dedicated Clean Energy Precinct for all forms of clean energy and associated technologies. It will become a leading production, storage and export hub for future clean products and technologies including hydrogen and green ammonia. The hazards introduced by handling these fuels can be mitigated with IoT monitoring of facility conditions and emissions.

The future of IoT will also play an important role in redesigning energy-efficient systems and bringing a full-scale revolution to the energy sector. The current renewable energy distribution and transmission systems are highly unreliable, leading to huge losses in transit. This can be easily handled via IoT by using smart grids. Unlike a traditional grid, a one-way communication with power flowing from the utility to consumer, the smart grid has two-way communications. It also allows users to check the grid's analytics to ensure its efficiency. The grid itself can make better choices for the whole system and relay the directive to all systems in the intermittent network. The technology enables the customer to pay for the energy consumed only and if excess power produced can be transmitted to the grid. IoT can

also help in analysing the demand as well the wastage of energy (Sivagami Ponnalagarsamy, 2021), in scheduling the load to reduce costs.

Data Gathering and Synthesis

Landing the net

An array of sensors, typical of IoT, generates a large volume and variety of data. This data needs to be transmitted and stored such that a benefit can be realised from its collection. Communication across the port is best handled with a private 5G network. Data sources external to the IoT may also be utilised with simple computer programs. The existing open-source relational database (MySQL) and cloud computing utilised by the PoN is suitable for the amount and type of data predicted from the IoT.

Data from sensors must be transmitted to a central location for storage and further use. Wired connections are reliable but not feasible for large ports and impossible for sensors on vessels or vehicles. 5G is well optimised for IoT, ensuring low energy usage, increased data security, and the ability to support high connection density. Transmission & storage (Ericsson, 2021).

Data is also available from third parties. Of particular relevance for the PoN is weather forecasts and measurements, primarily available from the Bureau of Meteorology (BOM). The BOM makes a number of real-time forecast, warning and observation products and analysis charts available freely via the web and file transfer protocol (Australian Government - Bureau of Meteorology, 2023). This information can be accessed and stored conveniently with simple computer programs (e.g. Python (Python Software Foundation, 2023)).

MySQL is an open-source relational database management system implemented by many organisations globally (Oracle, 2023). Data tables handled by MySQL are suitable for the data likely to be generated by IoT sensors. The format is also convenient for access and further calculation. Should the PoN become interested in the storage and analysis of data intense streams, like HD video feeds, an auxiliary data storage scheme may be required.

Cloud architecture has been in used at the PoN since 2019 and has allowed for greater collaboration with port stakeholders, as well as internally for the business with use in data

warehouse invoicing by preventing double handling, and through business intelligence software (PoN & PDC, 2023). Cloud computing and the increased accessibility, data storage and scalability has also enabled uptake of Digital Twins specifically as it permits collaboration between various stakeholders (Aita, 2022).

Digital Twins

Buoys will be buoys

Digital Twins are systems which provide virtual replication of physical objects, systems or processes. Through use of real time data, simulation and machine learning Digital Twins enable businesses to maximise efficiencies, increase productivity, explore detailed simulations and opportunities that are otherwise unanalysed (Agarwala, Chhabra, & Agarwala, 2021), (Heikkilä, Saarni, & Saurama, 2022), (Javaid, Haleem, & Suman, 2023), (Yao, Xue, Wang, Qi, & Su, 2021). Digital Twins enable ports to make effective decisions in real time, disseminate information with the port ecosystem, contributing to improved operational efficiency (Lind, et al., 2020). Digital twins have the potential to significantly benefit the multifaceted and interconnected processes undertaken at a port (Klar, Frederiksson, & Angelakis, 2023).

Digital Twins collect real time data from IoT (sensors, devices, other data sources) and utilise this information to create a digital representation of its real-world equivalent. In this sense, they are not a standalone system, technology or singular product. The uptake of Digital Twins has increased significantly in recent years through advancements in sensor technologies, Big Data and Analytics, Cloud Computing and machine learning algorithms (Attaran & Celik, 2023), (Becha, Lind, Simha, & Bottin, 2020), (Sharma, Kosasih, Zhang, Brintrup, & Calinescu, 2022).

In application at a port, a Digital Twin would constitute a combination of various technologies with the aim to monitor port assets, gain an increased understanding of performance optimisation via scenario modelling, and provide increased insight into analysis and visualisation of the entire port environment (Bills, 2023). Digital twins should provide situational awareness, data for analytics and interfaces to relevant stakeholders Klar (2023).

Benefits of Digital Twins & Realisations

In the context of PoN and shipping port industries at large, digital twins have emerged as a disruptive technology with the potential to positively impact port operations, and future proof the industry in line with the emergence of global megatrends. Digital twins at the port bring together live port scheduling, the IoT, data gathering and synthesis. Benefits of digital twins at the port might include operational efficiency, predictive maintenance, improved safety, improved environmental sustainability and improved collaboration.

Live port scheduling combined with monitoring of asset conditions, vessel movements, tidal and port depth conditions allows for optimisation of port movements, efficient maintenance planning activities leading to reduction in operational costs (Aita, 2022). Digital twins for port assets are possible through asset control signalling and monitoring (ACSM) systems, and analysis of datasets established with the IoT. Asset digital twins, allow for predictive maintenance, preventing 'over-maintenance' and more accurately identifying risks due to equipment failure.

Digital Twins can provide enhanced safety and security in ports, identifying potential risks and allowing PoN to proactively respond to potential incidents. The PoN operations are effected by weather conditions, tidal conditions, interaction of various lessees, shipping companies, vandalism etc. Where there is little time or resource to gather data and undertake in depth analysis, Digital Twins may already have the prediction (Gao, Chang, & Chun-Hsiehen, 2023). This empowers PoN to identify issues early, and plan corrective actions early or before an event has even occurred.

Digital Twins can assist in the increasing pressure to meet ESG's via optimising vessel movements, identifying patterns to gain efficiencies and in turn reducing emissions. The planned automated container terminal at the PoN is one such initiative which would benefit from sustainable port operation management. Many ports are using their Digital Twins to forecast and model their carbon emissions and the effect of climate change on their business gaining a better understanding of how to prepare for global changes (Lind, et al., 2020), (Royal HaskoningDHV, 2023).

Digital Twins hold the potential to facilitate collaboration among all stakeholders involved in the port ecosystem. Through collaboration and sharing of data and ship operators, port

authorities, regulators, and technology providers can all realise increased efficiencies while in turn improving sustainability. Collaboration between stakeholders establishes best practices, industry standards, and drives innovation, ultimately shaping a greener port ecosystem (González-Cancelas, Molina Serrano, Soler-Flores, & Camarero-Orive, 2020).

Why Digital Twins, not just SCADA ?

Though limited, the PoN currently utilises SCADA (Supervisory Control And Data Acquisition) at the recently commissioning Ship Unloader (PoN & PDC, 2023). SCADA is used extensively for monitoring of plant in processing, automation, manufacturing, mining and various other industries. Digital twinning is the logical progression of industrial automation after SCADA systems. Whilst SCADA is useful in fault finding, it does not predict failure modes/occurrences or prevent them from happening via automation in decision making (Andersen, 2018).

Block Chain

Even pirates need secure ledgers!

Blockchain is a decentralised and distributed digital ledger technology that is designed to record transactions and store data in a secure, transparent, and immutable manner. Ultimately, this is a formalised method to enact a transaction with a reduced administrative requirement throughout the process. For a transaction to be converted into a blockchain transaction, it must be measured digitally from implementation to completion. For example, a delivery would need an origin, quantity of product, destination, confirmation of completion and payment process.

Blockchain utilises technologies (such as: IoT) to create a secure network for parties to transact in a safe and transparent manner. This enables new transaction that normally a lack of trust would prohibit. This trust is afforded through the process using a distributed ledger technology that stores the information through an agreed and reviewable protocol. (Savjee, 2017)

Benefits of Blockchain

Some of the more common benefits of Blockchain are; transparency, security, reduction in administration and intervention, standardised documentation, expedited agreements/payments, and auditing & compliance improvements.

In a case proposed by Deloitte (2016, p. 16), utilising the connectivity of IoT, manufacturing sites can have work directed by the infrastructure when specific parameters are set. An additional benefit highlighted by Khan & Manzoor (2021, p. 286) was a reduction in ghost demands and pilferage. This supply chain benefit would benefits the PoN's customers through transparent automated calculations reducing human error and potential over or under supply situations.

An example of a transaction that could take place at the Port of Newcastle is a singular berthing charge. This could be contracted relatively simply for a time management and completion process using the aforementioned IoT sensors and tracking. Multifaceted transactions could take place passing on financial data, positioning, maintenance, cargo levels, draught height in the port and multiple other factors that impact one ship movement. The PoN's green energy precinct may require transparent transaction of green fuels from the generator to the consumer. Blockchain is being considered as a solution to verifying that fuels are indeed generated using renewable energy (Ricoh, 2023).

Challenges of Blockchain

Some challenges have been highlighted by Deloitte in that every opportunity needs to be reviewed with the risk it encompasses (Deloitte @ Telco, 2016). One risk is data stability, as a blockchain is an ongoing list of transactions or counter-dependencies in a chain. The size could become a concern if the chain grows to become digitally unsustainable.

Another clear challenge is governance and regulation. As the use of blockchain is still in its infancy. The governance and regulations set forth may not fully capture the risks and potential issues of the smart contracts. As the process grow in popularity and the increase in it use, this will begin to identify more, and the evolution of the regulations will need to be constantly updated.

Generally, with any change in process, the people are the key drivers or inhibitors. Defining success of the introduction will be at the hands of the Leadership team of PoN, Technology/Digital teams, Process owners, Customers/Suppliers, Finance teams, Legal and compliance teams, Digital Security, Auditors, and End users. Following the PPT approach of People, process and technology shows that the correct pathway begins with people (Jones, 2022).

PDC does not believe that the PoN benefits significantly by becoming an early adopter of blockchain technology. However, the introduction of digital port scheduling, the IoT platform and Digital Twins places the PoN well should significant industry participants or government bodies require its implementation.

Action Plan

Dive deep

Strategic considerations of digital technologies

PDC has reviewed and assessed different digital technologies offered on the market in detail. Below are strategic considerations that led to our implementation priorities.

- **Strategic Alignment:** Ensure the technology align with the port's strategic objectives and long-term vision.
- **ESG impact:** The port has environmental responsibility. Assessing the technology's ESG implications.
- **Maturity and adoption of technology:** PDC use the Gartner Hype Cycle (GHC) methodology to understand the stages and lifecycle digital trend and technology.
- **Stakeholder engagement:** Identify the key stakeholders and understand their requirements.
- **Cost and benefit:** Calculate the expected return on investment. Determine if the benefits of the technology outweigh the cost.

	Implementation Priorities	Strategic Alignment	ESG positive impact	Maturity and adoption of technology	Stakeholder Engagement	Cost and benefit considerations
Live Digital Scheduling	1	Improve the capacity of port and supply chain	Yes	Plateau of Productivity	Medium	Short -term investment (1-2 year/s) The cost options of implementation vary greatly depending on the detail and scope for the expectations of the digital solution. Solutions range from berth planning to full Terminal Operating Systems that can manage whole container terminals. A digital berth planning solution on a subscription basis starts from approximately $400 USD per berth, per month, whereas a full TOS can be a multi-million dollar investment. The benefits can be realised in a short space of time with some of the immediate benefits being faster vessel turn around time, greater customer satisfaction and the flow on effects being a reduction in green house gases with the optimised vessel program reducing he time vessels have to stay in the vicinity of the harbour.
Internet of Things	2	Clean Energy precinct Ensure Organisation sustainability	Yes	Plateau of Productivity to Slope of Enlightenment (depending on project)	Medium to High	Long- term investment (3-5 years) The cost of implementing IoT can be varied significantly from thousands to millions of dollars based on the scale of the deployment, customisation requirements, platform cost and etc. However, using condition monitoring has been approved to lead to significant return on investment :payback of two years and a return on investment by year five of 126% (Ericsson, 2021).
Digital Twin	3	Improve the capacity of port and supply chain	Yes	Slope of Enlightenment	High	Long- term investment (3-5 years) Scalable cost options - eg Microsoft Azure & Amazon AWS where subscription based licensed software permits cost effective sustainable growth of the Digital Twins model (Microsoft, 2023) (Amazon, 2023). Cost estimation methodology to be implemented in cooperation with PoN to identify cost drivers – investment costs, implementation costs, indirect costs and running costs (Oettla, Eckarta, & Schilp, 2022). Costly investment – an average organisation utilising Digital Twins spends >$1M USD per year on investment, development and deployment of Digital Twins (Dertien & McMahon).

						Difficult to quantify Return on Investment (ROI) in $ figure, however ROI can be justified via cost savings associated with improved decision making, resulting efficiency and safety improvements and reduction in downtime (Visionaize, 2023) (Bennett, 2023). Bills (2023) notes that Digital Twins are currently entering the third phase of the GHC - the “trough of disillusionment” and that caution should be applied in their assessment. In this cycle, interest in the technology wanes due to implementations that fail to deliver results. To reach the next cycle – “Slope of Enlightenment” – and to derive true value from a Digital Twins requires a clear use case (Sharma, Kosasih, Zhang, Brintrup, & Calinescu, 2022).
Blockchain	4	Improve the capacity of port and supply chain	Yes	Trough of Disillusionment	High	Long- term investment The cost and benefit of implementing Blockchain technology depends on whether and to what extent the wider industry adopts the technology. It is recommended that the PoN future proof by implementing the digital technologies above that can support Blockchain.

Seven Steps leading to digital transformation of Port of Newcastle

Think big: Global megatrends, like those identified in the CSIRO 2022 report (CSIRO, 2022) can be used to design the future of the port and to develop a long-term overarching strategy. The 2022 report presents an update on CSIRO's global megatrends out to 2042 with the view to guide long-term investment, strategic and policy directions across government, industry, the not-for-profit sector, and the broader Australian community. Identifying megatrends and understanding their impact is key to knowing how the port operates today and into the future.

Link a digital strategy to the overall port strategy. Technology strategy doesn't exist in a bubble. An upgrade needs to dovetail with a port's larger strategy and goals, whether those goals include improving the capacity of the port, facilitating new trades and supply chains, supporting the development of new facilities, and enabling infrastructure.

Develop a cohesive IT system that incorporates the requirements of all stakeholders affected by the business change. Port environments have become complex partner networks that include port authorities and port operator, terminal operator, shipping lines, rail, and logistics companies. To make digital transformation truly effective, the port must do more than simply adopt these technologies on its own. Instead, it must embrace platforms and services that make it easier for stakeholders to work together to promote the efficiency of the overall ecosystem and this must be done right from the start with the re-engineering of any business processes (SIa Partners , 2016).

Identify business needs and pain point that digital technologies could fix. After identifying areas that need improvement, the port needs to prioritise them and determine which could be solved using digital technologies. To decide which problem to tackle first, ports should identify one for which it is realistic to expect a solution, determine how much value would be created by addressing it, and assess how well the solution aligns with the port vision and strategic objectives. (Francois-Xavier Delenclos, 2018) it should followed by a detailing of the to-be business process, and then an operational analysis for identification of the main technological requirements.

Cross-functional teams are especially useful here to consider the full range of business requirements, IT-elements, and the regulatory environment, and provide an end-to-end view.

Decide whether to buy off-the-shelf technology or build a custom solution. (Francois-Xavier Delenclos, 2018) After prioritising the requirement, a port needs to determine whether off-the-shelf tech solutions meet its goals or if developing a system in-house or with the help of an outside partner is the best way to go.

Use an agile approach to manage risk. Adopting any kind of a digital technology involves risk. Adopting any kind of a smart-port technology involves risk. Software can be buggy. Once installed, it might not function as expected, or the intended users might resist switching to the new system. To minimise risk, ports should implement new systems in stages, agreeing to make a formal go/no go decision after each step. (Francois-Xavier Delenclos, 2018)

Create a culture that fosters change. Last but not the least, a culture of change is not only a fundamental for the port to navigate the complexities of digital transformation successfully but also for the long-term sustainability of the organisation. It empowers employees, enhance adaptability, position the port to thrive in a digital - driven world.

Conclusions

As we conclude our exploration of this digital transformation journey, it becomes evident that 'The future ain’t what it used to be'. This simple statement underscores the reality that becoming a smart and digital port is no longer a choice but a necessity.

Strategic alignment, ESG impact, maturity, ease of adoption and cost benefit analysis was considered by PDC to determine which technological investments would yield the most substantial benefit for the PoN. PDC believes that Digital Port Scheduling Tools, the IoT, Digital Twins and Blockchain, are four broad technologies that offer a range of

advantages that could position the PoN for long-term success in a rapidly evolving maritime industry:

Digital Port Scheduling Tools, already well established in many world-leading ports, will enhance efficiency, reduce vessel turnaround times, and could attract more business to the PoN. Real-time visibility and optimisation capabilities promise to minimise delays and enhance sustainability.

IoT sensor deployment directly supports the PoN in improving sustainable practice and provides the data required to establish various Digital Twins. The IoT's integration into the PoN's clean energy precinct and condition monitoring systems could contribute to cost savings and operational efficiency. Digital twins offer insights into asset management, safety improvements, and environmental sustainability, which are viewed as a long-term investment.

Blockchain technology presents exciting possibilities for improving supply chain transparency, security, and efficiency. While the cost and benefits of implementing blockchain depend on broader industry implementation, it remains a technology the PoN should be ready to introduce.

To navigate this digital transformation effectively, PDC has identified seven steps that lead to successful transformation. This includes aligning digital strategies with the PoN's long-term vision, engaging stakeholders, identifying pain points and adopting an agile approach to manage implementation risks.

By carefully considering the strategic priorities and action plan outlined in this report, the PoN can navigate the challenges and enjoy the benefits of the digital era, ensuring a bright future in the evolving world of port management.

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Appendix – The Gartner Hype Cycle

The Gartner Hype Cycle (GHC) methodology indicates through graphical means the maturity and adoption of technology/applications, their potential relevance in solving real business problems and exploiting new opportunities (Gartner, 2018). This is an important tool in assessing the potential technological options available to the PoN in its digitalisation transformation and in achieving its Port Master Plan goals.

- **Maturity and adoption of technology:** PDC use the Gartner Hype Cycle (GHC) methodology to understand the stages and lifecycle digital trend and technology. Each Hype Cycle drills down into the five key phases of a technology's life cycle.
- **Innovation Trigger:** A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist, and commercial viability is unproven.
- **Peak of Inflated Expectations:** Early publicity produces a number of success stories — often accompanied by scores of failures. Some companies take action; many do not.
- **Trough of Disillusionment:** Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.
- **Slope of Enlightenment:** More instances of how the technology can benefit the enterprise start to crystallise and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.
- **Plateau of Productivity:** Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off.