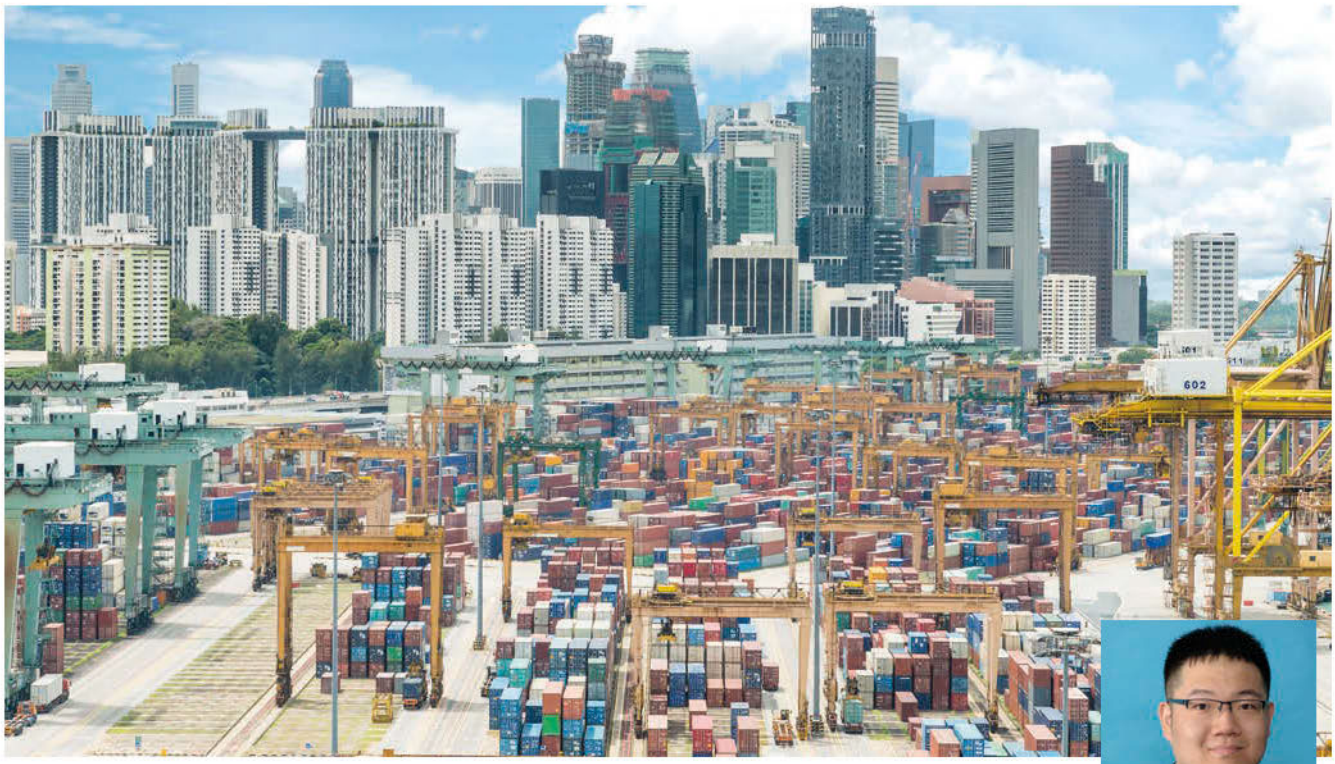

DIGITAL TWIN AND CAPACITY PLANNING

NEXT GENERATION PORTS

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As the scale and complexity of container ports operations grow, more sophisticated and accurate methods are required to derive precise planning for next generation ports.

The researchers from the National University of Singapore (NUS) are currently developing maritime digital twin systems to assist port operators in their decision-making on terminal capacity planning, as well as other maritime challenges.

With the integration of advanced simulation and optimization techniques, those decisions previously made by humans can be greatly optimized using machine learning, which is expected to bring millions of dollars of savings to decision makers.

To continue delivering world-class services and retain its global leading position as one of the world's top container ports, the Maritime and Port Authority of Singapore (MPA) has put in place the Next Generation Port 2030 Initiative.

Among the major components of this initiative is the next generation fully automated container terminal (Figure 1) with an annual capacity of 65 million TEUs, making it the largest single mega terminal in the world.

Due to land constraint and bid to increase productivity, Singapore is looking for innovative ideas to optimize the design and operation of its next generation port.

With support from the government and university, the Centre of Excellence in Modeling and Simulation for Next Generation Ports (C4NGP) has been established to help Singapore's maritime and port industries, develop innovative capabilities and enhance their global competitiveness.

Among all the maritime challenges, terminal capacity planning is fundamental because it affects the design of the container terminal.

Port operators need to determine parameters such as the yard dimensions, desired capacities, choice, the number of equipment and so forth.

As a common practice in the industry, capacity planning is based on past experiences.

For example, there is a suggested range for the ratio of the number of quay cranes to the number of vehicles. However, with the development of more advanced port operational technologies and increasing complexity of the terminal operations, costs have increased as well.

Thus, more sophisticated methods are required to help derive better and more cost-effective planning strategies.

DIGITAL TWIN

For complex systems like container terminals, the best practice to test and evaluate proposed designs and operation strategies is to build the digital twin of the system, as illustrated in Figure 2.

The digital twin of a container terminal comprises of comprehensive simulation models, which simulate the operations strategies, and controls over

Figure 1: Illustration of next generation port at Tuas (Photo: MPA)

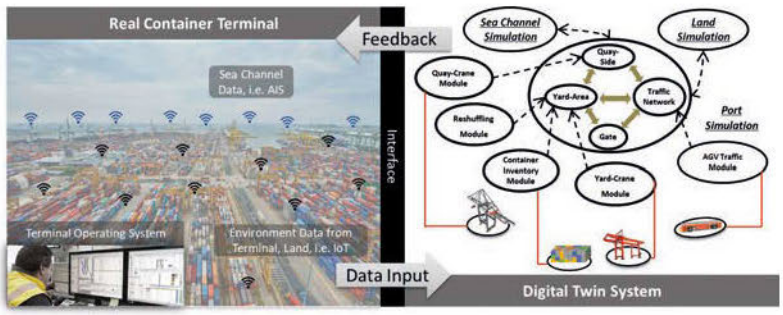

Figure 2: Illustration of container terminal digital twin

time by incorporating various simulation optimization algorithms.

The proposed port digital twin is a discrete event simulation software that captures the equipment and cargo movements as well as the operational logics for a port terminal, together with related sea and land traffic, to form a digital replica of the physical system.

With the ability to simulate the port as a complete system with different combinations of layout, equipment and technologies and so forth, it enables the objective comparison of various options during the port design and transformation process.

Furthermore, with a synchronized digital twin system, the advance decision-making technology integrates simulation and optimization for improved planning and operational policies across different parts of the entire port operation e.g. berth planning, yard allocation and equipment deployment. With real-time operational data, it enables collective analysis scenarios on any 'look-ahead' and 'what-if' scenarios and serve as the basis for information sharing and coordinated decision making, thus leading to operational improvements and productivity gains.

CAPACITY PLANNING

Applying the digital twin alone is still insufficient for finding the optimal solution since it still requires evaluating a lot of scenarios and strategies. Therefore, there is a need for an efficient framework to conduct simulations for various candidate solutions, and to find the optimal solutions amongst them.

Our research team developed an innovative decision-making framework for the capacity planning for mega container terminals via integrating container terminal digital twin and advanced simulation-based optimization techniques [1]. The framework helps port operators obtain the optimal resource configuration in terms of the number of the quay cranes, yard cranes and vehicles in an efficient and accurate way.

Soon, our team plans to develop the digital twin system to incorporate other details in port operations, e.g. the transportation system based on various yard layouts, interaction with external vehicles, gate booking system, different policies for berth allocation, yard planning and traffic control, for more realistic simulation.

With our modelling and simulation capabilities, decision-making in the container port will be much more efficient.

FUTURE ROADMAP

With the Tuas Next Generation Container Port still under construction, besides working on the development of digital twin system for the Tuas port, C4NGP is also building a maritime eco-system, to include sea, terminal, gate and land.

With this comprehensive maritime digital twin, the center can investigate real industrial challenges and provides practical solutions, such as traffic congestion management at lighterage terminal [2], and traffic network design in container terminals [3].

The center aims to be a global leading research center in modelling, simulation, and optimization of next generation ports and maritime systems, collaborating closely with companies in Singapore's maritime and port sectors, to improve their technical know-how, efficiency and productivity, contributing to Singapore's economic development and society.

The centre will also lead the translation of research results into innovations, help nurture the commercialization of the innovations and create value for Singapore by being the strategic research think-tank for the port and maritime related industry, and for Singapore.

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Dr. Zhou Chenhao is Assistant Professor (Research) at the Centre of Excellence in Modeling and Simulation for Next Generation Ports (C4NGP), National University of Singapore (NUS). He has academic and industry experiences in transportation and maritime logistics, and his publications can be found in top-tier journals such as Transportation Science, IISE Transactions, etc.

ABOUT THE ORGANIZATION

Established in 2018, C4NGP is an S$18 million Research Centre to help Singapore's maritime and port industries develop innovative capabilities and enhance their global competitiveness. C4NGP aims to be a global leading Research Centre in modelling, simulation, and optimization of maritime systems, collaborating closely with companies in Singapore's maritime and port sectors to improve their technical know-how, efficiency and productivity, contributing to Singapore's economic development and society.

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