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WSC@SINGAPORE: REIMAGINE TOMORROW

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ABSTRACT

In spite of a complete lack of natural resources, Singapore is a global economic powerhouse as the second-richest country in the world in terms of purchasing power parity. A hub for maritime, logistics, advanced manufacturing, and financial services, the secret to its success is its insatiable appetite for re-invention: "Singapore Reimagined" as part of the Smart Nation initiative is its latest re-invention project. In this panel, we will hear from the leaders of some of the key Singaporean industries about their contributions to this ambitious national project and the role played by simulation in enabling their contributions.

1 INTRODUCTION

Home to nearly 6 million people, Singapore is an island of 719km^2. Smaller than New York City, the land partitioned between urban areas (79%), forests (22%), and agricultural space (1%). Even though the country does not have any natural resources, it is one of the highly developed economies (with a Human Development Index of 0.938) and the second-richest country in the world in terms of purchasing power parity. This is because Singapore has become an economic powerhouse in Southeast Asia supported by world-class manufacturing, maritime and logistics, and financial services. In fact, Singapore's manufacturing sector contributes up to 25% of the country's annual GDP. Key manufacturing clusters include electronics, chemicals, and pharmaceuticals along with logistics and transport engineering. Close behind Singapore's manufacturing industry is its financial services industry, which includes over 200 banks. Singapore is also the largest transshipment sea port hub, international maritime center, largest bunkering hub, and the fifth largest ship registry. Other emerging industries that are making significant contributions to Singapore's economy include biomedical technology, aerospace engineering, clean energy, healthcare, and content development.

Singapore's success is driven by its relentless desire to re-invent itself. This is enabled by significant investment in education (about 20% of the annual budget) and by an impressive information (internet penetration of 92%) and logistics infrastructure (one of the world's busiest container hub ports with 37.5 million TEUs and the top bunkering hub with 50.04M tons of total sales volume in 2021).

The theme of WSC'22 is naturally derived from Singapore's Smart Nation initiative, "Singapore Reimagined." WSC 2022 will "Reimagine Tomorrow" to evaluate not just living in an urban future where cities are safe, green and environmentally secure with seamless power, water and transportation networks, but also working in an environment where both sustainable high-tech manufacturing and novel services play an essential role.

Our distinguished panelists who lead some of the key industries in Singapore elaborate how tomorrow would be imagined in their domain. In particular, they discuss their contributions to this ambitious national initiative, the role played by simulation in designing and deploying these contributions, some of the challenges they face in this process, and the profile of people they need for successful transition.

2 KENNETH LIM, MARITIME AND PORT AUTHORITY OF SINGAPORE

2.1 Contribution to the Smart Nation Initiative

2.1.1 Next Generation Ports

Singapore is the world's busiest transhipment hub. Tuas Port is expected to handle up to 65M TEUs when it is fully operational in 2040. To enable our port to handle the increased traffic, MPA has renewed the Port Technology R&D programme with PSA in 2021 to accelerate technology research, development and facilitate live trials in the areas of automated container port systems, advanced port optimisation techniques, and green port technologies for application in existing container terminals and the new Tuas Port. The programme will also uplift capabilities of the local port ecosystem including small and medium enterprises and research institutions.

Furthermore, MPA renewed the MOU with Jurong Port in 2022 to enhance the port's resilience as a next-generation multi-purpose port. The MOU will focus on 4 themes, namely: (1) Automation and mechanisation, (2) Sustainability and future green fuels, (3) Digitalisation, and (4) Safety and security.

2.1.2 Digital initiatives to enhance regulatory efficiency

Developing an advanced digital infrastructure is also central to improving regulatory efficiency and facilitating timely information exchange and data flow among port users and stakeholders, locally and beyond the region. digitalPORT@SG streamlines vessel, immigration and port health clearances across multiple agencies into a single application by consolidating 16 separate forms. Shipmasters and ship agents from more than 550 shipping companies can now submit, track, and receive approval for arriving and departing ships through the portal. As a result, the industry can save up to 100,000 man-hours per year.

In the next phase, digitalPORT@SG will also facilitate just-in-time marine services such as bunkering and repairs by providing port stakeholders with real-time information to better coordinate, plan, and allocate resources. This not only enhances the efficiency of port operations and reduce the turnaround time of ships, but also minimizes the ships' idling time, which cuts greenhouse gas emissions from ships.

Beyond our shores, Singapore has also embarked on the digitalOCEAN initiative, partnering with key stakeholders to work on common data standards and application programming interfaces to exchange data with ports and shipping-related platforms with the aim of improving efficiencies in port clearances. This should serve to reduce repetitive and manual completion of forms at ports along trade routes.

2.2 The Role of Simulation

Port congestion is a growing worldwide issue exacerbated by the COVID 19 crisis and geopolitical tensions. There is a need for ports to deploy resources efficiently to process cargo, containers, and vessels to mitigate supply chain disruptions. MPA supported the *Centre Of Excellence In Modelling And Simulation For Next Generation Ports* (C4NGP) to be a global leading research centre in modelling, simulation, and optimisation 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 and contribute to Singapore's economic development and society.

C4NGP's capabilities in digital twinning and optimisation of ports and ancillary depots will enable their industry stakeholders to design their terminals and allocate port resources more efficiently to become more resilient in the face of supply chain disruptions.

2.3 Open Problems

Simulation could solve larger global and industry-level challenges relating to supply chain optimisation taking into consideration just-in-time or just-in-case priorities. This is especially pertinent and relevant not just to the shipping community but also to port authorities and governments today as sustained supply chain disruptions and congestions would have an impact on the global economy.

In port operations, modelling and simulation can be used to evaluate the efficiency and robustness of just-in-time arrival concepts to deliver increased navigational safety, reduced fuel consumption and CO_2 emissions for Singapore's hub port and ship operations. Modelling and simulation has also been used to optimise the routing and the number of automated guided vehicles in a container port. Here are two further innovation challenges where optimisation, modelling and simulations could add value under Smart Port Challenge 2022, which is open for applications until 8 July 2022:

2.3.1 Better Visibility of Lighter Boats

Currently, tracking lighter boats within the port waters is a challenge. This lack of visibility on the movements and activities of lighter boats makes scheduling difficult and often inaccurate. Late arrivals of lighter boats result in long wait times for delivery trucks and loading backlogs for terminal users. Jurong Port is looking for a cost-effective solution that can be adopted by lighter boat owners to provide real-time location visibility of their fleet. This data should be easily accessible by Jurong Port to allow them to improve scheduling, reduce congestion, and improve overall productivity and operational efficiency at the Lighter Terminals so that the industry is able to better streamline its logistics chain.

2.3.2 Consistent Quality in Additive Manufacturing

Additive manufacturing (AM) holds potential for the maritime industry especially in built-to-order spare parts for vessels. By enabling on-demand layer-by-layer AM closer to the user, the use of AM can reduce lead times and transportation costs, overcoming the challenge of spare parts inventory management. However, the maritime industry today is still not readily accepting the technology despite its potential due to various barriers for wider adoption. One of them is the uncertainty of the quality of AM-built marine spare parts and their reliability for onboard installation and application.

To build confidence and assure the quality of AM built parts, multiple traditional industry practices are usually employed, including feedstock sampling, qualification tests, test specimens, non-destructive and destructive inspections, etc. However, these tests are not optimized for new manufacturing processes such as AM, leading to unnecessary costs and lead times to end-users. Currently, the fidelity of AM built parts depends largely on the track record of the service bureau with a certified facility as well as the experience of the operator, which in itself is already a largely uncertain factor. The industry requires more efficient ways to ascertain the fidelity of AM built parts, repeatedly and consistently.

The American Bureau of Shipping (ABS) is looking at innovative technological solutions to ensure consistent and repeatable quality in the AM process so as to streamline AM qualification processes. These technologies may leverage the power of data to improve decision making during qualification.

2.4 Ideal Profile for Smart Nation

Researchers at our MPA centres of excellence, including C4NGP, should have a strong technical background coupled with maritime domain knowledge. A multi-disciplinary background with a diversity

of perspectives in different fields would be an added bonus. For instance, the researchers at C4NGP should have deep technical capabilities in modelling, simulation, optimisation and digital twin development. Additionally, the ability to engage and secure stakeholders and collaborators, to translate and deploy that centre's research for impactful maritime applications is also essential.

Sound project planning is key —not just relying on expensive technology. Goals should be determined first before appropriate technology to be selected to meet the objectives. Notable traits for start-ups / practitioners are to be agile, able to understand new challenges in the maritime industry, and synthesize ideas. These include leveraging technology stacks to build new solutions for the port and maritime industry while remaining flexible and innovative. For example, Dravam started off as a solution that was developed using fluid-flow mechanics to detect water quality. Through the Smart Port Challenge, they were able to pivot towards fuel quality monitoring solution for bunkering thus ensuring the quality of the fuel that is bunkered and addresses the industry's need for quicker bunker quality testing.

3 NGIEN HOON PING, SMRT

3.1 Contribution to the Smart Nation Initiative

3.1.1 Mobility services

SMRT Corporation Ltd (SMRT) is a public transport service provider. Its primary business is to manage and operate train services on the North-South Line, the East-West Line, the Circle Line, the new Thomson-East Coast Line and the Bukit Panjang Light Rail Transit. In 1987, SMRT started with serving just five stations in northern Singapore. Today, it operates a network of five train lines that spans the island with over 100 stations. This is complemented by bus, taxi and mobility services.

SMRT has always be a strong proponent of Smart Nation. With engineering and technology driving the work we do, are always assessing and implementing the best solutions to keep us in the forefront of what we do. We have been on the Digital Transformation journey since the beginning to find digital solutions that benefit our people, our commuters and the wider society.

We have developed and been progressively rolling out new digital systems such as the integrated solution Track Access Management Systems (TAMS), that digitises and automates track access allocation for routine maintenance and engineering work planning. Another initiative we have is Project Overwatch to provide real-time alerts on Trains dwell time at the various stations, Advance Train Operations Management Systems (ATOMS) to help Train Captains manage their duty roster and admin matters on a mobile device as well as Advance Station Operations Management Systems (ASOMS) to facilitate Station Managers in performing their duties. Our buses are also equipped with a fleet management system which provide real-time location information for commuters. Some of these data are piped into the LTA DataMall. We have introduced the NaviLens app at one of our integrated bus interchanges to help the visually impaired seamlessly navigate the bus interchange. We worked in consultation with social service agencies, the Guide Dogs Singapore Ltd (GDS) and Singapore Association of the Visually Handicapped (SAVH), for tests in real-world situations. This resulted in various refinements that best addresses the needs of our visually impaired commuters. We are now in the midst of implementing this to all our bus interchanges by the end of this year.

With the advancement of technologies and big data, we see a vision where Singapore and the region to be more connected via digital platforms and solutions. This will allow us to provide a more seamless service, understand our customers better and enhance their experiences.

3.2 The Role of Simulation

In Singapore, we are one of the few countries in the world with a CBTC simulation facility for all our lines. These facilities are loaded with hardware and software similar to actual signalling systems, allowing operators to test out new signalling software in isolation before uploading them to existing train lines, as well as help them gain experience in troubleshooting system faults.

Engineers can simulate scenarios, such as how signalling software modifications interact with regular train operations, implementing temporary speed restrictions or holding a train at a platform in an emergency. These simulation facilities make testing more robust and minimise potential disruptions to passenger service.

Transport Modelling could help Authority to design spaces to optimise commuter flow both in Transport Network as well as Pedestrian Simulation. Digital Twin coupled with Video Analytics on CCTV images would be helpful to drive attention to abnormal occurrences and allow security personnel to be alerted to the location of potential breaches and enable the quick response to such incident. Digital Twin could also be a way for rail operators to use LIDAR Scanner to scan the areas surrounding the rail tracks over different time periods and plotting the data cloud on a Digital Twin platform to verify that any variance is within tolerance and to alert for maintenance if any of the area is out of specifications. Data and analytics will also be a key area of focus for us. To maximise the potential of modeling and simulation, we will need to unlock the power of data, and to develop a more data and digital centric organisation. These are some of the works in the pipeline for us.

3.3 Open Problems

Some of our challenges include:

- A common standard, which will allow a model to be re-used or re-applied across different development needs or operating environments may be helpful to enhance interoperability and lower the cost of model construction.
- Enhancing safety and reliability are two key focus areas of Public Transport systems. It would be very useful if the simulation community could develop models that can enhance the safety and reliability of our public transport system.

3.4 Ideal Profile for Smart Nation

In SMRT, we seek to entrench a Kaizen culture that seeks to improve our thinking and processes all the time. This is the mindset and attitude that will enable a researcher or practitioner to pursue and achieve excellence. We also need people who have the dare and have convictions about the difference they can make, and work as a team. Other than domain expertise and technical skills, design thinking coupled with agile methodology would be helpful for the researcher or practitioner. We also need leaders who can feel the pulse of the nation to develop solutions where it matters most to our stakeholders. We need to be Doing Right, Doing Good, Doing Well.

4 ONG KIM PONG, PSA INTERNATIONAL

4.1 Contribution to the Smart Nation Initiative

PSA International (PSA) is a leading port group and trusted partner to cargo stakeholders. With flagship businesses in Singapore and Antwerp, PSA's global network encompasses over 50 locations in 26 countries around the world, including more than 60 deep sea, rail and inland terminals, as well as affiliated businesses in distriparks, warehouses, and marine services. Drawing on the deep expertise and experience of its diverse global team, PSA actively collaborates with its customers and partners to deliver world-class port services alongside, develop innovative cargo solutions and co-create an Internet of Logistics.

One of the key pillars of the Smart Nation initiative is the digital economy. PSA is one of the founders of SGTraDex, a digital infrastructure that facilitates trusted and secure sharing of data between supply chain ecosystem partners. This was formed in June 2021 as part of the Singapore Together Alliance for Action (AfA) on *Supply Chain Digitalisation*, which is a public-private partnership to examine how ecosystem players can participate meaningfully in the digital economy. It aims to co-create a supply chain future that is trusted, efficient and resilient. With this digital transformation, data connections can be made to a wide range of data contributors and users in Singapore and around the world.

To enable Singapore to achieve its Smart Nation goal, digital infrastructure has been identified as a key enabler for Singapore to build on its existing strengths in connectivity and trade. One such key initiative is

next-generation connectivity such as 5G. Since 2019, PSA has been collaborating with the Infocomm Media Development Authority (IMDA) to trial 5G solutions involving automated guided vehicles (AGVs) and rubber tyred gantry cranes (RTGs). The goal is to deploy up to 2,000 AGVs concurrently at Tuas Megaport, leveraging on the increased bandwidth and lower latency of the 5G network. Findings from the port trial will provide deep learning for future 5G deployments to a wider range of parties, including the government, service providers and various industries.

With increasing adoption and awareness of data and digitalisation both nationally and in the region, we imagine greater interconnectivity and enablement of more efficient public and private processes. This will lead to new possibilities and opportunities for various stakeholders to explore and potentially transform the way we live and work. Nevertheless, while technology can act as an enabler, cybersecurity and data privacy concerns are emerging areas that will require greater dialogue and consensus.

4.1.2 Digital initiatives to enhance regulatory efficiency

Developing an advanced digital infrastructure is also central to improving regulatory efficiency and facilitating timely information exchange and data flow among port users and stakeholders, locally and beyond the region. digitalPORT@SG streamlines vessel, immigration, and port health clearances across multiple agencies into a single application by consolidating 16 separate forms. Shipmasters and ship agents from more than 550 shipping companies can now submit, track and receive approval for arriving and departing ships through the portal. As a result, the industry can save up to 100,000 man-hours per year.

In the next phase, digitalPORT@SG will also facilitate just-in-time marine services such as bunkering and repairs, by providing port stakeholders with real-time information to better coordinate, plan and allocate resources. This not only enhances efficiency of port operations and reduce the turnaround time of ships, but also minimizes ships' idling time, which cuts greenhouse gas emissions from ships.

Beyond our shores, Singapore has also embarked on the digitalOCEAN initiative, partnering with key stakeholders to work on common data standards and application programming interfaces to exchange data with ports and shipping-related platforms, with the aim of improving efficiencies in port clearances. This should serve to reduce repetitive and manual completion of forms at ports along trade routes.

4.2 The Role of Simulation

Modelling captures key and significant features and relationships of real-life problems, putting them into a mathematical or computational representation. This allows us to analyse the model to gain insights, make predictions, and prescribe business decisions —all using well-established scientific methods. This capability is gaining importance and will be critical for companies to survive and thrive as the business landscape becomes more challenging in complexity and scale. More specific areas of modelling that PSA uses include:

4.2.1 Simulation models

Simulation is useful for us to generate counterfactual data under different scenarios that can be analysed to estimate the probability of various outcomes. We have used simulation as a predictive analytics tool to forecast the operational outcomes for future scenarios in making informed decisions. It plays a crucial role in decision-making in PSA for use cases such as:

- Design of facility layout and operating concepts for the development of greenfield container terminals, as well as expansion of existing terminals. Examples include Pasir Panjang Terminals and Tuas Megaport in Singapore as well as other PSA terminals overseas.
- Selection of container handling equipment types and their operating concepts for a given container terminal or container logistics facility.
- Design of terminal and facility road layout/junctions to minimize congestion and minimize carbon emissions.

- Tuning, evaluation, and testing of intelligent algorithms driving an automated container terminal.

4.2.2 Data analytics models

Data analytics models, applying statistical methods, including machine learning techniques on huge amounts of data, allow us to gain insights and to predict outcomes. Such predictions can guide decision makers in making informed decisions backed by data. Alternatively, these predictions can further be used by simulation or optimization to develop prescriptive solutions. Areas of application include container terminal operations and planning such as forecasting vessel arrivals and throughput, container handling activities, container yard storage, equipment failures and matching that to available berth, crane and yard capacity together with available manpower and resources, to deliver customer service quality while controlling costs.

Increasingly, supply chain efficiency and resilience are emerging business objectives, while energy consumption as well as carbon emissions are important ESG/sustainability goals, which will require data analytics to be optimized.

4.2.3 Optimization models

Optimization models, which are based on mathematics and algorithms, help us to generate optimal decisions, which are humanly impossible due to the millions of possible permutations. PSA has been utilising these models for more than 30 years, starting in the early 1990's. We have since been continuously improving and adding new models in new areas of decision-making.

Areas where optimization is utilised across various decision milestones in container terminal operations include strategic planning and subsequently operational decisions for liner allocation to minimise inter-terminal transfers, deciding quay crane working sequences, and real-time assignment of jobs to equipment such as prime movers and yard cranes. These have been carried out with the objective of reducing costs and increasing productivity, performance and capacity to maximise returns and improve customer satisfaction. We have also observed the application of optimization in newer areas of our business such as supply chain orchestration and logistics, as well as in areas of sustainability such as reduction of carbon footprint.

Moving forward, with the growing complexity of the business environment and as terminals become increasingly automated and grow in operational scale, there will be higher demand for optimization and more sophisticated methods.

Aside from traditional optimization techniques, optimization models that are adaptable and robust in face of uncertainties as well as those that have learned from or trained with data are taking shape. We see evolving methodologies of cross-integrating data analytics methods with traditional optimization algorithms, simulation with optimization, data analytics with simulation, and IOT integration of these models with streams of historical data. These areas have been gaining greater attention whereby we foresee great opportunities within this space.

4.3 Open Problems

Challenges that can be addressed include speed, cross integration, and ease of explanation. Drawing reference to the popular movie "Ironman," the lead character, Tony Stark, developed an AI system, J.A.R.V.I.S, which was able to compute and advise on the best course of action within seconds. In the real world, while simulation is capable of answering "what-if" questions and determine possible outcomes based on a given scenario, it may take some time for the speed of analysis to match or even surpass the speed of such fictional AI systems.

Taking it another step further, "what-if" only provides outcomes to a given scenario. However, what will be more useful will be "what-is" (the best), i.e., what is the best course of action that will result in the best simulated outcome. To achieve this, a methodology integrating cross-disciplinary techniques in data analytics, machine learning and optimization will be required.

Finally, once a best course of action is determined based on the simulated outcome, this should be able to be easily explained. This prevents the process from being a black box and provides an explanation of why the decided course of action was selected.

4.4 Ideal Profile for Smart Nation

For the Smart Nation initiative to succeed, we will not only need intelligent individuals, but will require them to work together as a team. Similar to team sports, every individual is vital for their strengths and capabilities, together coordinating and synergising their ideas, and contributing to the overall blueprint.

Researchers or practitioners should therefore not only possess deep capabilities within their respective areas, but at the same time have the breadth to look across and collaborate/integrate ideas with their peers. They should also sense the reality on the ground so that they are able to marry the elegance of well-researched theory with the imperfect reality to solve real-life problems in industry.

AUTHOR BIOGRAPHIES

KENNETH LIM is the Assistant Chief Executive (Industry & Transformation) at Maritime and Port Authority of Singapore (MPA), a rich and diverse ecosystem comprising over 170 international shipping groups and 5000 maritime establishments. Most recently, as the industry promoter and developer, his team launched the refreshed Sea Transport ITM for 2025, building on MPA's strategic long-term plans to develop Singapore's Next-Generation Port. Internally, he is MPA's Chief Transformation Officer ensuring MPA's focus on being digital to the core, talent-focused, resilient, and agile.

NGIEN HOON PING is the Group CEO and Executive Director of the SMRT Corporation. Mr Ngien was the CEO of FairPrice Group's Supply Chain Business from September 2020 to June 2022. Prior to that, Mr. Ngien served as the Chief Executive of the Land Transport Authority. An engineer by training and profession, Mr. Ngien holds an Electrical and Electronics Engineering degree from the University of Manchester, UK, and a Master of Science in Systems Engineering from the National University of Singapore. At NTUC, he implemented supply chain digitalization and process enhancements to boost the resilience of Singapore's food supply chain and ensured continuity of Singapore's food supply, especially during the Covid pandemic.

ONG KIM PONG is the Regional CEO of PSA Southeast Asia, PSA International, with the overall responsibility for PSA Group's portfolio of operating terminals, investments, and expansion in Southeast Asia. In addition to other appointments in the trade and maritime sector, he serves as the Chairman of CrimsonLogic and sits on the board of PSA's corporate venture capital arm, PSA unboXed, as part of PSA's technology and innovation transformation efforts.

ENVER YÜCESAN is professor of Operations Management at INSEAD. He has served as the Proceddings Co-Editor for WSC'02 and Program Chair for WSC'10. He was a member of the WSC Board of Directors as a representative of I-Sim over 2012 – 2020. He is has a degree in Industrial Engineering from Purdue University and a doctorate in Operations Research from Cornell University. His research is in the domain of simulation optimization and the analysis of agricultural supply chains. He has received the I-Sim Distinguished Service Award in 2015. He is an INFORMS Fellow.