TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 19
Number 4
December 2025

DOI: 10.12716/1001.19.04.21

Digital Twin Technology in Maritime: A MAAP Innovation Strategy

A. Baylon & E.M.R. Santos
Maritime Academy of Asia and the Pacific, Mariveles Bataan, Philippines

ABSTRACT: Following the fourth industrial revolution and recent advances in information and communication technologies, the digital twinning concept is attracting the attention of maritime academia and the maritime industry worldwide. A digital twin is a representation in digital form of a physical item, thing, or system: a vessel, a car, a wind turbine, a power grid, a pipeline, or equipment such as a thruster or an engine. One of the key initiatives at the MAAP is to apply Digital Twin technology in the development of MASS (Maritime Autonomous Surface Ship), e-navigation, ship engine room management, training, and validation of operational concepts associated with smart and autonomous ships. To this end, the progress realized in adapting and exploring digital twin (DT) technologies at MAAP will be presented. In particular, the Kognitwin technology system (a Digital Twin system) developed by Kongsberg Maritime and other systems applicable to decision-making that ensure cost-effective, safer, and sustainable operations will be described. The focus will be placed on using digital twin technology in some of the grey areas: Optimization of Fleet with Virtual Transition of Ship Control System, Enhancing the Port and Terminal Operations, Awareness Situation about Operational Parameters, End-To-End Supply Chain Optimization, Amplified Security Ensuring Safety and Better vessel design and operation.

1 INTRODUCTION

The advent of Automation in Maritime Surface Ships (MASS), the rapid adoption of big data, The Internet of Things (IoT), and artificial intelligence have caused developmental leaps and novel paradigm changes in the maritime industry.

AMOSUP, as the significant labor supply union for the international fleet, has to ensure that its current and prospective members/seafarers are abreast with modern development. In contrast, prospective members/cadets should be well grounded on the fundamental principles of the fourth industrial revolution. They can manifest competence in working at the operational level onboard automated ships or ashore, supporting operating such ships.

MAAP, in the furtherance of its vision, mission, goals, and objectives, is providing the requirements of AMOSUP by pursuing a relevant, dynamic, and relentless innovation strategy in order to ensure its lead in the world's maritime labor supply market and also create a niche for competent Filipino Merchant marine Professionals.

As a leading institution in maritime education and training, MAAP cannot sit on its "laurels," conduct "usual business," or even hope to go back to the "old normal." Given the tight competition with other labor supply countries vying for the diminishing seafaring jobs aboard a ship, MAAP has to anticipate and understand the changes in the industry, adapt to the new models and processes, and prepare for the implementation of new methods/equipment/courses through collaboration with the industry and cooperation within the Academy.

The digital twinning concept is one of the recent advances in information and communication technologies, attracting the attention of maritime academia and the maritime industry worldwide. A digital twin is a representation in digital form of a physical item, thing, or system: a vessel, a car, a wind turbine, a power grid, a pipeline, or equipment such as a thruster or an engine. One of the key initiatives at the MAAP is to apply Digital Twin technology in the development of MASS (Maritime Autonomous Surface Ship), e-navigation, ship engine room management, training, and validation of operational concepts associated with intelligent and autonomous ships. To this end, MAAP partners with Kongsberg Digital to explore and realize the adoption of digital twin (DT) technologies at MAAP, particularly the Kognitwin technology system (a Digital Twin system) developed by Kongsberg Maritime along with other systems applicable to decision-making to ensure cost-effective, safer and sustainable operations. The focus will be placed on using digital twin technology in some of the grey areas: Fleet Optimization with Virtual Transition of Ship Control System, Enhancing the Port and Terminal Operations, Awareness Situation concerning Operational Parameters, End-To-End Supply Chain Optimization, Amplified Security Ensuring Safety and Better vessel design and operation. This paper also presents the significant basics of digital twinning followed by in what way it may improve the decision-making of MAAP for the maritime sector, such as ports and others in the shipping ecosystem, and in developing standards that will support the integration of transport supply chain operations and the optimization of digital twins for operational enhancement and strategic planning.

2 METHODOLOGY

This paper utilized descriptive research using the following data collection methods: observation, interview, internet, literature searches, and content analysis.

3 FINDINGS AND DISCUSSIONS

3.1 *Decision Making based on models*

Decision-making is the central activity of all organizations, and decision-makers use causal models and decide based on the effects of the interventions. Decision-making is typically improved by openly sharing decision models with others and then calibrating the data from the vast and growing Internet of Things (IoT). The quality of data (real-time data for model building and reality assessment) used for calibration will determine the value of the decision model. The problem with interventions is that some do not work and might harm the subjects, such as infrastructural investments for a port below the intended return. The most rigorous approach to decision-making is to build a high-fidelity mathematical model, or digital twin, of the concerned environment and to simulate varied interventions and exploration of counterfactuals, such as what if we did A instead of B.

What is good about having models is that they do not physically harm people or the environment. Instead, models provide a theoretical foundation for decision-making for future sustainable maritime business operations. There are three methods or techniques. One is to build a theory from data. Second, to test a theory by building a theory in one or more real settings through interventions. Third, to test a theory several times using a digital twin to simulate many probable settings is best because it is safer and most effective.

Digital twins require building a detailed set of equations for each component in the model and the collaboration of these components. Data are needed in the operation and will be calibrated. Once the digital transformation proceeds, the required data needed to calibrate digital twins of the various components of a ship, including elements of the transport infrastructure, like the goods being transported, will be created. In the maritime sector, "emerging opportunities exist to digitally represent and simulate objects and events prior to decision-making" [1].

As more devices are linked, such as innovative MAAP training vessels with data generated by different routine or procedure cases (e.g., completed transport time, deviation signals, and organization operation associated with vessel activities and processes) [2]. Digital data streams built upon shared standardized data will provide opportunities for real-time representation and simulation of realistic situations. The Digital twins will displace simulation models because of the improved representation of the physical world and the recalibration via digital data streams to local conditions.

3.2 *Digital Twins*

A digital twin is a replica in digital form of a living or non-living physical entity. Data is provided by combining the physical and the virtual world, enabling the virtual entity to exist simultaneously as the physical entity. Digital Twins presents a virtual model of a physical ship, producing valuable insights from data. A digital twin duplicates physical items that can be utilized for varied purposes. This digital representation shows how an Internet of Things (IoT) device works and lives throughout its life cycle. There is no need for a physical test cycle because the processes are presented digitally,

A digital twin represents a physical model in the form of a digital. By joining the simulated physical and virtual worlds, one can analyze the data and monitor the system, avoiding unwanted results, decreasing downtime, finding opportunities, and being ready for the future. The digital twin's technology has advanced to handle more items like buildings, machinery, and even vessels, and perhaps in the future, would include people having their digital twins, further broadening the idea. The technology can modernize and optimize shipbuilding or highly specialized systems requiring continual inspection and repair. Digital twin technology, including manufacturing, can alter virtually any organization's companies and objects.

The digital twin integrates all data and simulations obtained during the subject's lifespan. Theoretically, unlimited processes can be accomplished within the digital twin environment.

A digital twin is a representation in a digital form of an item or a system that describes its characteristics and properties as a set of equations. It uniquely describes a person, product, or environment's key characteristics and properties in a binary format and can be made in one or more physical or digital spaces (2). Complex processes involving many actors challenge decision-making environments best modeled digitally before action. A digital twin includes the hardware to gather and analyze data and the use of software for data representation and manipulation. Digital twins are more powerful than simulations and models because they control digital data streams to extend across the obstacles between the physical object and its principal. Digital twin analytics depend on historical data and real-time digital data streams (e.g., IoT-generated data to analyze possible outcomes (Figure 1). A digital twin is a generic situation model that can be customized to a specific situation by specifying relevant parameters to answer "what develops if …" or "what develops if this does not …" to support decision-making.

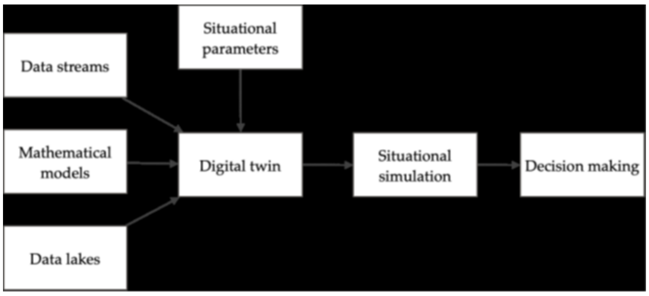

Figure 1. The compositions of a digital twin [1]

A digital twin is a representation in digital form of physical items, things, or systems: a vessel, a vehicle, a wind turbine, a power grid, a pipeline, or equipment such as a thruster or an engine. It can contain various digital models and collections of information and processes related to this object. By integrating real-time digital data streams, a digital twin can be continuously calibrated through its entire lifecycle (3). This means that a model can be continually refined to converge to a very high-fidelity model of reality.

3.3 *Standards to Support Digital Twins*

Traditionally, data modeling is used to come up to the surface of the center composition within a standard and to safeguard compatibility across standards. This has been followed by efforts to define standardized interfaces for communication, so-called APIs (Application Protocol Interfaces). It is accepted that data have two roles: processing the transaction and analyzing the data; both are done by digital twin technology. Hence, standardized digital data streams using standardized APIs must support a digital twin. There is a need to redesign business processes to support the generation of IoT-derived data necessary for digital twin creation and operation to become powerful tools for risk management analysis, mitigation, and effective decision-making aids. Standardization bodies like UN/CEFACT, GS1, WCO, and DCSA have developed varied building blocks like the Smart Container data model of UN/CEFACT and the connectivity infrastructure of DCSA IoT. Extra standards are still needed to prepare for the era of the digital twins. Standards must serve both today's transactions and the digital twins of the future.

3.4 *Importance of Digital Twins*

A digital twin can simulate the ship's performance without testing it in the real world. This concept also allows access to every bit of ship information, from engine performance to hull integrity, available at a glance throughout the whole lifetime of the vessel. During operation, using a virtual model, such as the digital twin, provides an excellent opportunity to visualize all essential components, conduct analyses, and improve the operation of a ship's structural and functional components. Using digital twins, operators can plan for preventive measures, avoid damages, and perform better inspections, maintenance, and evaluation of the ship's performance. Operators can develop a ship's visual models and intrinsic systems, such as engine specifications, and continuously record its fuel consumption, distributed on energy sources like boilers, engines, and batteries. Other results could be simulation and analytical models prepared to generate the maximum fuel consumption for a trip with a particular cargo, including external factors like wind, current, and weather conditions. Some areas for potential improvements that a digital twin can calculate are:

- Optimal operation of machinery systems
- Optimal retrofit of batteries, more efficient thrusters, bulbs, and others
- Clean-performing hull or propeller
- Verify ship performance on a detailed level.
- Visualize the effect of design choices and changes.
- Benchmark performance towards other ves-sels in the fleet.

3.5 *Kongsberg Maritime and Kognitwin*

Kongsberg Maritime is a Norwegian technology enterprise within the Kongsberg Gruppen. Kongsberg Maritime delivers positioning, surveying, navigation, and automation systems to merchant vessels and offshore installations. Kongsberg is digitalizing the world's industries, generating exceptional impact and value with partners to create a better tomorrow for people, businesses, and society. Understanding the vessel will allow its partners to unravel the value of its data simply and cost-effectively – hence providing a competitive edge in the fast-paced digital world. Digital Twin will provide their partners instant and easy access to fleet overviews, vessel-specific dashboards, and analysis tools.

So, how does the digital twin work? The digital twin connects the physical and virtual digital worlds. First, smart components utilize sensors to gather data about real-time status, working conditions, or positions combined within a physical thing. These components are linked to a cloud-based system that gathers and analyses all the data. Innovative technology provides the lessons gained while opportunities are shown within the digital environment. The opportunities can then be applied to the physical world.

The SaaS-based solution provides vessel-to-cloud data infrastructure, capturing and aggregating quality data cost-effectively and securely. The cherry on top is that Konsberg Clients or partners have access to Kognifai Marketplace, granting access to extensive applications and services that can turn their data into business value. Access to all real-time data from the oil and gas asset in one place through a simple virtual interface called Kognitwin® provides visualization, simulations, and physics-based models, helping clients or partners make better decisions to ensure safer, cost-efficient, and sustainable operations. The tool prevents unwanted future events and explores and finds the best asset settings for better efficacy. Indeed, Kognitwin®, a dynamic digital twin, is a core enabler for the digitalization of oil and gas assets.

3.6 *Maritime Academy of Asia and the Pacific Innovation initiatives*

MAAP activated an Innovation Projects Office (IPO) directly under the Office of the President, with graduates of doctorates and masters from World Maritime University and other foreign universities; members of the Quality Improvement Team, Thought Leaders from ACAD, MIITD, MSC, and 3D printing office and other persons designated by the President. The IPO is s tasked to undertake activities to:

1. Increase awareness of the situation in the commercial maritime domain to validate clients' needs and requirements and be up-dated on the industry's technological and human element demands.
2. Conduct research and focus group discus-sions with maritime industry practitioners and academics to develop pioneering courses of action for MAAP.
3. Conduct further studies to prepare a priori-ty list of relevant, suitable, flexible, and timely measures MAAP should take to en-hance innovative thinking, methods, new courses, and facilities. All projects should be research-based with long-term signifi-cant benefits to the Academy.
4. Shepherd the initial implementation of the projects and monitor their effectiveness and efficiency in their early stages before turn-ing them over to departments.
5. Conduct post-project reviews to fine-tune project implementation and assess the out-come.

The overall objective of IPO is to enhance MAAP's prime position in education and training in developing its midshipmen/trainees using innovative methods to ensure the provision of a continuing stream of highly employable officers in the international merchant fleet. In addition to being technically and academically competent, Officers must have soft skills and leadership traits necessary in their operational and leadership roles in the maritime industry.

For MAAP, the digital twins will act as a platform for training that will increase MAAP students' understanding of the whole vessel and train them to think about the system so they can see the integrated consequences of actions taken. In addition to maritime education and training, the digital twins will also offer a platform for research and development in various technological disciplines as it increases understanding of the system and facilitates knowledge exchange. Digital twins will also prepare MAAP students for future maritime industry roles.

- Deliver a tool for visualizing vessels and sub-systems, qualifications and analytics of opera-tional data, optimization of the vessel perfor-mance, improved internal and external com-munication, safe handling of increased auton-omy, and safe decommissioning.
- Provide a tool to enhance the system's integra-tion, apply technology performance, perform a quality assurance system, and provide needed services for monitoring and maintenance.
- Offer a systematic model that can be set up with applications to feed live information and gather required reports from each ship. This ensures higher-quality reporting on critical is-sues without burdening the crew.

Because digital twins require specialized consultancy services, MAAP partners with Kongsberg (Figure 2) so that MAAP can accelerate its students and trainees (seafarers) the digital twin's concept, like the state-of-the-art requirements and standards for model exchange and handling of large-scale data.

Figure 2. MOU Signed between MAAP and Kongsberg Digital

MAAP Philippines (President Vadm Eduardo Ma R Santos, AFP (Ret)) signed Key Simulation Contract with Kongsberg Digital (KDI Sr. Vice President for Maritime Simulation Morten Hasaas). MAAP has been a first adopter of new simulation-based training tools for several years. Through the partnership, Kongsberg Digital will deliver a range of maritime simulators to the newly established Innovation Laboratory of MAAP (Figure 3). Kongsberg Digital's simulator systems are critical to the future-oriented MAAP Innovation laboratory that will boost a large-scale of K-Sim products, strengthening the position of MAAP as a regional institution of innovation and excellence for maritime education and training. The agreement consists of a Long-Term System Support Program (LTSSP), which consists of the commitment of Kongsberg Digitals to delivering cutting-edge maritime simulators for MAAP's Innovation Laboratory with emphasis on Digital Twin Engine Simulator, Celestial Navigation Simulator, Shore Control, Remote Control Center, and MASS (maritime autonomous surface ship) technologies. The partnership will enable MAAP to enhance training and assessment, conduct advanced research, and validate operational concepts like smart and autonomous ships.

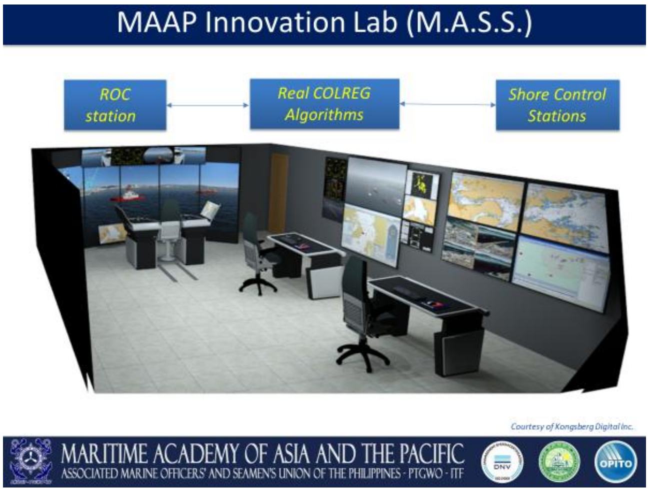

Figure 3. MAAP Innovation Laboratory

Figure 4. MAAP Lecture Series and Course Development

As part of the MAAP Digital Twin initiative, Kongsberg Digital's Vessel Acumen will be installed on MAAP's training ship. This will provide MAAP's students with a leading role with first-hand experience in capturing vessel-to-cloud data infrastructure and allowing them to analyze data of the vessel over time. The installation of a brand-new celestial navigation simulator system allows instructors to provide trainee officers with hands-on experience in a safe, controlled, and realistic environment, meeting the standards in the STCW requirements. Kongsberg Digital will deliver new consoles for MAAP's existing K-Sim Navigation bridge simulators and a mid-life upgrade of its motion platform, including four class-B K-Sim Engine room simulators. This will extend and complete MAAP's wide range of existing K-Sim simulators covering various training purposes, like ship handling/navigation, engine room management, cargo handling, and advanced firefighting simulator system. [4]

As a prime adopter of the new digital technology in 2019, MAAP started using Kongsberg Digital's K-Sim Connect platform for cloud-based simulation training to complement classroom education. Since then, the cloud-based K-Sim Engine training applications have allowed the Academy's students to practice and prepare for MAAP exams anytime, anywhere, and at their own pace. Kongsberg Digital will soon promote its latest addition to the organization's cloud-based simulation portfolio, the K-Sim Navigation, including delivering this brand-new training application. MAAP is one of the first training centers worldwide to use an inspiring, innovative digital twin initiative for blended learning. MAAP also conducts lecture series and course developments on MAAP and Digital Twin Project, including Green Shipping, Robotics, and Risk Management in Maritime Cybersecurity as part of MAAP Innovation and Knowledge Center (Figure 4).

Although MAAP is a leading higher educational institution for maritime education and training excellence in the Asia-Pacific region, the worlds of maritime training and simulation always stand firm. The longstanding relationship of MAAP with Kongsberg Digital has constantly prepared MAAP to retain its position as a pioneer in using new simulation-based training tools. MAAP, as an early adopter of digital twins in the Philippines, would be able to train its students to make some optimization decisions digitally rather than through physical tests, and this development will increase along with the introduction of digital tools. The partnership shall explore the enormous abilities of "digital twins" for the way forward.

Create a digital platform for the use of the vessel. A digital copy of the MAAP vessel will enable MAAP to improve the vessel's design, maintenance, production, and sustainability. An Open Simulation Platform (OSP) will eventually be coursed through with a simulated ship and a dynamic position system, performing a dynamic positioning operation. (Figure 5). Other MAAP partners invited to participate in the project will create a platform open to others to exchange information and store simulated ships, systems, and equipment. An open simulation project (OSP) with potential partners would result in a joint maritime industry project establishing a maritime industry standard for models and system simulation. The standard will allow organizations to reuse simulation models and construct digital twins of existing and future vessels for safety and cost-effectiveness. The model will use cloud technology to facilitate teams in enhancing system design and vessel performance, verifying correct handling of failures within the vessel's automated positioning system's control system, and verifying system changes and the operational impact. MAAP will first use this tool to create a digital twin to determine the MAAP vessel's capacity and propulsion system modules and their integration in a virtual setup.

Establish autonomous ships for a variety of operations. A Digital Twin of an MAAP ship project (Figure 6) will be developed that will simulate ship behavior to help optimize ship operations using data analytics and visualization tools. Kongsberg will provide expertise in coupled physical-numerical modeling and simulation to evolve solutions that improve the predictability and control of the behavior and response of the ship.

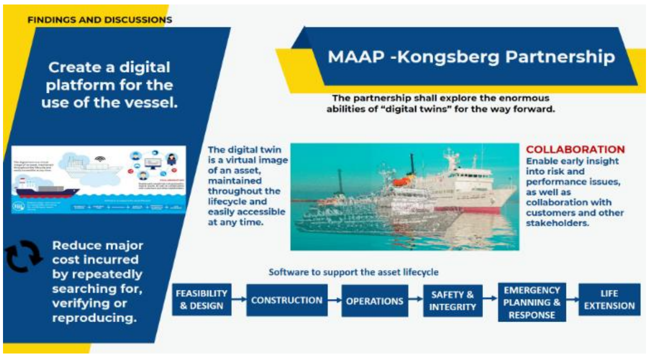

Figure 5. Open Simulation Digital Platform for Collaboration

Figure 6. MAAP Digital Twin

Indeed, the contract signed manifests a severe commitment of MAAP to pioneering new simulation-based training tools and cloud-based solutions, investing and demonstrating severe intent regarding seafarers' future education and training.

3.7 *MAAP Use of Digital Twins in the Future*

MAAP acknowledges the use of Digital Twins in the future as an opportunity for maritime sector improvement. Using Digital twins to predict probable hazards and make the best plan will significantly boost safety and operation. The digital twin concept can help the maritime industry better use digitalization and move to a new era. Five areas will likely benefit from digital twins: fleet optimization, port and terminal optimization, end-to-end supply chain optimization, situational awareness optimization, and security optimization to ensure safety.

3.7.1 *Optimization of the Fleets*

Typically, a shipping company serves multiple clients simultaneously, and clients may utilize varied maritime companies simultaneously. Hence, a maritime company needs to maintain and gain competitiveness by improving its fleet in terms of ships and their cargo-carrying capacity. A digital twin could serve this need for sensitivity analysis based on historical data, ongoing, and predictions of transactions. The digital twin could form the basis of strategic decision-making by testing various scenarios for trade patterns and shipping fleets. Furthermore, a digital twin for fleet optimization could improve operational decision-making under diverse contextual factors, such as weather conditions that create a typical situation and various options that need to be rapidly reviewed.

3.7.2 *Optimization of Ports and Terminals*

The efficiency of the port relies on balancing demand and supply flexibly and integration within the entire transport system. [5] A port depends on a continual in and outflow of cargo and passengers arriving and departing through various transportation means. The port and its partners must capture continuous historical and projected future trade in a digital twin for strategic planning. A model should integrate various parameters and relationships that the decision-makers may include in their strategic planning and decisions, like investment in infrastructure, port design, and terminal capacity. A digital twin with multiple data streams of historical databases and real-time data is also an operational planning tool for coordinating and synchronizing port operations [6] that may provide information like the number of berths needed for the ports to meet target time goals or yard space to allow different customers to store cargo as it moves between transport services. It could be used to formulate a virtual arrival system, understand green steaming [7], and enhance the use of infrastructure transportation for diverse needs.

3.7.3 *Optimization of Situational awareness*

Transport buyers, cargo owners, and customers wanted improvements in the visibility and predictability of the transportation of goods from their origin to the final destination. It is crucial to consider a parallel connection of significant digital twins. Repercussions of a delay in one stage can be analyzed, adjusted, and updated. Digital twins are a tool to investigate coordinated infrastructure investments and developments across a web of ports that interact so that crucial stakeholders will also gain long-term situational awareness. This allows them to jointly make decisions to serve the mutual goals of the ecosystem, like minimizing port emissions. There is a need to build and use high-fidelity models of that world to enable people to perceive and understand the present and future state of a complex interacting world. This exercise will enhance situational awareness for these groups.

3.7.4 *Optimization of the container flows in the end-to-end supply chain*

Smart containers supporting IoT connectivity standards have been introduced [8]. As explained earlier, innovative container data streams are essential for optimizing fleet, port, terminal, and situational awareness. Containers that pass through several transportation hubs are managed by different carriers (of the same and different types) in the end-to-end supply chain. The data generated by connected containers is a precious source of data for digital twins, whether retrieved from a data lake or handled as a data stream in real-time because they provide transport buyers and coordinators opportunities to optimize the transport mode and route for serving their clients. This strengthens the strategic relationship with transport producers (carriers and transshipment hubs). Moreover, a digital twin will serve as the foundation for enhancing the flow of empty containers, and these connected containers are an electronic necessity for "smart" supply chains [9] and a significant building block for digital twins of supply chains.

3.7.5 *Optimization of Security Ensuring Safety*

Several companies and societies, like DNV-GL and Mitsui OSK Lines, have seen profit in this innovation and invested their time and resources to establish the maritime sector's digital twin. Digital twins will satisfy the needs of the maritime industry, given that collaboration among research societies and companies prevails. Digital twins are built upon general mathematical depictions of several components.

4 CONCLUSIONS AND RECOMMENDATIONS

There is no doubt that the digital twin is the future. Predicting potential dangers and creating the optimum design will significantly enhance safety and operation. The digital twin concept can help MAAP better use digitalization and move to a new era. Moreover, standardized digital models of all components in the shipping industry are the next wave of standardization if the maritime industry is to achieve higher levels of capital productivity through analytics-based operational and strategic decision-making. All components' physical instances need embedded sensors that generate a standardized data stream to calibrate their associated digital model. MAAP, through Digital twins, can guide current operations and future needs to allow the maritime sector to cooperate and standardize digital data streams and models of digital components, contributing to the realization of the MAAP Innovation Strategy. [10]

REFERENCES

[1] Lind,M., Becha, H., Watson R., Kouwenhoven,N., Zuesongdham,P. & Baldauf U, (2022) .Digital Twins for the Maritime Sector. Working paper. Research Institutes of Sweden (RISE), UN/CEFACT, University of Georgia, IBM, and Hamburg Port Authority

[2] Pigni, F., Watson, R. T., & Piccoli, G. (2021). Digi-tal Twins: Representing the Future. Working pa-per. University of Georgia

[3] Safety4Sea (2019) The Digital Twin Concept Ex-plained taken at https://safety4sea.com/cm-the-digital-twin-concept-explained / accessed on August 13, 2023

[4] Maritime Executive (2022). MAAP and Kongs-berg Digital Sign Key Simulation Contract taken at https://maritime-executive.com/corporate/maap-and-kongsberg-digital-sign-key-simulation-contract and at https://marsim.kongsbergdigital.com/products/kognitwin / both accessed on August 8, 2023

[5] Becha H., Lind M., Simha A., Bottin F. (2020). Smart ports: On the move to becoming global lo-gistics information exchange hubs, Smart Mari-time Network, 20/4-2020 (https://smartmaritimenetwork.com/2020/04/20/smart-ports-on-the-move-to-become-global-logistics-information-exchange-hubs/)accessed on July 28, 2023

[6] Lind M., Bjørn-Andersen N., Ward R., Watson R.T., Bergmann M., Andersen T. (2018). Syn-chronization for Port Effectiveness, Ed. 79, pp. 82–84, Port Technology Journal (http://www.porttechnology.org) accessed on Ju-ly 31, 2023

[7] Watson R.T., Holm H., Lind M. (2015). Green Steaming: A Methodology for Estimating Carbon Emissions Avoided, Thirty Sixth International Conference on Information Systems, Fort Worth 2015. https://dcsa.org/dcsa-establishes-iot-standards-for-container-connectivity / accessed on August 1, 2023

[8] Becha H., Frazier T., Voorspuij J, and Schröder M., (2020). Standardized Container IoT is Key for "Smart" Supply Chains, The Maritime Executive, 27/05-2020

[9] Becha, Hanane (2020 May 27). Standardized IOT for Containers in the key for smart supply chains. https://www.maritime-executive.com/editorials/standardized-iot-for-containers-is-the-key-for-smart-supply-chains-1 accessed on August 5, 2023

[10] Santos, Eduardo Ma (2021). MAAP Innovation Strategy: It's background, objective, concept of implementation, organization and administra-tion support, 3-page unpublished paper and PowerPoint briefing presentation.