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***Abstract*—With the pressure to achieve Net-Zero targets and decarbonisation, smart asset solutions are becoming urgently required to manage assets and resources more efficiently and sustainably. This paper showcases work-in-progress from a collaborative research project between MJM Marine Ltd. and Ulster University in the development of a Marine Digital Twinning Platform (MDTP) for the optimisation of marine outfitting.**

***Index Terms*—digital-twin, marine outfitting, BIM, process optimization**

I. Introduction

Marine outfitting is a specialized construction activity that is subject to SOLAS regulations (Safety of Life at Sea) [1]. While the value-add work tasks involved in marine outfitting are similar in nature to general construction outfitting activities, SOLAS regulations require expertise in material selection and process design for installation. Outfitting activities do not affect the structural integrity of the vessel but do involve all mechanical and electrical elements, fire classification of bulkheads through dry lining, and surface finishes.

Marine construction projects are complex undertakings that require diligent planning and effective project management. Some of the primary challenges that need to be addressed for such projects to succeed include coordinating design with multiple trades; managing the logistics of material and labour movements; collaborating with the project's architect to develop concepts; scheduling work using a box labour profile; evaluating the cost of work; accurately reporting progress and optimizing labour usage. Overcoming these challenges demands a multidisciplinary approach that involves the expertise of various professionals, including designers, engineers, architects, project managers, and contractors. By addressing these challenges effectively, marine construction projects can be completed efficiently and safely while meeting all necessary regulations and standards.

Digitalisation in the UK Architecture Engineering and Construction (AEC) sector has been rapidly adopted over the last two decades. This journey started to gain momentum when Building Information Modelling (BIM) was mandated to be used in public projects since 2016 [2] as per the implementation of the 2011 UK Government Construction Strategy. As evidenced in Motawa [3], the adoption of BIM with its interoperability features and the capability of intelligent relationships between the elements in the building model has shown great benefits to the industry such as: facilitating information sharing and reusability, visualization, design simulation, resolving conflicts, improved production quality and sequencing, and faster and more effective processes. However, despite the fact that the adoption of BIM has helped in providing advanced tools for more efficient management of the design and construction processes, it was not enough to provide solutions that require real-time data capture and manipulation over the life cycle of assets. Therefore, the Digital Twin (DT) concept and technologies have emerged to bridge this gap. As shown in Opoku et al. [4] in their 2022 systematic review, DTs have the capability to integrate various asset models in a way to

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interact with the physical asset during all development and operation phases. In this regard, high quality and secure data is required to improve the efficiency of asset design/operation and bring sustainable savings for stakeholders, ensure societal benefits, and generate less waste to the environment. BIM and DT have the potential to serve other industries too such as the proposed approach presented in this paper for the optimisation of Marine Outfitting.

II. Aim of Paper

This paper showcases original and innovative work-in-progress on the development of a Digital Twin for the Marine Sector in relation to the interior outfitting / refitting of Cruise Ships. This work is a collaborative R&D project funded under the auspices of Innovate UK's Knowledge Transfer Partnership (KTP) programme between MJM Marine Ltd. and the School of Computing and the School of the Built Environment at Ulster University.

III. Related Research

A number of papers outline the potential for and application of digital twinning in the maritime industry and shipbuilding. In 2020, Arrichiello and Gualeni [5] highlighted that marine industry's awareness towards digital twin models is continuously increasing. In this work, authors examine the benefits derived from a digital twin model, which are not only able to help engineers to anticipate key problems in the ship, but its long-term value is even greater, being useful in different phases of the ship's life. Despite its benefits, it is crucial to recognize the challenges of implementing digital twins in the industry including the likes of, design, computer power, IP protection, and maintenance.

Giering and Dyck [6] discuss various Digital Twin applications across the lifecycle. Digital twinning applications can be used for operational purposes or to, perhaps, virtually stress test aspects of the ship. Work by Miličević et al. [7] uses QR markers and Unity 3D to implement augmented reality to essentially merge reality with CAD models, providing feedback to help ship outfitting during its construction. This system aims to facilitate fast interexchange of data and information between all the parts involved in the building process.

Kunkera et al. [8] discuss the significance of 3D-modelling (i.e., having a Digital Twin) to enhance maritime industry competitiveness. They showed that the use of a Digital Twin can improve the project productivity by 20%, allowing up to 70% of ship outfitting to take place in the early stages of construction, resulting in a 20% reduction of energy consumption and decreasing the injury rate by over 40%. There was also a significant decrease in the number errors during assembly activities.

IV. Methodological Approach

The ideal approach for MJM's project delivery was the adoption of an agile methodology with a sequential thread of events to complete the refurbishment of any marine vessel space. The digital twin model should be initiated from the early stage of the project lifecycle, such as during tendering for cost modelling and programming, and then proceed to concept development, project execution, planning, and finally handover to the owner for maintenance. This ensures a comprehensive approach to project management, enabling effective coordination and optimization of resources throughout the project lifecycle.

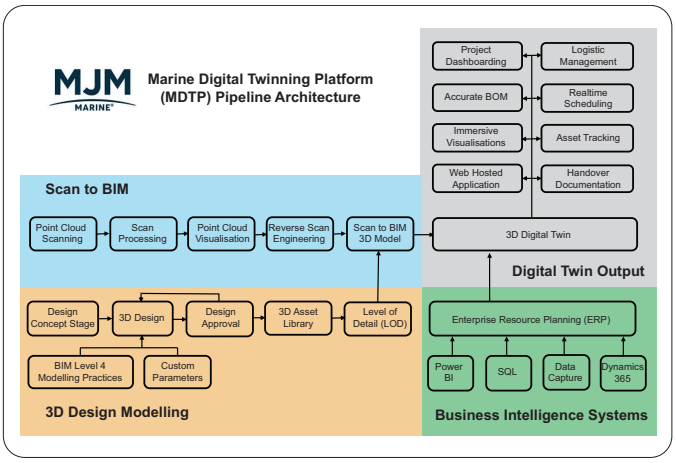

Fig. 1. Marine Digital Twinning Pipeline Architecture for the Optimisation of Marine Outfitting

Fig. 1 illustrates the digital pipeline that utilizes Scan to BIM technologies to create an accurate 3D digital twin representation of a physical area. The process involves using laser scanning cameras to capture high-resolution scans of the physical area. These cameras emit laser beams that bounce off surfaces in the area and return to the camera, creating a point cloud.

Next, the point cloud data is processed using specialized software to remove noise and merge overlapping points. The result is a highly precise and accurate 3D model of the physical area. The 3D model can be used to redesign and optimize the space, making changes and adjustments to improve efficiency, functionality, and aesthetics. It can also be used to visualize how changes will impact the space, allowing for better decision-making during the design process.

The resulting digital twin can be integrated with business intelligence systems, providing valuable data analysis, asset tracking, and other insights. This integration can allow for the real-time monitoring of assets, resources, and personnel during the construction process. Furthermore, the digital twin can be viewed and shared through immersive reality devices, live documentation, dashboarding, and web-hosted model access, enabling stakeholders, clients, and project teams to view and interact with the digital twin, providing a better understanding of the physical area and the construction process.

The Scan to BIM process involves the use of 3D laser scanning technology to capture precise and comprehensive information about a building or structure. This data, in the form of point clouds, is crucial for the creation of a detailed and accurate 3D digital model of the environment, using 3D

Fig. 2. Scanned Point Cloud

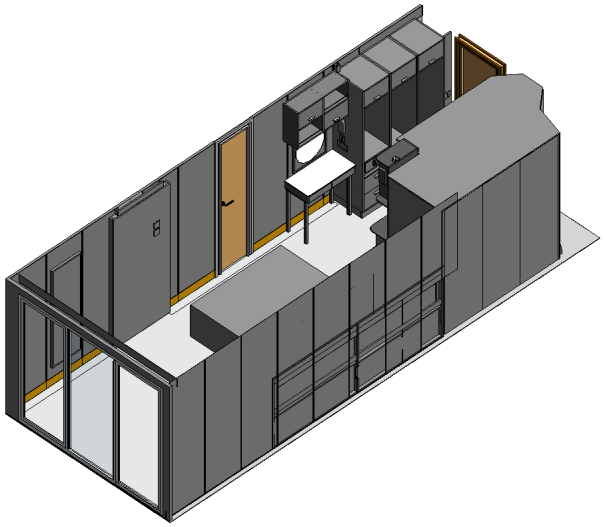

Fig. 3. 3D Parametric Model

Fig. 4. Final Refitted Cabin

modelling design software. In addition, the creation of 3D digital assets with intelligence that includes custom parameters, and integration with business intelligence systems, enables the development of a powerful digital twin asset throughout the project's lifecycle. This approach facilitates the accurate management of materials, on-site logistics, scheduling, and asset tracking, through the deployment of project progress dashboards.

Figures 2, 3 and 4 provide an in-depth comparison between the as-designed and as-built phases of a project. Fig. 2 exhibits the initial laser scan data of a cabin during the project survey. Fig. 3 showcases the 3D parametric model generated using CAD packages, 3D asset libraries, and custom parameters. Fig. 4 displays the final output of the completed cabin during project delivery.

Overall, the Scan to BIM process enables the creation of a robust digital asset that can be leveraged throughout the lifecycle of the project, improving project efficiency and reducing the risk of errors.

The S.W.O.T. Analysis presented in Fig. 5 highlights the Strengths, Weaknesses, Opportunities and Threats of the Digital Twin Approach to Marine Outfitting.

V. Discussion and Future Work

With the Scan to BIM process in place, the next phase of this collaborative project will integrate this workflow with the company's Enterprise Resource Planning (ERP) system. Integrating digital twin technology with an ERP system can be a valuable tool for businesses and a driving force behind Industry 4.0 solutions. This integration provides a real-time, comprehensive view of operations through a virtual replica of physical assets, systems, or processes that can be used for modelling, simulation, and analysis.

The link between the virtual model and the ERP system enables companies to gain insight into the entire value chain, from procurement to construction to maintenance and operations. As a result, this integration can lead to better coordination and optimization of the marine construction process,

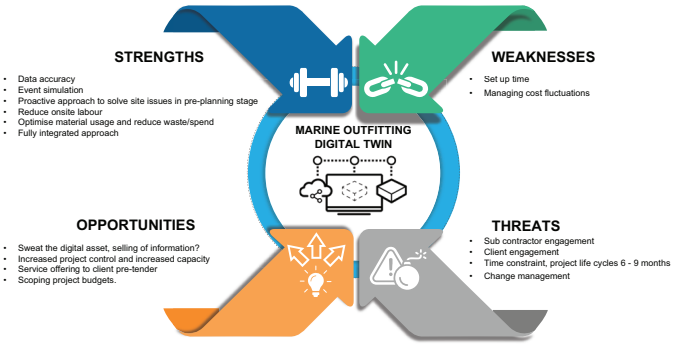

Fig. 5. S.W.O.T. Analysis of Digital Twinning Approach for Marine Outfitting

including improved scheduling and resource allocation and better decision-making through data analysis.

Once this ERP integration is complete, the core Marine Digital Twin Platform (MDTP) will be in place. Further work already in planning involves the integration of Discrete Event Simulation (DES). DES is a powerful computer-based technique that models and simulates systems with a sequence of events. In marine construction, DES is a valuable tool that helps designers simulate different scenarios, evaluate project aspects, and optimize designs for functional and efficient spaces. By modelling complex systems, DES enables a better understanding of variable interactions, allowing for more informed decisions and reducing time on site. DES can be used for various tasks in construction, including scheduling, resource allocation, and productivity enhancement, improving project efficiency and effectiveness. Simulation models are also used for traffic flow, occupancy analysis, energy efficiency, and emergency response planning, enabling designers to optimize designs before implementation and creating safer, more efficient spaces throughout the lifecycle of construction projects.

VI. Conclusion

In summary, the creation of an accurate digital twin representation of a physical area using Scan to BIM technologies offers significant advantages in the construction process, allowing for more efficient design, planning, and management of marine outfitting. Construction managers can use the digital twin to simulate various scenarios and test different solutions, providing a dynamic representation of the physical asset. Additionally, this integration enables more accurate cost tracking and management, as well as better risk management.

Overall, integrating an ERP with a digital twin can improve construction project efficiency, reduce costs, and enhance quality control. It can also foster better collaboration and communication among team members, leading to more effective teamwork in achieving project goals.

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