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# Sustaining And Managing Ships' Historical Data Through Digital Twin Alternatives

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**Abstract:** This paper outlines the views for sustaining and managing floating structure information, exclusively in dealing with hull integrity through digital model (DM) and digital shadow (DS). The gains of utilising DM and DS are highlighted, covering the economic cost of development, operating and maintenance, time management in tracing ships' historical information for operation purposes and resource strategy in project planning. While most of the major industry players intended to invest in Digital Twin (DT) due to the push of Industry Revolution 4.0 (IR4.0), micro-small-and-medium enterprises (MSME) were left behind due to either a lack of capital in acquiring DT technologies or a lack of resources in developing the system. Also, there is the risk of not receiving a positive return on investment (ROI) when investing in DT, as the price of DT is high due to the high order with fewer service providers. The types of technology and practical applications covering all ship life cycle phases, from shipbuilding to ship operation and ship decommission through utilising DM and DS, are highlighted. Besides, existing DM and DS applications and strategies used by other industries were examined and suggested in the paper; ergo, it could be used as an innovation repository that could be improved for maritime engineering applications. Although DM and DS applications require human intervention, the potential benefits when combining the features of intelligence tools and human-in-the-loop (HITL) could be remarkable due to the tool's flexibility, expandability, and accessibility.



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## 1. Introduction

On average, ships and offshore units typically have a designed life of around 20 years before the end of their operational life, and in many cases, ship owners tend to opt for life extension. Regardless of opting for life extension or decommissioning the assets towards their end of field life (EOFL), the ships must undergo rigorous ship maintenance and survey as required by company policies, administration, and classification.

The surveys can be statutory, new construction surveys, damage surveys and periodical surveys, which are initiated to ensure that the assets meet the safety requirements. The type of survey stated above is normally called Preventive Maintenance (PvM), in which maintenance must be conducted within the designated survey period and timeframe. During the survey activities, any anomalies found during the exercise must be resolved as per agreement with the attending surveyors, classification and administration.

Non-compliance with the agreement and related certifications issues will prevent the ship from operations [7]. The occurrence of such incidents could impact the ship owner's profitability and reputation and, sadly, indicate that the vessel is not in a safe condition. This is because the roles of classification and administration are to ensure that registered vessels are safe, including the crew's safety, impact on the environment, and operability.

Thus, ship operability depends on the finding data collected by inspection companies and ship surveyors. In addition, the data collected for offshore units or marine vessels could be utilised later in the asset life, such as conducting a Risk-Based Inspection (RBI) plan, a Life Extension (LE) plan, or a ship conversion. The most underutilised purpose is Predictive Maintenance (PdM).

Prior to the digital era push, the data collected was typically used to complete specific tasks only and tended to be forgotten throughout the years. This mainly occurred due to the lack of a single point of truth, the culture of crucial person dependencies, and probably awareness of data usage.

As digital advancements have increased accessibility exponentially, all organisations shall take advantage of this by transforming traditional data collection into effective data visualisation of their ships' historical data.

Nomenclature:

| | |
|---|---|
| BI | Business Intelligence |
| CAD | Computer-Aided Design |
| CRUD | Create-Read-Upload-Delete |
| DM | Digital Model |
| DS | Digital Shadow |
| DT | Digital Twin |
| EOFL | End of Field Life |
| HITL | Human-in-the-loop |
| IoT | Internet of Things |
| IR4.0 | Industry Revolution 4.0 |
| LE | Life Extension |
| LNGC | Liquified Natural Gas Carrier |
| MSME | Micro-small-medium Enterprise |
| PdM | Predictive Maintenance |
| PvM | Preventive Maintenance |
| RBI | Risk-Based Inspection |
| ROI | Return of Investment |
| UT | Ultrasonic Thickness |

## 2. DIGITAL VISUALISATION

Digital utilisation in engineering is a common practice as the industry is always flexible in accepting new inventions into the industry. For instance, before the existence of CAD, also known as DM, engineers produced technical drawings manually before fully migrating to CAD application.

Currently, DT has become an engineering invention in which large corporations have invested significantly to accomplish the transformation. Numerous academic and industry research studies have been conducted to highlight the benefits of DT. However, due to relatively new technologies, a large capital requirement is required to accomplish the DT connectivity, which consists of acquiring relevant sensors, establishing IoT, cloud connectivity, digital storage, and digital modelling. With the outlined constraint, MSME organisations may not consider DT an option for investment due to high investment costs, unpredictable ROI and need for skills resources. Because of the aggressive push on DT, industry players tend to forget the available alternatives, which are more economical and less technologically dependent. The technology called Digital Shadows is something that engineers overlook.

There are three options that developers could utilise in developing digital visualisation in maritime engineering applications: digital model (DM), digital shadows (DS), and digital twin (DT).

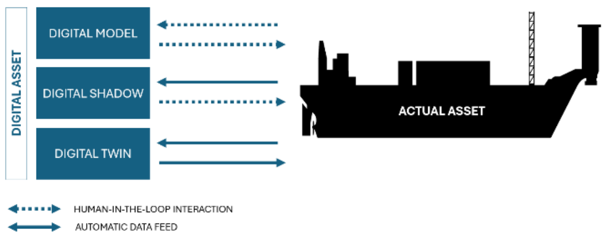


**Fig. 1 - Digital Model (DM), Digital Shadow (DS) and Digital Twin (DT) Functionality**

### 2.1 Digital Model

According to Kim et al. (2024), the Digital Model is a passive digital asset where full human-in-the-loop (HITL) interaction is required towards and from the actual asset [3]This means no live interaction exists for the digital model functionality. DM is usually used early in the project phase for construction, documentation submission, and detailed drawings. As DM is a mature tool in engineering applications, the magnitude of software options is huge at an affordable subscription cost, which could be affordable to all levels of users, including MSME owners.

Sometimes, the digital model is reverted into "as-built" drawings, where changes are made due to on-site adjustments. Otherwise, the digital model is always used when troubleshooting, re-engineering, or other tasks related to design clarification and optimisation are required.

Unfortunately, the purpose of the digital model tends to remain the same, holding it back from exploring new uses and opportunities. This could be happening due to the industry's focus on IR4.0, which focuses on automation and forces DM usability to stay stagnant.

### 2.2 Digital Shadows

Digital Shadows (DS) is one of the less popular digital visualisations among the three options. Putting aside DS's popularity, the system has positive potential for industry players, specifically for maritime applications, where the framework could be implemented in a hybrid state and possibly have a similar outcome as per DT.

The primary function of DS is to feed live data, typically from physical assets, to the user database for further evaluation. Some scholars believe DS can be used as the preparatory process for companies interested in investing in DT since its functionality replicates the result between digital and physical assets. A study by Santolamazza et al. (2020) found that implementing the DS in manufacturing can improve at least two main operation factors, asset health prediction and life cycle management, due to the constant data feed from the factory to the tools [10]. The author successfully implements this by integrating high-performance cloud facilities assistance from the site to the HITL phase for quality management purposes.

### 2.3 Digital Twin

The current state of the art in digital visualisation, Digital Twin, requires multiple sub-elements of drivers to ensure it is fully functional. According to the British Standard Institution, to enable the DT, the system typically comprises relevant sensors that act as data collectors, simulation capabilities, data analytics functionality, and machine learning frameworks and concludes with data information management [1]. As DT mimics an actual asset, relevant parties can make decisions quickly without physically being on the asset.

Even though DT is relatively new in the maritime industry, there are several requirements required by the classification society to replace the traditional physical survey by crediting it via digital approval. Based on the Lloyds Register ShipRight publication, there are four main requirements to be accredited that are Digital Twin Ready, Digital Twin Approved, Digital Twin Commissioned and Digital Twin Live [4]. Table 1 below briefly explains the criteria for each component that complies with Lloyds Register ShipRight Design and Construction Digital Compliance. The main objective of getting approval from a classification society like Lloyd's Register is to ensure that the system deployed is reliable and capable of capturing related risks and that the data collected is being analysed accurately.

**Table 1 - Description of Lloyd's Register Digital Twin Approval Level [4]**

| DT Level | Description |
|---|---|
| Ready | DHM provider has proven able to provide a reliable digital twin |
| Approved | DT and DM have been established |
| Commissioned | Deployed DT proven operated successfully and satisfactorily |
| Live | DT has proven to operate at high accuracy as per onsite asset |

## 3. Practical Application

### 3.1 Maritime Industry Applications

#### 3.1.1 Case Study A: Shipyard Monitoring

Traditionally, project monitoring in shipbuilding and ship repair activities depends on the Gantt Chart and numerous reports such as survey reports, S-Curve, service reports, work-pack and repair drawings. This means the amount of repair will increase linearly as the number of defects is discovered. With a large magnitude of defects required for repairs, the attention to detail may be affected. Moreover, the number of parties involved in reviewing the documentation also influences efficiency as it is required for at least three different parties for quality control. For example, in a typical ship repair process, the process will be started by the shipyard alongside the ship surveyor, followed by inspection report production, repair drawing development, classification approval, client approval, repair execution with quality check, repair witness by all stakeholders and report close-out (see Figure 2). This shows the significant time required for the process that can be simplified using DS.

Case Study A has been implemented in one of the Southeast Asia shipyards on a floating offshore project as a pilot study. The DS has been integrated into their existing framework, and significant improvement has been shown, especially during the approval stages between all stakeholders. The pilot study was completed successfully by implementing two foundation approaches of software development and naval architecture project management strategies. A web-based application has been developed with an online database, which is becoming the focal point of the project information that comes with Create-Read-Upload-Delete (CRUD) functionality.

This has eliminated the document transfer dependencies, which are normally in a hardcopy format, and forced the stakeholders to implement a finish-to-start dependency.

Due to automation configurations, the DS of Case Study A has shortened the process and allows concurrence review between stakeholders, as highlighted in the dotted line. It also allows the inspector to conduct single-entry survey findings instead of multiple entries from the site into a pre-assigned template.

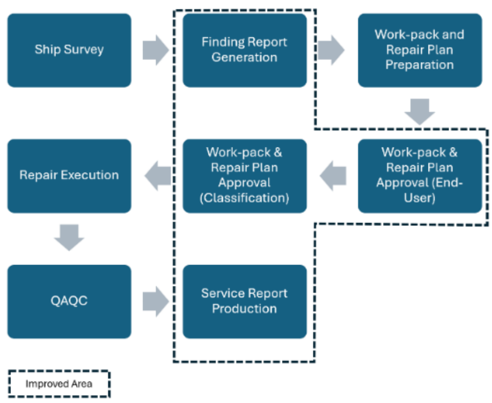


**Figure 2. Before and after automation Implementation the DS applications**


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As the DS background requires a single point of truth, the system capabilities can be extended to dashboard reporting and 3D visualisation. The 3D reporting system has been developed and utilised in the shipyard monitoring project that feeds live status of the repair in the traffic light status with red indicating pending repair, yellow indicating scheduled to be repaired in the reporting day and lastly, green indicating repair has been completed. This has allowed a simplistic reporting method, as commonalty used in higher management meetings where only high-level information is required to be presented.

The DS automation has benefited the user in all three core project management areas: cost-time resources (CTR). Time and Resources directly impact the operation, as the higher the utilisation of the DS automation, the lower the time required for the engineers to complete their tasks. Thus, the additional time saved from the system could be utilised in other critical thinking work requiring a human touch, such as structural optimisation and risk assessment.

However, the Cost element required additional strategies and processes to translate unrealised benefits into realised benefits. This is because it directly relates to the Time and Resources elements mentioned in this section. Thus, the user of DS innovations needs to utilise the saving elements in Time and Resources into cost-beneficial steps such as career improvement for the stakeholders; otherwise, underutilisation of saving factors could negatively impact the cycle.

### 3.1.2 Case Study B: Asset Health Log

There are numerous benefits of sustaining historical information on assets, such as technical drawings, inspection reports, shipyard status reports, and repair reports. Even though the data collected could be enormous, implementing additional assessments, such as adopting BI tools, could unleash beneficial information that could be beneficial to ship owners. The immensity of centralising the asset information can provide benefits across disciplines such as engineering, finance, procurement teams, and others. This is due to the nature of supply chain management, which is also dependable across disciplines. Concurrently, the culture of specific person dependency and reliance could be minimised or even terminated immediately.

There are two technical examples of implementing BI with DM and DS from the technical point of view of assessing LE for a Floating Offshore structure asset and structural issues on similar assets, commonly known as sister ships in the maritime industry.

After data collection and processing are completed, a live data dashboard can be created by implementing the HITL from the field into the company's database.

#### 3.1.2.1 Life Extension

LE program is a common activity for floating offshore assets or Liquified Natural Gas Carrier (LNGC) as typically the asset has been going through many operation years, and some of them have a previous year as a different type of vessel after it being re-life through ship conversion activity. As the industry is bound to stringent regulations required from administration and classification, each LE program must go through four main parts that are feasibility studies, detailed assessment, conditional acceptance and concluded with rectification and certification (see Figure 3).

According to Lloyd's Register Life Extension of Floating Offshore Installation at Fixed Location, the historical data review will be required for nearly all areas covering the Basis of Design (BoD), technical drawings, stability and loading conditions documents, environmental data, design assessment reports, and survey data [5]. This shows the importance of sustaining and maintaining an asset's historical information to ensure high-quality life extension prediction.

The reason historical information is being re-evaluated is to assist all stakeholders in determining the asset's risk level, and, to some extent, some information will be briefly used for predictive maintenance measurement. In the end, as long as the assets are in good standing with a low risk of failure to impact the environment, organisation, finances and safety, they may be allowed by administration and classification to extend their life span.

In such scenarios, technological advancements in DM and DS could assist the users in several aspects, including connecting the dots of the data collected, identifying potential issues of the assets based on anomaly categories, tank spaces, and severity, reviewing previous UT readings, and projecting them to the new EOFL. Also, this could be treated as part of the PvM and PdM assessment.

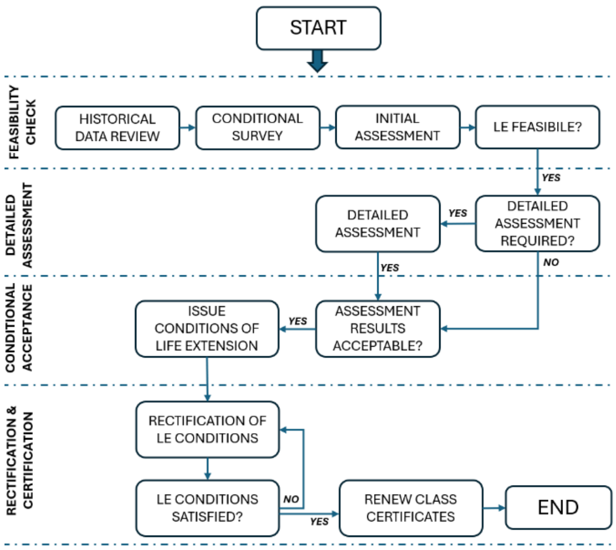


**Figure 3. Lloyd's Register Life Extension Process for Floating Offshore [5]**

This is accomplished due to the nature of the software architecture on the backend, where primary keys, through the data normalisation process of each item, could be utilised to link all the information. In addition, by implementing data analysis and statistical knowledge, the actual asset condition estimation will be presented at higher confidence levels, eventually benefiting all stakeholders.

Based on the Lloyd's Register database and Offshore Magazine publication on Australian FPSOs' age, which some may be plying different countries' flags, it averaged 21.5 years, with more than 50% exceeding 20 years old [6][9]. This indicates that the assets with such age years may have gone through at least four (4) Special Survey programs that required them to be dry-docked on the shipyard for inspection and repair purposes. This demonstrates that large numbers of inspection, repair and rectification data shall be processed and evaluated.

Thus, the role of BI assistance and the combination of DM and DS can improve the investigation process and increase the accuracy of risk assessment due to the lack of asset information. In addition, with an appropriate framework, operational expenses could be lowered and diverted to precious tasks requiring additional resources.

#### 3.1.2.2 Sisters' Vessels Management

It is standard practice in the maritime industry to have similar ship designs for several productions. This is usually done for enforcement ships, trading ships, and other supporting ships like tugboats and barges. Producing similar designs for assets typically saves several factors, such as classification approval fees, supply chain processes, purchasing power, and professional fee costs.

Due to the nature of enforcement ships and trading ships that operate around the clock, some countries have even exceeded the design life, resulting in a shorter structural fatigue life. For example, a study found forty-nine of the Royal Malaysian Navy (RMN)'s ships currently operate beyond the estimated lifespan [2]. Fortunately, with the expertise of RMN personnel, the asset's life has been successfully extended through multiple innovative approaches, such as implementing Smart-Refit, Re-Hull and Re-powering, while waiting for new acquisitions of new vessels.

With such scenarios, unpredictable ship equipment and structure defects tend to happen more frequently than expected and could be costly. This typically started with a single vessel in the early stages before the pattern of defects was recognised on other sister ships.

Thus, the benefit of having a platform with data sharing among the sisters' vessels will be a benefit as the unplanned incidence on a single vessel could be shared throughout the rest of the sister ships. The representation of the model, either DM or DS, will be accelerated by the interpretation processes and decision-making from the technical and management teams. This allows the technical team to further investigate the whole sister vessel in a group instead of conducting it in multiple assessments over multiple periods.

### 3.1.3 Case Study C: Shipyard Project

Managing projects in any phase of an asset's time frame tends to be challenging. It involves balancing the expenses, cash flow, resources, and time needed to establish them. In the offshore industry, every period of inoperable production equals losses to the company. Thus, company decision-making tends to be biased in ensuring the assets operate at the maximum timeframe and pushing other needs as secondary.

Some other areas that are affected are during the shipyard campaign, where the assets have a tight timeframe to complete necessary repairs or inspections to meet the classification and statutory requirements. Ergo, comprehensive preparation, such as project planning, execution, resource planning, and scope of work preparation, is required.

As the shipyard campaign involves multiple parties, such as the assets owner, shipyard representatives, classification society, contractor and administration, a single point of truth system shall be created. Traditionally, a paper-based approach where email is used as a means of communication, and unfortunately, as the project scale gets more extensive, numerous miscommunications between all parties tend to occur.

The implementation of BI and DM in the shipyard campaign conducted on a floating offshore asset in the Asia Pacific region has been proven, and a system is being created on top of the traditional approaches that allow all relevant parties to view and analyse applicable information across the disciplines and contractors. The system also has supplemented the shipyard's use of DM to assist the quotation processes, creating a win-win situation between shipowners and the shipyard where the possibility of over- or underquoted issues can be eliminated.

In addition, as the system can show highly detailed information, the shipyard has used it to manage its equipment and resources in several activities, such as staging preparation and resource planning. On the other hand, the ship owner could track activity progress nearly live on the ground, and the information provided can be used for management meetings and other purposes.

## 3.2 **Other Industry Applications**

### 3.2.1 Manufacturing

In a volume production business like manufacturing, the benefits of DS are valuable as they could help the manufacturer identify gaps that could be improved. For example, DS has been used to monitor operational issues in production that are impacting productivity [8]. Upon implementation of DS, the bottleneck problems have been identified after data collection and data processing.

In addition, the author made five direct impacts in their studies, which are the effect of dominos after optimising the manufacturing process. At the early stage of the DS implementation, comprehensive monitoring was conducted by reviewing each stage of the manufacturing level and understanding the drivers directly and indirectly related to the organisation's quality, the so-called gap analysis.


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Upon completing the gap analysis, close monitoring of the flagged area will be done, and improvement actions will be made to eliminate and close the flagged issues. This has improved the production of the manufacturing organisational efficiency by reducing downtime. Finally, the main goal of implementing the DS of enhancing the operation cost can be obtained through production monitoring, optimisation, and improvement. Figure 4 below summarises the process flow of implementing DS in manufacturing.

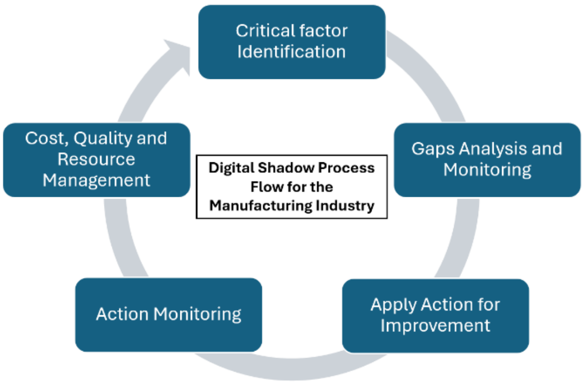


**Figure 4. DS Manufacturing Process Flow**

## 4. DIGITAL VISUALISATION

Implementing DT as an alternative in the industry can have several positive impacts on multiple industries, especially the maritime industry. Previously, DT was only accessible to corporations with significant capital and optimistic ROI estimation, but now, with the creativity of DM and DS implementation, it could benefit other market segments.

In addition, due to the maturity of DM and wide usage in the engineering industry, the cost of implementation is affordable, and there are challenges in recruiting resources with the knowledge of DM. The alternatives of DT can encourage the innovation culture within the MSME sector where it is extorting the business owner and industry professional to implement open-source options and match the DT capabilities.

Furthermore, implementing DM and DS can improve data interpretation by eliminating paper-based approaches that are usually confusing and difficult to control when new revisions are issued.

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The opinions expressed in this paper are solely those of the author and do not necessarily reflect the views or policies of Lloyd's Register or Floating Solutions Consulting Pty Ltd.

## References

[1] British Standards Institution. (2020, November 10). Automation system and integration industrial data - Industrial data - Visualization elements of digital twins. ISO Technical Report ISO/TR24464. *https://www.iso.org/standard/78836.html*

[2] Daniel, T. (2024, July 10). Malaysia's dire naval shortfalls, reliance on us laid bare in damning audit. Institute of Strategic & International Studies Malaysia.

[3] Kim, D. B., Bajestani, M. S., Lee, J. Y., Shin, S.-J., & Noh, S. D. (2024). Introduction of human-in-the-loop in smart manufacturing (H-SM). International Journal of Precision Engineering and Manufacturing-Smart Technology, 2(2), 209–214. *https://doi.org/10.57062/ijpem-st.2024.00115*

[4] Lloyd's Register. (2018, September). ShipRight Design and Construction Procedure for the Approval of Digital Health Management Systems. London; Lloyd's Register Group Limited.

[5] Lloyd's Register. (2023, March 1). GN-027 Guidance Notes for Life Extension of Floating Offshore Installations at a Fixed Location. LR. *https://www.lr.org/en/knowledge/lloyds-register-rules/guidance-notes/guidance-notes-for-life-extension-of-floating-offshore-installations-at-a-fixed-location/*

[6] Lloyd's Register. (2024). LR ships in class. *https://www.lr.org/en/about-us/who-we-are/lr-ships-in-class/*

[7] Lloyd's Register. (2024b). Port State Control. Services to support Port State Control. *https://www.lr.org/en/services/classification-certification/port-state-control/*

[8] Mourtzis, D., & Balkamos, N. (2023). Design of manufacturing systems based on Digital Shadow and Robust Engineering. Applied Sciences, 13(8), 5184. *https://doi.org/10.3390/app13085184*

[9] Offshore Magazine. (2022, December 13). 2022 worldwide survey of Floating Production Storage and offloading (FPSO) units. *https://www.offshore-mag.com/vessels/document/14287001/2022-worldwide-survey-of-floating-production-storage-and-offloading-fpso-units*

[10] Santolamazza, A., Groth, C., Introna, V., Porziani, S., Scarpitta, F., Urso, G., Valentini, P. P., Costa, E., Ferrante, E., Sorrentino, S., Capacchione, B., Rochette, M., Bergweiler, S., Poser, V., & Biancolini, M. E. (2020). A Digital Shadow Cloud-based application to enhance quality control in manufacturing. IFAC-PapersOnLine, 53(2), 10579–10584. *https://doi.org/10.1016/j.ifacol.2020.12.2809*