The International Maritime Transport and Logistics (MARLOG 13) - ISSN 2974-3141
http://dx.doi.org/10.21622/MARLOG.2024.13.1.86
Towards Smart Green Blue Infrastructure

The Readiness of Mena Shipyards to Adopt an Integration of Lean Manufacture with Digital Technology in Ship Repair

Ahmed Samir Ghowel

University of Technology Malaysia-UTM, *iahmed@gradute.utm.my*

ABSTRACT

Shipping is vital for world trade and specifically to the Middle East and North Africa (MENA) region, this permits the related SME shipyards in this region to play an essential role in the economic growth of MENA countries. The cost, schedule, and quality of ship repair facilities minimize the waste and bring value to the client, making it more attractive for the shipping companies to stop for repair in this area while they are chartering. The challenge of upgrading the ship repair production system is that it is irregular compared to shipbuilding. This is due to unforeseen factors that represent a high percentage and influence the production planning of any yard. Thus, this study commences adopting lean digital approach in the operation management of ship repair. However, the first step is to determine the yard's readiness for such transformation, which is crucial to the level of change required. This research is about determining the readiness factor and the first steps as a road map for lean digital transformation for the Small to Medium Enterprises- SME ship repair facilities in the MENA region. Follow by another study focus on the combination of leagile in ship repair.

Keywords: Ship Repair, Lean Manufacturing, Leagile, Digital Transformation, Shipyard, Last Planner, Waste Assessment Model.

INTRODUCTION

Shipping is crucial in world trade and has significant implications for the global economy. Ships transport more than 80% of world trade volume and about 70% of trade value, as per the Econofact database (2021). Shipping trade significantly impacts countries' economies in the MENA. The growth pace was the most rapid in 2017, when exports increased by 430%. In line, the pace of growth was the most pronounced in 2016, with an increase of 252%. The level of exports peaked in 2021 and is likely to see gradual growth in years to come, as per the Index Box database (2023) for MENA's market analysis.

In the past few decades, the focus of various industries worldwide has been eliminating waste in the production process due to increasing competition and clients' demands to get the maximum from products or services. One of these approaches for minimizing or eliminating waste was the lean one developed by Toyota as the TPS Toyota Production System between 1948 and 1975. There are countless studies and publications focused on lean transformation and implementation in the shipyard industry, specifically to participate in shipbuilding in different layers, as by Moura, D., & Botter, R. (2011) [1] and about the impletion of lean in the design office for shipbuilding or the one for (Chu et al., 2021) [2], where he pointed out more about the supply chain. On the other hand, agile was known for its adding value to the flexibility that indeed required in ship repair environment. `Leagile is the combination of the lean and agile paradigms to best match the need for responding to a changeable demand for the scope upstream. In this study, will have more focus on the lean and on the further study will give more insight into the agile combination.

PROBLEM AND METHOD

Problem Definition

On the other side, limited attention is given to the ship repair sector since many factors influence getting the maximum value of it. Therefore, there is a need to understand what can motivate shipyards, especially in MENA, to adopt lean manufacturing processes in ship repair activities. For this purpose, this research was done to study the readiness of the MENA ship repair yards to adopt lean in conjunction with digital technologies.

Method and Design

This research will be conducted based on the research onion model proposed by Saunders et al. (2023) [3], where the model makes steps for better illustration, which is composed of multiple layers. The outermost layer reflects the philosophy by selecting Pragmatism. This is followed by the approach, which will be deductive, and the methodical choice will be a simple mixed method.

The method of collecting data will be through the Waste Assessment Model WAM, which consists of a Waste Relationship Matrix- WRM, to determine the relationship between waste and a Waste Assessment Questionnaire- WAQ, to identify the causes of waste, as explained by Widi et al. (2022) [4].

WAM is used to check and determine which shipyard wastes should be prioritized in the execution of improvements (Ali and Fahad, 2015) [5], which is critical in defining the road map for digital lean transformation.

For the digital maturity level, we will use simple quantitative methods to rate the maturity level and examine the relationship between technology development and the root cause of waste.

This paper will highlight general WAM steps, allowing more focus on the findings and the related action plan Selecting SME ship repair yard.

SME SHIPREPAIR

SME is Starting Point

Like in other industries, Small to Medium Enterprises- SMEs in shipyards refer to smaller to medium scale businesses compared to large shipbuilding corporations. These smaller enterprises may provide various services and products related to the maritime industry's shipbuilding, repair, maintenance, or other aspects. They could include companies specializing in welding, electrical work, equipment manufacturing, or even smaller specialized projects.

SMEs in the shipyard industry typically have several characteristic features that distinguish them from more giant shipyards:

- *Flexibility:* These shipyards are often more agile and flexible in responding to the needs of their clients. They can adapt quickly to changes in the market or specific project requirements.
- *Close-knit Workforce:* Due to their size, SME shipyards often have a close-knit and highly skilled workforce. Employees may have multifaceted roles and strong technical expertise.
- *Innovation:* SMEs can be innovation hubs, where novel approaches and technologies are more accessible to develop and improve in the processes.

SMEs are now widely recognized as economic development engines, as Otman (2021) [6] described. Also, his research listed the opportunities and challenges SMEs face in the Middle East/North Africa (MENA).

Based on the vital role of SMEs in the economy, this research focuses on the active SME shipyards (concerned about ship repair) in MENA, which represent the majority with a total number of approx. Thirsty-one active yards [away from countries that suffer from conflicts] as per SME- MENA Yard at Figure [1], as per the database Trusteddocks (2023), and are mainly located in Egypt and UAE. Compared to the big shipyards as the one in KSA (under development).

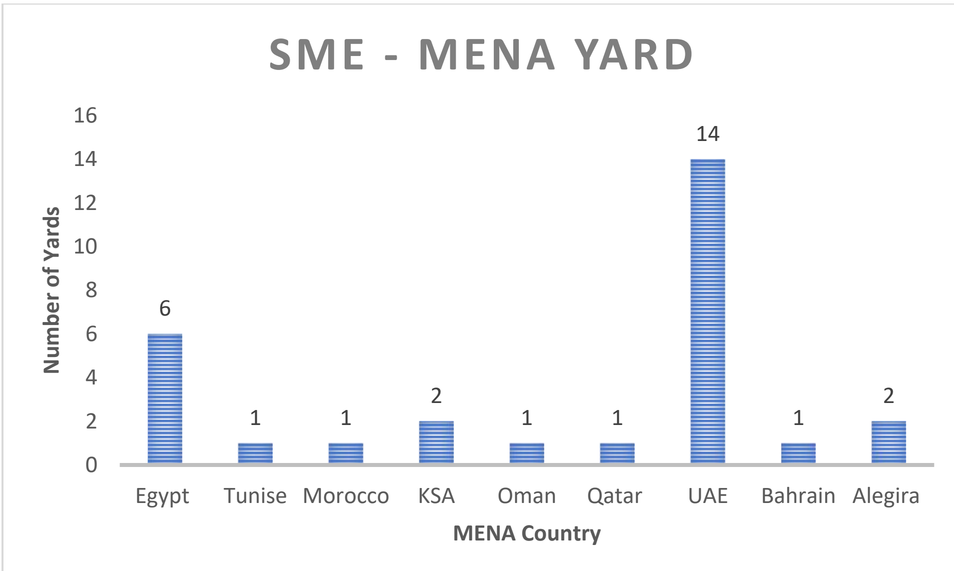

Figure 1: SME- MENA Yard.

Ship Repair is More Challanging

Lean has a good record all over proven numbers in shipyards with the nature of work of shipbuilding by adopting lean shipbuilding, as it is becoming the primary practice for waste and cost-effective reduction in different studies, in both concepts and approaches through case studies, and has proven its result and outcome. An example of these is Zoren & et al. (2022) [7] illustrated an excellent example of who applied lean in the sales process of shipbuilding, and the outcome was that the average annual cost of the sales process significantly decreased (EUR 1,930,840) in the total annual revenue of the shipyard (EUR 140,000,000, in conditions of the improved state of the process) from 2.7% to only 1.4%.

From MENA-SMEs Shipyards, this research focuses on scoping ship repair as a nature of work. This is because the nature of work shipbuilding is the more standard flow of work and clear output at each stage, compared to the ship repair, which varies from one project to another due to the different scope of work or repair as per the client and Class societies that represent the international audit, to ensure the safety of passengers and the cargo.

This means that it is more challenging to control repair work, the majority of which is unforeseen and changeable from one type of ship to another and also relies on the shipping company's strategy for maintenance and repair. Thus, many factors related to the repair project make it challenging when it comes to lean format and even when it comes to the usage of technology, which has limitations due to the safety, productivity, and sustainability in the harsh environment of a shipyard.

In line, there are very few studies of the integration between lean principal and ship repair as per the literature review utilizing all the searching keywords. A few of these studies, such as the one Chryssolouris G (1999) [8] developed, focused on planning and control in ship repair. And the other Verma (2008) [9] for fleet repair and maintenance.

There are no related studies that discussed the lean digital model for ship repair in the MENA region and even in other places worldwide, compared to a different model for lean shipbuilding, which has already been done, tested and developed through the years, starting from Japan and spreading in different places.

METHODOLOGY STEPS FOR MEASUER YARD READDIESN

For other industries, several research and studies have demonstrated these gains and the measuring tools to determine organization leanness, such as the one developed by Flores and Alevites (2022) [10] by reviewing the lean manufacturing model for production management to serve the company's product and other works out in making maturity model for each area inside the organization to see its efficiency and effectiveness for further improvement.

Back to ship repair, there are insufficient studies, mainly as Lai (2020) [11] listed the barriers to applying lean in this field and the other relates as Neves et al. (2023) [12], and it is worse when it comes to ship repair because of its known characteristics of being interconnected activities and unclear scope.

To solve this problem, this research set a baseline of specific criteria, consisting of the guidance of the lean wastes [Defect-Overprodction-Waiting-Transportation-Inventory-Motion-Extra processing] along with the digital maturity level [Incidental-Intentional—Integrated-Optimized], as identified by Justin (2018) [13].

In line, this research set readiness criteria based on the outcome of the WAM, which commences by articulating the definitions of each type of the seven wastes and their overlapping areas, as explained by Rawabdeh (2005) [14]. This concluded from the Waste Relationship Matrix- WRM, to determine the association between waste. And a Waste Assessment Questionnaire-WAQ to find the causes of waste.

This criterion screens and measures the shipyard maturity index for digital lean transformation. It compares with the knowledge management of the shipyard as described by (Sharma & Gandhi, 2017) [15], which represents the records of all the aspects of the project, such as lessons learned from previous projects.

A Waste Relationship Matrix (WRM) was developed based on the analysis of data as per the below steps of Figure [2]as per Fitriadi and Ayob (2022) [10],

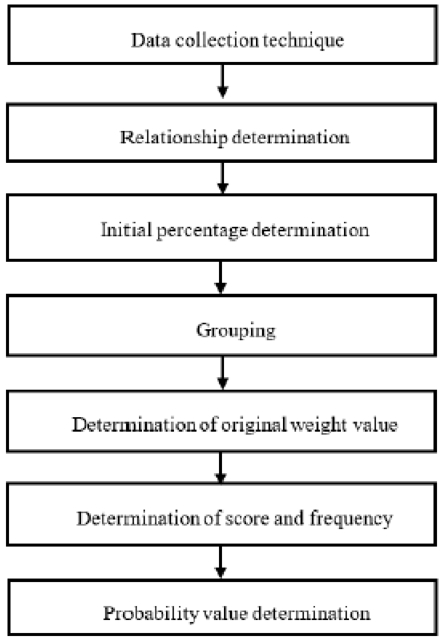

Figure 2: Analysis of Data steps.

with main mathematical model of where Sj is the score of the waste, and K ranges between 1 and X (number of questionnaire).

$$S_j = \sum_{K=1}^{K} \frac{W_{j,k}}{Ni} \quad \text{for each type of waste j}$$

Then, the WAQ spread to different stakeholders in SME shipyards in MENA to get their evaluation for allocating waste. Nevertheless, it is essential that such questionnaire results from the community-based Participatory Action Research process model (CBPAR), which is a collaborative approach to research that involves all stakeholders throughout the research process, from establishing the research question to developing data collection tools to analysis and dissemination of findings.

The main reason behind selecting the CBPAR method is that action research may be defined as an emergent inquiry process in which applied behavioural science knowledge is integrated with existing organizational knowledge through the stakeholder and applied to address real organizational issues. Shani, A. B., & Coghlan, D. (2019) [15].

These are the main steps for it:

1. *Identify an area of interest/problem.*
   The main objective is to analyze past ship repair projects to evaluate the overall performance and productivity to determine the reasons for drawbacks concerning the seven wastes of lean principles. And the strategy and percentage behind adoption technology.

2. *Identify data to be collected, the format for the results, and a timeline.*
   For the above objective, a questionnaire was circulated for a determined sample of MENA shipyards [with total number of 20 yards participant] to the critical stakeholders like the production manager,

project manager ...etc. to collect their feedback about the reasons that cause the project to be underperformance or productivity targets.

3. *Collect and organize the data.*

This questionnaire is sent through a Google form and will be collected directly from the database for processing such data to have specific information.

4. *Analyze and interpret the data.*

Analyzing these data will determine the root cause of the process to be away for transformation.

5. *Decide upon the action to be taken.*

The highest cause of one reflects the main reason that caused the significant impact. This one will be processed into the Theory of Constraint - TOC to recognize the process backlog.

6. *Evaluate the success of the action.*

Evaluation of what has been done, along with what needs to be done more, is crucial in the continuous improvement process.

FINDING AND DISCUSSION

WAM and Digital Maturity Aftermath

Waste Assessment Model outcome consists of WRM in ship repair that the cause of waste from most significant to lowest are waiting and inventory with more than 45% approx., followed by processing, motion, and transport within approximately 30% and ends by defects and overproduction, as shown in Figure (3) WRM outcome. For the WAQ concludes that the root causes of waste are wait time, inventory, and processing.

Waste Factor	Waste weightage % (Approx)
Wait	45%
Inventory	
Processing	30%
Motion	
Transport	
Defects	25%
Overproduction	

Figure 3: WRM outcome.

These three causes of waste (wait -inventory-processing) are due to these root causes:

1. Ship repair suffers from unforeseen scope, which drives the difficulties to manage.
2. Higher than 60% of the scope are listed under inaccessible areas, like the underwater or upper areas in some tanks, categorized as "after inspection" means after ship arrival and docked.
3. Level 2 planning is far the shipyard concluded based on the data received from the client.
4. No 3D modelling case was recorded for ship repair, except if it is combined with upgrade/conversion.
5. Production planning inside the shipyard suffers from unorganized input from priorities and work scope.

And with the measuring of the digital maturity to the sample of the participants shipyards, it shows that:

6. Most shipyards fall under the "Incidental" digital maturity level, which means they are executing a few activities that support the digital transformation that happens by accident, not from strategic intent.

7. There is low awareness of it at the business level of merging between lean and digital when it comes to the strategic planning for the shipyard.

Digital Lean Road Map

That said, the next step for digital lean transformation is to apply the Theory of Constraint- TOC, as a management philosophy for facilitating the bottlenecks, as explained by Goldratt (1984) [16]. It starts from improving the first two steps of ship repair operation: initiation and planning that align with the rest parts of ship repair operations, such as supply chain, execution, and resource planning.... etc. Put in order the following stages of execution, monitoring, controlling and closing of each project, which direct the project's management plan, which in return is allied with the shipyard's production planning.

Initiation stage

Digital technology will be utilized and maximized by using different remote inspection tools, such as drones and Remote Operated Vehicles- ROVs, that furniture the way for diagnosing the status of the underwater hull and rooms and confined spaces, in addition to other set of devices like borescope that can be used for internal components such as cylinder pistons, values and boiler tubes. Such tools and others can clear most of the unforeseen scope that represents the key factor for the unorganized nature of ship repair. This can be enhanced further by the ship's owner if he decides to adopt and merge an advanced maintenance system with the repair plan, like Predictive Maintenance and Reliability Centered Maintenance (RCM), that allows the self-detect of faults and analyzes the condition of the equipment during the operation.

Planning stage

Which relies more on two main approaches; the last planning, as Daniel et al. (2017) [17] approaches consist of [a Master schedule- Phase scheduling- Look-ahead planning - Weekly work planning - And learning]. This comes with the aid of using 4D planning tools, such as a 4D comparative schedule method, which is more used in the civil and construction industry and shipbuilding yards as part of its Product Lifecycle Management-PLM. The objectives of both approaches are to combine critical chain schedule with parametric modelling to optimize schedule and resources, with the aid of 3D scanning tools that can be part of the initial stage prior to the arrival of the vessel to the yard.

Eventually these first steps drives towards shipyard 4.0 that explained by Ton Yon (2021) [18] in his study towards implementing Industry 4.0 in the shipyard environment, stating, "Shipyard 4.0, we believe a right framework is required to assist in designing a virtual work environment."

NEXT STEPS

Field Application

For the validity of this research, it is essential to apply the outcome factors to a running repair facility, which represents a case study. Thus, as the author spent more than 17 years of practical experience in different shipyards located in MENA, he selected one of these yards to apply the outcome factors and determine its digital leanness indicator before and after. The details of the case study and the results before and after are still under development and will be listed in the comprehensive research study, adding some economic [as ROI] and a detailed transformation road map. However, the main output as an application to the initiation and planning stages is explained as the primary guidance.

Further Points

Here, there are three aspects: first, is the adding the agile as it brings value specific to the ship repair and with its flexibility tolerance and acceptance. Nevertheless, second is the consideration for the next iteration of PDCA (Plan- Do- Check- Act), and the finally is the points that need to be merged from other studies to complete the road map, that related to culture and behavior of the human resources.

The first aspect is more related to the study of the following stages of the projects: execution, monitoring, control and closing. These points must be viewed from a digital lean perspective, especially after implementing the first initiation and planning upgrade. This is continuous improvement to optimize the lean digital operation for ship repair.

Then, there are another point worth considering when such lean digital is planned in action, as the challenges related to human culture and environment, especially in the MENA region. There few studies explored the same. However, it can be summarized here by Liker (2004) [19], in his The Toyota Way, who stated Toyota Way principle 4: "Build a culture of stopping people fix problems."

Moreover, lean principles help reduce environmental pollutants and optimize resources for eliminating waste, as Shipyard industrial waste is one of the industrial groups that produce hazardous and toxic waste, as Rachmat et al. (2021) [20] discussed.

Also, there are studies focus on the barriers that obstruct the application of lean and, in another term, the failure of lean, and this concluded the challenges for lean application in shipbuilding, like the one stated by Edwin (2020) [9] and the other that explore more as the barriers for Lean Transformation Sustainability - LTS, that was done by Osman (2020) [22].

CONCLUSIONS

This study helps discover the sustainability factors influencing ship repair yards toward lean digital transformation. The study significantly reduces the waste generated from ship repair yards, in line with others such as Fitriadi and Ayob (2022) [10] for improving production planning for shipyards. The same has been reflected by Osman (2020) [22], as a transformation from a conventional production system to a lean digital production system has helped many manufacturing companies reduce costs and improve their business performance. The main gains are:

Firstly, theoretical contribution: This study will contribute a new conceptual framework, including a guide for digital lean transformation and measurement models to help academics and researchers explore the area of ship repair yards in the MENA region from a systematic approach.

Secondly, industrial or business contributions to this study will help provide a model for all shipyards, for those looking for standardized work that solves production problems as per Patange (2019) [23], And for those working towards digital lean transformation to understand the factors influencing lean implementation and the others that barrier it. Such understanding allows companies to explore the requirements for manufacturing and production. Moreover, the study will give industrial players confidence in implementing digital lean to influence more market competition and embed this in their strategic behavior approach.

Finally, in addition to that, it can be utilized in the marketing strategy for attracting new customers by minimizing downtime to this part of the world that sustains and leverages its economic growth.

ACKNOWLEDGMENTS

I want to acknowledge the University of Technology Malaysia as a valuable institute of knowledge by accommodating this research under Dr Siti Zaleha's supervision. Furthermore, the Maritime Arab Academy platform that permit this publishing opportunity within MARLOG 13.

REFERENCES

[1] Moura, D., & Botter, R. (2011). Can a shipyard work towards lean shipbuilding or agile manufacturing? *Sustainable Maritime Transportation and Exploitation of Sea Resources*, 559-565. https://doi.org/10.1201/b11810-85

[2] Chu, N., Nie, X., Xu, J., & Li, K. (2021). A systematic approach of lean supply chain management in shipbuilding. *SN Applied Sciences*, 3(5). https://doi.org/10.1007/s42452-021-04562-z

[3] Saunders, M., Lewis, P., & Thornhill, A. (2023). *Research methods for business students*. Pearson.

[4] Astutik, W., Setiawan, I., & Asmal, S. (2022). ANALYSIS OF CONTINUOUS QUALITY IMPROVEMENT USING WASTE ASSESSMENT MODEL AND DEMING CYCLE METHOD (STUDY CASE: TAPIOCA STARCH MANUFACTURING). *Journal of Industrial Engineering Management*, 7(1), 51-56. https://doi.org/10.33536/jiem.v7i1.1104

[5] Ali, B., Jaweed, S., & Fahad, M. 2015. Implementation of waste assessment matrix and line balancing for productivity improvement in a high variety/high volume manufacturing plant, *Proceedings of ESMD* (pp.68-75). Karachi, Pakistan: Industrial & Manufacturing Department, NED University of Engineering & Technology

[6] 6- Otman, K. (2021). Small and medium enterprises in the Middle East and North Africa region. *International Journal of Business and Management*, 16(5), 55. https://doi.org/10.5539/ijbm.v16n5p55

[7] Kunkera, Z., Tošanović, N., & Štefanić, N. (2022). Improving the shipbuilding sales process by selected lean Management tool. *Machines*, 10(9), 766. https://doi.org/10.3390/machines10090766

[8] Chryssolouris G (1999) A planning and control method for shipyard processes: a ship-repair yard case study. In: *10th international conference on computer applications in shipbuilding, ICCAS 99* https://doi.org/10.3390/machines13490766

[9] Verma, A., & Ghadmode, A. (2008). An integrated lean implementation model for fleet repair and maintenance. *Naval Engineers Journal*, 116(4), 79-90. https://doi.org/10.1111/j.1559-3584.2004.tb00306.x

[10] Fitriadi, F., & Ayob, A.F.M., (2022). Identifying the Shipyard Waste: An Application of the Lean Manufacturing Approach. *International Journal of Global Optimization and Its Application*, 1(2), 100-110. https://doi.org/10.56225/ijgoia.v1i2.19

[11] Lai *et al*.: Barriers Affecting Successful Lean Implementation in Singapore's Shipbuilding Industry: A Case Study *Operations and Supply Chain Management* 13(2) pp. 166 - 175 2020

[12] Neves, Â., Godina, R., & Erikstad, S. O. (2023). Enhancing efficiency in the Maritime industry through lean Practices: A Critical Literature Review of Benefits and Barriers. *In Lecture notes in mechanical engineering* (pp. 293–306). https://doi.org/10.1007/978-3-031-38165-2_35

[13] Computing, C. (2018). Digital Maturity Model: A Vital Strategy for Thriving in the Automated Economy. Cooperative.Computing. https://www.linkedin.com/pulse/digital-maturity-model-vital-strategy-thriving-automated/

[14] Rawabdeh H (2005) A model for the assessment of waste in job shop environments. *Int J Oper Prod Manag* 25(8):800–822, DOI 10.1108/01443570510608619

[15] Sharma, S., & Gandhi, P. J. (2017). Scope and impact of implementing Lean Principles & Practices in shipbuilding. *Procedia Engineering*, 194, 232–240. https://doi.org/10.1016/j.proeng.2017.08.140

[16] Shani, A. B., & Coghlan, D. (2019). Action research in business and management: A reflective review. *Action Research*, 19(3), 518–541. https://doi.org/10.1177/1476750319852147

[17] Goldratt, E. M., & Cox, J. (1984). The goal: a process of ongoing improvement. http://cds.cern.ch/record/2159563/

[18] Daniel, E. I., Pasquire, C., Dickens, G., & Ballard, H. G. (2017). The relationship between the last planner® system and collaborative planning practice in UK construction. *Engineering, Construction and Architectural Management*, 24(3), 407–425. https://doi.org/10.1108/ecam-07-2015-0109

[19] Pang, T. Y., Restrepo, J. D. P., Cheng, C., Yasin, A., Lim, H., & Miletic, M. (2021). Developing a digital twin and digital thread framework for an 'Industry 4.0' shipyard. *Applied Sciences*, 11(3), 1097. https://doi.org/10.3390/app11031097

[20] Liker, J. K. (2004). The Toyota way: 14 management principles from the world's greatest manufacturer. In McGraw-Hill eBooks. http://ci.nii.ac.jp/ncid/BA65390491

[21] Ashari, R., Soesilo, T. E. B., & Herdiansyah, H. (2021). Strategy for shipyard industrial waste management in controlling water and air pollution in ship repair. *IOP Conference Series*, 716(1), 012009. https://doi.org/10.1088/1755-1315/716/1/012009

[22] Osman, A. A., Mamat, R. C., & Ali, M. M. (2020). Lean transformation sustainability models: A critical review /. *Advances in Business Research International Journal*, 6(2), 2020, 1-18. https://ir.uitm.edu.my/id/eprint/47135/

[23] A. D. Makwana and G. S. Patange, "Strategic implementation of 5S and its effect on productivity of plastic machinery manufacturing company," *Aust. J. Mech. Eng.*, vol. 00, no. 00, pp. 1–10, 2019, doi: 10.1080/14484846.2019.1676112.