CENTS: A Research Network for the Sustainable Transport Community

Circular Economy Network+ in Transportation Systems

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CENTS Feasibility Funding Case Study Template

Title of Feasibility Study: Circular Economy- Increased Value Extraction from End of Life Marine Assets

1. Project Team

Dr Sefer Anil Gunbeyaz (Principal Investigator) i*s a Chancellor's Fellow (Lecturer) at NAOME. Dr Gunbeyaz's main body of research relates to sustainability in the maritime domain and circular economy. He obtained his PhD through research into the design of ship recycling yards and their optimisation using a simulation tool to develop a framework. In addition to his research in yard design and optimisation, he took part in several projects related to ship recycling, including but not limited to the development of a Sustainable ship recycling industry in Indonesia, the Development of Framework for Sustainable Decommissioning, Sustainable and Safe Ship Recycling in Bangladesh, Identification and Valuation of Equipment and Materials for Reuse, Remanufacturing and Recycling on Marine Assets. In addition to the research, he is also actively developing training for ship recycling workers through the IMO SENSREC and BoatDIGEST projects.*

Dr Rafet Emek Kurt (Co-Investigator) *is a Senior Lecturer at NAOME. Dr Kurt's current research focuses on human factors, accident investigation, resilience engineering concepts, maritime workarounds, human reliability modelling, ship recycling and offshore decommissioning. Dr Kurt also supported the development of international maritime regulations through attending the International Maritime Organisation's (IMO) Maritime Safety Committee and Marine Environmental Protection Committee meetings. Dr Kurt is currently acting as principal investigator of EU funded SAFEMODE Project and MARED Project, IMO funded SENSREC Project, and British Council funded NEWTON Institutional Links project focusing on the Indonesian ship recycling sector.*

Prof Osman Turan (Co-Investigator) *is one of the world's leading experts on shipping safety, design for safety covering human factors. Prof Turan has been involved in more than 20 EU projects and was the coordinator of the FP 5 Flowmart Project, the technical coordinator of COMPASS and DIVEST projects. The Co-ordinator of FP7 SEAHORSE project, which received the LR-RINA Maritime safety award in 2017 and 2018 he was awarded TRA vision senior researcher award at TRA 2018 organised by European Commission*.

Dogancan Okumus, MSc (Research Assistant), *is a PhD candidate at NAOME. He has double engineering degrees in naval architecture and industrial engineering fields and a master's degree in industrial engineering. His PhD studies focus on circular economy and its subtopics, mainly in transportation, machinery, and power generation industries. He has six years of professional engineering practice, and his background includes hands-on experience in several circular economy subtopics such as reusing, remanufacturing and rebuilding products and components.*

Dr Onder Canbulat (Research Associate)
Dr Canbulat was a research associate at the University of Strathclyde, Glasgow, UK. His research focused on the Integrated Energy Efficiency of Shipping. He utilised Bayesian Belief Networks (BBNs) and ARENA simulation methods to minimise a ship's energy consumption during integrated port operations in his PhD. He undertook a methodological approach to analysing various case studies in the shipping sector. Furthermore, He completed my MSc dissertation on Green Ports during my time in the Global Supply Chain Management Programme at the Brunel University of London between 2013-and 14. He currently works for the UK Chamber of Shipping as Decarbonisation Expert.

Dr Evanthia Giagloglou (Research Associate)
Dr Evanthia Giagloglou is a certified Ergonomist from the Chartered Institute of Ergonomics and Human Factors and an Associated Member of the Institution of Environmental Science. She is working as a researcher at Human Factors and Safety centre at Strathclyde University. Her academic background combines disciplines of Cognitive Ergonomics (PhD), New technologies (MSc) and Environmental Science. She has experience working on international EU and WHO (World Health Organisation) projects, covering safety topics and inequalities of risk and injuries at work. She has written and presented several scientific papers and technical reports dedicated to Safety Standards, New technologies in occupational settings, Decision Making, neuro-ergonomics approaches and sustainable work.

2. Executive summary (max 200 words)

While shipping is classed as one of the most energy-efficient transport modes, it currently lags behind sectors such as aerospace and automotive in terms of circular economy approaches, sustainability, accountability and the applications of technologies that have seen the other sectors excel in those areas above. The Circular economy approach is not well-established in the maritime, and there is a need to "close the loop" to minimise waste and increase the revenue stream. The current linear consumption economy inherent in shipping results in increased costs, improved health, safety and environmental risks and harm efforts in achieving sustainability targets. Ship recycling contributes significantly to reducing the demand for emission of intensive mining of iron ore and new steel production through steel scrap. However, the equipment of ships is currently underutilised, considering their potential for reuse, remanufacturing, and repair.

This project, therefore, aims to tackle this gap by developing a circular economy approach for the maritime industry through i) identifying the barriers to the successful implementation, ii) mapping the high-value and high-risk items onboard ships, iii) identifying the current and potential reuse, remanufacture and recycle rates through investigation of the market iv) identification of technology solutions and creating the overall structure for software and hardware to support the end-of-life strategies for high potential and high-risk items.

The problem (max 200 words)

While the circular economy concept has become more prevalent in other industries, including the automotive and aeronautical transport modes, shipping presents a mixed overview (Gunbeyaz, 2019, McKenna et al., 2012). The maritime industry focuses on the recycling step only when considering the circularity, and equipment from ships is currently being underutilised in terms of their potential for reuse, remanufacturing and repair due to the significant barriers in the maritime sector. In this project, we first focused on these gaps and obstacles to investigating the reason behind this low utilisation through different perspectives, which also created the background for other tasks of this study. Following issues have been identified in the maritime industry

Conflict of interest between the stakeholders,
Working conditions of the ships (long life, change of technology, impact of sea and cargo),
Lack of logistics for the circularity,
Regulatory barriers (changing rules, rules preventing reuse/reman, import bans in some countries),
Perception of the industry members (owners/yards do not favour used equipment,
The lack of transparency (equipment lists etc. are not known),
Lack of understanding of the maritime industry (as above, recycling is understood as circularity or "net-zero" efforts mainly focus on the operation stage).

Therefore, this project investigated these issues to understand the actual scale of the problem developed a questionnaire, and interviewed the stakeholders to know if these issues could be overcome. To overcome these issues, potential solutions to set the maritime industry base were then discussed. By establishing a focused circularity behaviour, the maritime industry can close the loop and reach its goals of net zero by including the actual "full life cycle" rather than limited steps.

The approach (max 100 words)

This project first conducted a comprehensive literature review. Then, current and potential reuse/remanufacturing/recycling rates were discovered through a circular economy focused questionnaire, face-to-face interviews with stakeholders and the authors' own experiences. Different stakeholder-specific questions are designed in the survey, and the results are analysed accordingly. Following the questionnaire, a real case study is included, which demonstrates a great example of engine remanufacturing with the collaboration of ship owners, OEMs, and authorised dealers. In the final part of the study, strategic, software and hardware solutions for tracking maritime assets and onboard equipment are investigated. Following this, an overall database structure is developed and suggested as an agile solution convenient for quick implementation.

Novelty (max 100 words)

This project is the first detailed study to focus on the issues of the maritime industry in depth, starting from industrial barriers and valuable components on board to investigating current applications in detail and analysing the viewpoints of industry stakeholders to seek strategic and technological solutions ultimately. This project is also the first to suggest a holistic solution that will rapidly move the industry forward: the database solution that covers all the maritime industry's stakeholders to track up-to-date equipment and component information on marine vessels. On the other hand, this project's suggested solution can only be successful with the involvement and incentives of the policymakers and an industry-wide approach to the supply chain.

Results (max 500 words)

This project has been achieved through four main tasks:

Task 1: identifying the barriers to the successful implementation, and Task 3

Industrial barriers are identified mainly as;

- *The life cycle of the ship,*
- *Disintegration through the life cycle and no-feedback mechanism to the design stage from the end of life*
- *difficulties in the core collection – reverse logistics,*
- *core quality,*
- *lack of standardisation,*
- *lack of appropriate skills at obtaining cores at recyclers,*
- *lack of means for keeping accurate inventory for the yards,*
- *demand requirement for sustainable remanufacturing business,*
- *perception of the industry towards reuse/remanufactured items*
- *not a good design for remanufacturing (DfRem) focus.*

Legislative barriers:

- *regulations do not oblige remanufacturing,*
- *lower awareness levels of local authorities,*
- *high tax on labour in developed countries,*
- *lack of commitment from classification societies,*
- *certification,*
- *and potential conflict of interest for OEMs.*

Questionnaire results to identify the barriers and opportunities
25% of the participants have never heard of the circular economy concept before.

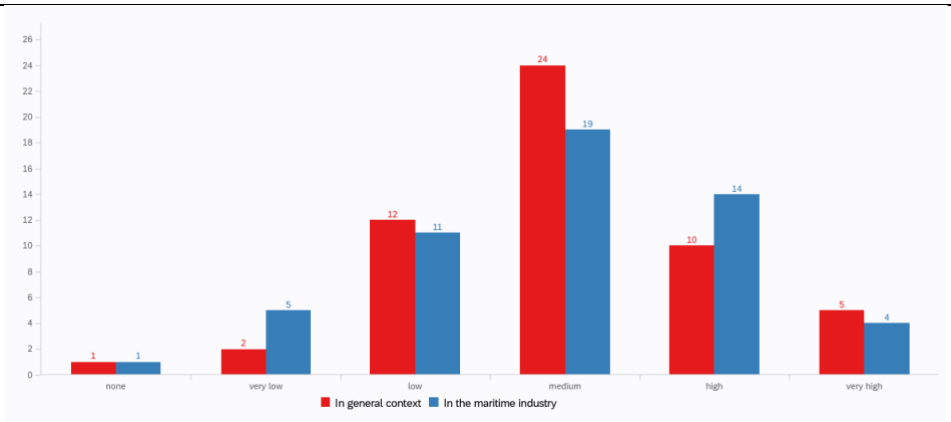

Figure 1: Familiarity with CE

Further in the questionnaire, 41% of the participants stated that they would prefer remanufactured components on their vessels, while 41% said it would depend on the incentives. The rest strictly rejected the idea.

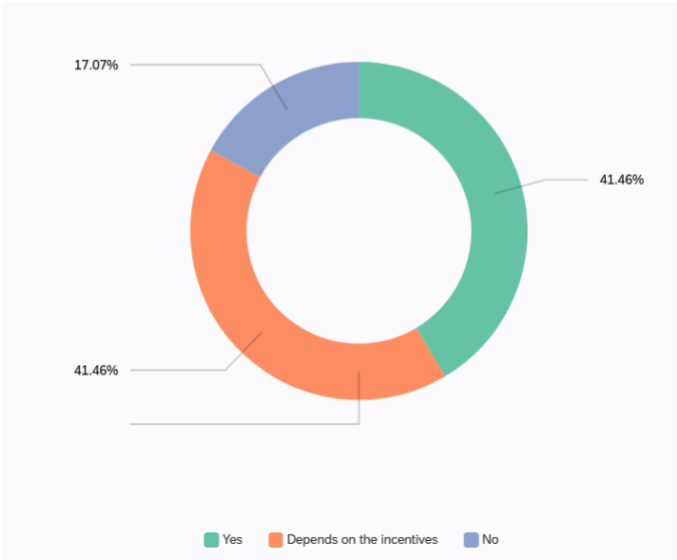

Figure 2: Would you use remanufactured components on the vessels?

The main factors making remanufactured products preferable are discovered as warranty from OEMs, more economical than new alternatives, aftersales support and legislative incentives. These factors constitute 84% of total importance in respondents' eyes. Moreover, there is a high willingness amongst researchers and manufacturers of the industry as 81.8% of them intend to take a further step to focus on RRR. Only one-fifth of the researchers from academia and professionals from OEMs stated that they have ongoing studies for design for remanufacturing.

On average, the expected savings on the acquisition cost with remanufactured components is around 35%.

When presented with the opportunities, our survey showed that the industry might prefer the RRR goods as 90% of the participants who rejected and were tentative respondents for remanufactured products stated that they would choose remanufactured products if they offer the same reliability and quality as a newly manufactured alternative. Remanufacturing and reusing practices are already underway in the industry, triggered mainly by OEM initiatives. They stated that the most significant challenges in collecting core parts are demand from the market, know-how gap at recyclers, regulatory barriers, and lack of marketing opportunities, in descending order.

Task 2: mapping the high-value and high-risk items onboard ships

This task identified the case study item on which part to focus as a demonstration case. First, we have conducted a desktop study and identified high value and high-risk items (in terms of RRR processes) onboard a ship (Supported by the questionnaire and through validation by experts).

Task 3: Case study - Developing EOL Strategy for Marine Engines We also investigated the current circular economy metrics, such as reuse- remanufacture-recycle (RRR) practices, adopted by certain maritime engine manufacturers (OEMs) worldwide. After that, we involved an overview of the engine remanufacturing process in the maritime industry, followed by a case study of remanufacturing the main engine.

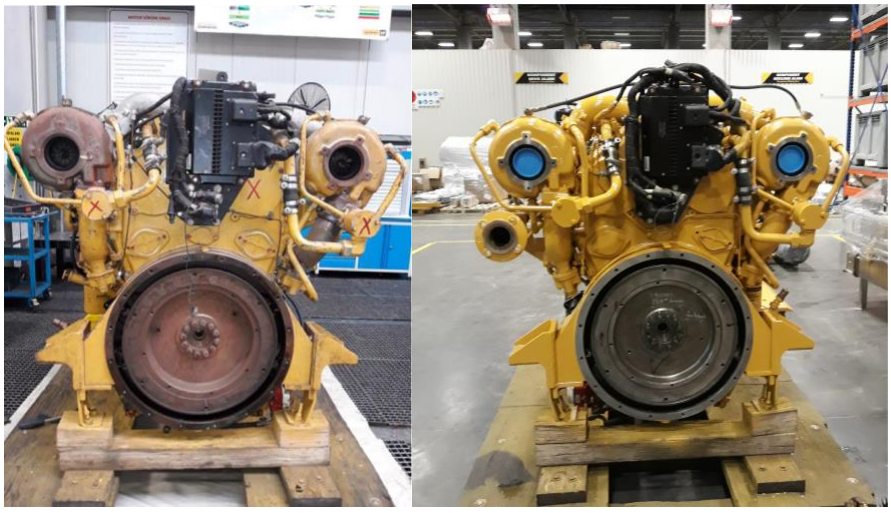

Figure 3: Before-after the reman process

Task 4: Identification of solutions
Several strategic and technologic (hardware and software) solutions are examined for tackling the barriers and creating the overall solution structure. Some of the strategies are closed-loop supply chains (CLSC), Seeding, Take-back strategies (trade-ins), and Product Service System (PSS). Software solutions: Industry 4.0, IoT, Big Data Analytics and AI, Digital Twins, Database and Blockchain, and Smart Recovery Decision Making (SRDM). Hardware solutions: various sensors, RFID and QR codes.

Strategic and technological solutions, whose details were given above in this section, are concepts applied to different extends in various sectors today - in manufacturing and remanufacturing operations. However, due to the many barriers and complex nature explained in previous sections, the global maritime industry only utilises the mentioned advanced systems to a limited degree. They depend on individual or

internal studies of organisations that take the initiative. The strategic solutions presented in this section can be used as a guide for remanufacturing OEMs to supply cores and implement advanced technological applications. However, from a holistic point of view, as a solution that will rapidly move the industry forward, this study suggests a database solution that covers all the maritime industry stakeholders to track up-to-date equipment and component information on marine vessels. The proposed database consists of tables, relationships between tables, forms, queries and reports.

Key finding 1 (max 50 words)

Even though currently, circular economy is widely perceived as recycling amongst various stakeholders, when explained, the stakeholders find more advanced circular economy principles – such as remanufacturing, reuse, reconditioning, etc. quite favourable. There is a considerable gain potential for ship owners, OEMs, recyclers and almost every stakeholder in the industry. With higher awareness levels, remanufacturing business, in particular, could ace.

Key finding 2 (max 50 words)

Many technology solutions are available that would benefit from tracking vessels and onboard components. The easily applicable database solution suggested in the study would form an excellent basis for future improvements while enabling all the features desired at the beginning of this research.

Testimonial from ECR/project team (max 500 words)

First of all, we would like to thank the CENTS group for providing us with the chance in this project. As an early career academic, this was my first independent project, and I, Sefer Gunbeyaz, have improved my knowledge on the subject thanks to this project. Although I have been working on the end-of-life aspects for the past eight years, this project helped me develop a further understanding of this area.

As part of this project, we were able to contact researchers, policymakers, industry experts and other stakeholders to identify the issues, barriers, opportunities and challenges in this area. Although we were familiar with previous studies on the end-of-life aspect, some problems identified were new to us.

In this report and the extensive report, we have emphasised that the maritime industry's understanding of circularity is mainly on recycling. This was also prevalent in our group, and this project enabled us to understand the fundamental approach in similar industries and the bigger picture.

Our research on this topic showed us that the Circular economy should not be a question of "if" but it is a "when" for the maritime industry considering the vast scale of the industry and the benefits it is going to bring. On the other hand, the barriers in the industry are highly complex in a way that none of the stakeholders can address on their own. This has proved that in the next step, we will need to involve different stakeholder groups to overcome these issues, especially the regulatory barriers. The involvement of high-level policymakers is a MUST to achieve the ambitious aims. To create this awareness, industry-wide campaigns are necessary as well.

Our efforts also demonstrated that the current supply chain of the maritime industry is nowhere ready for the reverse supply chain to complete core collection, take back strategies or circular economy hubs. These will need to be addressed shortly.

Furthermore, during the investigations of this project (along with COP discussions), we have realised that the maritime industry's approach to net-zero is not also covering the requirements of the circular economy. Currently, decarbonisation focuses on mainly the operation stage and alternative fuels, but the efforts on the production stage are very limited. This project also changed our perspective in terms of the approach to the circular economy, and we will investigate the energy side of circularity, especially in production.

In conclusion, this study has demonstrated to us that the maritime industry is way behind the other transportation industries, and without an industry-wide action, the massive potential of the industry towards sustainability will be wasted. Especially in the UK, strong collaboration links are required to create expertise within this area and pioneer the developments within the area.

We want to thank the CENTS Circular Economy Network+ in Transportation Systems group for the opportunity provided with this funding. We are looking forward to working with the group on future projects.

Testimonial from Industry partner(s) (max 500 words)

Have the project, and its findings had a beneficial impact?

Impact (max 200 words)

Wider applications and beneficiaries

Next steps (max 200 words)

*Future research directions, publications, follow on funding achieved**
In addition to the above tasks, we have been conducting additional activities for stakeholder interaction. We have attended the below events for dissemination as well as to contact the stakeholders;

- *Shaping the Future of Shipping – International Chamber of Shipping, Technology and Innovation Centre– Attended by very high-level stakeholders of the maritime industry, including the International Maritime Organisation, Various Class societies, shipowners, government bodies and NGOs.*
- *SHIPPING POST COP26 - AN INDUSTRY FOR TOMORROW'S WORLD: 11 November, Hosted by MALIN Group*
- *4th Global Conference on innovation in marine technology and the future of maritime transportation – Abstract submission and presentation: Circular Economy Approach in the Maritime Industry: Barriers and Opportunities, Dogancan Okumus, Sefer Anil Gunbeyaz, Rafet Emek Kurt, Osman Turan*
- *7th International Conference on Ship and Offshore Technology – Invited speaker: Workshop on Greener Shipping, Dr Sefer Gunbeyaz: Circular economy in the maritime domain: path to sustainability*
- *Abstract submitted to 9th Transport Research Arena TRA Lisbon 2022, Portugal: Circular economy approach in the maritime sector: Barriers and the path to sustainability, Dogancan Okumus, Sefer Anil Gunbeyaz, Rafet Emek Kurt, Osman Turan – Full paper development in progress.*

As a next step, Mr Dogancan Okumus, who is doing his PhD on this subject will take some of the tasks as part of his PhD further. He will investigate the closed-loop supply chain and database approach for

the maritime industry, and he will work on developing circularity metrics for the industry to complete a framework for the marine industry.
In parallel to this PhD study, we will look for further funding in this area to realise the goals and address the gaps in the industry. I have started preparing a New Investigator Award, which aims to take the ideas and solutions proposed in this project further with research and practical applications. I will contact the the CENTS group for potential discussions and involvements in this proposal.

It was also clear that the design approach of the maritime industry is not suitable for the remanufacturing methods. Hence, we will revisit our past efforts on design for x concepts since we have a better understanding thanks to this project.

Renewable energy is one of the pillars of the Circular Economy concept. However, this aspect is currently overlooked, and there are no extensive studies on it, which is a big gap that is worth investigating in future research. We aim to combine this with the decarbonisation approach and electrification of the manufacturing. We have already approached a shipyard on this, and put in a proposal to the internal University fund (impact fund). Although it was rejected, we were encouraged to expand the scope, and we were suggested with a better fit.

In addition to the above, we are aiming to develop two papers on this subject:
- *One paper summarising the gaps identified in the CE approach*
- *A second paper focuses on the solutions and their potential use in the maritime industry.*

*CENTS team will be in touch towards the completion of the CENTS project (end of 2022) to update the impact section