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The Flow of Sustainability Information Through Interorganisational Shipbuilding Ecosystem

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ABSTRACT

Marine industry is a complex and unique field of industry with a single shipyard having a supplier network of possibly over a thousand separate tier 1 suppliers and contractors. While the European Corporate Sustainability Reporting Directive (CSRD) regulation will create pressure on the bigger companies, the need to supply the environmental information will be passed on to all levels of the supply chain. When discussing the sustainability of the cruise ship construction process, including but not limited to environmental impacts, it is essential to understand the complexity of the value network and its possibilities to utilise Life Cycle Assessment (LCA) information sharing in the interorganisational network. This paper presents a qualitative study of various shipbuilding network companies. In the interviews, a number of company representatives with expertise in sustainability, LCA, business processes, and information systems were present. The aim was to gather the information from the participating companies' understanding and knowledge of LCA and sustainability information in general, existing sustainability information, methods of acquiring sustainability information, standards and practices used, data quality, quantity and formats, and the internal flow of data through the company processes. The level of knowledge about environmental matters varied significantly among the interviewed companies. This is natural as the interviewees represented actors from different stages of the supply chain and the companies varied in size. The companies had various amounts of environmental data gathered either from their own suppliers or other data sources such as open emission databases for materials. Some of the mutual challenges recognised were lack of common naming systems and missing automatic data flow.

Keywords: Sustainability information, Environment, Carbon footprint, Marine industry, Information systems, Ecosystem

INTRODUCTION

While the marine industry's sustainability focus often lies in the operational phase (Ramoa et al., 2020), there is room for improvement in increasing the involvement of the design and construction sectors, as well. Because of

the harmful effects of climate change to nature and people (IPCC, 2023), it is important to minimize emissions across all sectors. In particular, shipbuilding industry uses a lot of steel, which creates heavy environmental impacts. In order to drive the development to a more environmentally friendly direction, accurate data is needed for good decision making.

When discussing the sustainability of the cruise ship construction process, concentrating on the environmental impacts, it is essential to understand the complexity of the value chain. The complexity of the value chain and the fact that the production is highly customized creates challenges for the interorganisational information flow (Strandhagen et al., 2022). This research is part of a larger research project focusing on sustainability of shipbuilding. The aim of this work is to study the availability and flow of sustainability data within a ship's value chain concentrating on the environmental impacts.

Based on previous studies and researchers' follow-up of the marine industry, the capabilities for generating and utilising sustainability information are still not ready to affect the overall market (Jokinen, Mäkelä, Heikkilä et al., 2022; Haaja & Saarni, 2023). The earlier studies focused on the project partner network and collaborative insight sharing on sustainability development. The results of the earlier research showed the need for more open and diverse information flow and sharing among project partners (Jokinen, Palonen, Kalliomäki et al., 2020). Since then, some improvements have taken place, and sustainability perspectives are gradually more often included in communications within the industry – for example sustainability reports (see e.g. Meyer Turku, 2022).

BACKGROUND

Motivation

Even though there has not been mandatory reporting of the environmental effects of shipbuilding, the need for such reporting will arise from the new corporate sustainability reporting directive, CSRD (Directive 2022/2464), which will require large companies to report their sustainability indicators including effects on climate change. This will cause reporting needs to propagate through the value chain. To be able to fulfil the reporting requirements, a certain degree of digital maturity is a necessity (Svensson, 2023).

CSRD strengthens the existing European rules, and it considers three pillars of sustainability including environmental, social and governance (ESG) information. It is anticipated that the number of interested users of information on sustainability will grow with the necessity of a transition towards sustainability in all aspects. New reporting standards are likely to create new costs for the companies, but on the other hand, the positive changes resulting from standardised, comparable and verifiable sustainability reports are expected to take place primarily in the companies themselves. (Odobaša & Marošević, 2023). Other drivers for producing and acquiring more data on environmental effects could be needed for green funding, where EU taxonomy (Regulation 2020/852) has to be applied.

A ship consists of thousands of parts and different materials. When the requirements to evaluate the environmental impacts of the shipbuilding company or the ship arise from the CSRD, data for the evaluation will be needed from different suppliers and material producers. The environmental effects, especially carbon footprint, can be approached using generic data or more product specific data. The more generic data is used, the less precise is the calculation result. Also, the development work done for the more environmentally friendly materials or manufacturing methods will not be visible in the calculations. Hence, it is good to use as much specific data as possible. The challenges come from the large amount of materials, getting the relevant data and lacking emission data. Each producer adds something to the product's emissions so the data flow through the ships value chain needs to be fluent for the ship builder to receive accurate data.

In an ever more globalising world, it is harder and harder to compete with mere price, and the materials, methods, premises, conditions, and values used to build various industrial products can vary immensely depending on where the product is made and by whom. Moreover, consumers have become more aware of sustainability issues, thus requiring more from their cruise providers, and thereby pressuring the shipyards and their networks to improve their sustainability practices (Han, Lee & Kim, 2018). For example, in the recent Cruise Ship Interiors Awards, the Sustainability Award winner voted by the public was NIT Naval Interior Team for Carbon Footprint Calculation for Ship Interiors (CSI Awards 2023, 2023).

Within the marine sector, there is much desire for sustainability innovations that have a positive impact on efficiency of products and processes through reduced use of raw materials, energy and resources as well as fewer emissions. Companies are expected to gain competitive advantage with the sustainability information flow as they can create added value to their products in global markets. Launching sustainable offerings is an efficient way of exploiting opportunities associated with the growing number of customers that are concerned for the environment. The transparency in sustainability-related issues (including HR and work safety) is expected to give competitive advantage not only in the marine sector but also in other areas of the manufacturing industry.

Sustainability Information

Sustainability is a wide-ranging topic that includes three pillars: environmental, social and economic. All these pillars have their own subcategories, describing various aspects, and information related to any of these aspects can be classified as sustainability information. Therefore, the amount of the sustainability data is enormous, and to gather business' all sustainability information is a huge workload. In some cases, data collection can be extremely challenging or not even possible, and sources of secondary data have to be utilised.

One way to describe environmental impacts of a product is the Environmental Product Declaration (EPD). The requirements are outlined in ISO 14025 standard and, in practice, the building products' EPDs in Finland,

like Europe in general, are made according to the EPD standard EN15804 (International Organization for Standardization, 2006a; European Committee for Standardization, 2019). General framework and requirements of LCA are defined in ISO 14040 and 14044 standards (International Organization for Standardization, 2006b; 2006c).

Even when only one aspect, such as carbon footprint, is evaluated, the data collection can be demanding. Calculating the carbon footprint can require information for example about materials and components used, energy consumption, transportations and direct carbon emissions, depending on the defined system boundary (see World Resources Institute and World Business Council for Sustainable Development, 2011). Some of the data must be obtained from suppliers, while the remainder relies on the business' internal process data. The workload can be substantial, as information must be gathered from different sources. It is also possible that suppliers do not have sufficient data about their products, which causes a challenge in data collection.

When expanding the scope of sustainability evaluation to include other aspects, the data requirements and workload are increased exponentially. Sustainability calculations and passing sustainability information is a time-consuming effort and task in addition to the overall process of the organisation. As CSRD reporting becomes mandatory in the future, initiating the collection of sustainability information early on is advantageous.

The collection and evaluation of sustainability data are crucial in order to quantify business' sustainability performance. Once hotspots are identified, it becomes easier to pinpoint where actions are most urgently needed. To reach environmental goals such as a carbon neutral cruise ship and shipyard, also smart technology and process innovations must be taken into use. Digitalisation gives tools for improved data collection and analysis, information sharing, and knowledge distribution within the shipbuilding network.

Sustainability Information in Interorganisational Ecosystem

Almost every company possesses data, practices, and tacit knowledge that can be identified, formulated, and brought forward (made explicit) as measurable sustainability information. In the shipbuilding network, sustainability data sources are distributed horizontally and vertically. Horizontal distribution refers to the heterogeneous set of supplier companies and their dedicated suppliers in *lower tiers*. Suppliers who control relatively wide supplier networks themselves can find it difficult to provide the sustainability information of their products to their clients due to the multitude of sources, data types, and standards.

Vertical distribution refers to the various business functions of a single company. In manufacturing, this refers for example to quality and efficiency of materials, use of energy, and workforce related practices. In addition, every shipyard has some sustainability-related information in existing reporting practices, such as Inventories of Hazardous Materials according to Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (International Maritime Organisation, 2023).

Distribution of this data requires interfaces from system to system and from person to person, either digitally or manually. In order to distribute the sustainability information to an ecosystem network, both organisational and interorganizational, as well as intranetwork and extranetwork interfaces must be working (Baraldi, Gressetvold & Harrison, 2012).

These interfaces are required to have understandable and reliable information transition between the receiver and sender, both human and machine. Hence, the technical solutions required include determining data types, data reliability information according to different types of sustainability data sources as well as information standardisation. The data storages, data upkeep, and data life-cycle must be also commonly - if not agreed upon - at least understood (see e.g. Baraldi et al., 2012). Also, on a human level there should be work done in determining the organisational work processes around the sustainability data as well as interorganisational information sharing protocols and procedures. The organisations connected to the network and those working with the network organisations should have a clear understanding of the information and the methods of receiving and conveying information.

Due to the nature of the shipbuilding ecosystem, many of the suppliers in the supplier chains supply also outside of the network thus possibly having to have multiple different interfaces. Moreover, some tier 2+ suppliers may be reluctant to adapt required sustainability information interfaces for various reasons including but not limited to costs. It should be noted that accessing different data sources is not only a technical question. Organisations tend to be protective about data and information they have produced themselves and restrict the access even from the closest business partners. It is also possible that the value of the data is not recognised and therefore interfaces for accessing it have not been implemented.

METHODOLOGY

The data was gathered through six interview sessions from the Finnish shipbuilding network (hence participating companies) where a number of company representatives with expertise in sustainability, business processes, and information systems (IS) were present. The aim was to gather the information from the participating companies' understanding and knowledge of LCA and sustainability information in general, methods of acquiring sustainability information, standards and practices used, data quality, quantity and formats, and the internal flow of data through the company processes. The willingness and ability of the company to modify the existing information systems to better provide for internal and external flow of sustainability information and incorporating the sustainability information to the product information was also under inspection.

The interviews were semi-structured, with questions about LCA and IS. Additionally, the interview included 17 more or less open questions selected through a meticulous analysis of the current situation and experiences gathered from previous projects. During the interview the IS structure, ERPs (enterprise resource planning), EPDs (Environmental Product Declarations),

and other related documentation and functionalities were reviewed and discussed. The interviews were recorded and several notes were made during the interview. This material was analysed, and through deductive logic several results could be obtained from both company and ecosystem level.

RESULTS

Knowledge About Environmental Impacts

The level of knowledge about environmental matters varied significantly among the interviewed companies. This is natural as the interviewees represented actors from different stages of the supply chain and the companies varied greatly in size. Consequently, the potential regulations, as well as the demand and need for environmental information created by customers, also differed among the companies.

As regards the topic of LCA standards, awareness of these was generally very limited among the companies. Experience with broader LCA calculations was almost non-existent, which meant that the LCA standards were also unfamiliar. Consequently, there was no knowledge of calculation standards or guidelines used by other companies in the supply chain, except for EPDs. Some companies had commissioned EPDs for specific products or product categories. However, these were carried out by third parties, so the understanding of the matter was obtained from outside the company itself.

Especially in the case of larger companies, understanding their own and their supply chain's impacts was considered important or at least a subject of interest. This is natural already due to CSRD, which will, starting from the year 2024, require larger companies to report on the social and environmental risks their activities pose and their impacts on people and the environment. For smaller operators, understanding of their own impacts mainly revolved around carbon footprint, and they hadn't even considered the broader group of impact categories.

Although the understanding of environmental matters varied and was generally quite limited, what united all the companies was their interest in these issues. Overall, they had a willingness and interest in learning about sustainability matters and their implementation, whether the motivation stemmed from tightening regulations, gaining a competitive advantage, or achieving economic benefits. Regardless of the source of motivation, interest is a positive sign and, above all, a prerequisite for development.

Despite the positive and curious attitude towards environmental matters, the question regarding the value of such information was also raised. Developing and creating environmental information for a company's products and activities needs resources and creates costs. The environmental data needs to create value for the company, either by being able to provide data for a customer, who is requiring it, or creating new business based on it and being able to use it in marketing.

Besides environmental data, several companies mentioned quality standards and even social responsibility was brought up by one company. Practically, the only environmental indicator in the discussions was the carbon

footprint. In cases where EPDs exist, there are many other indicators also available, describing e.g. resource use, acidification and eutrophication.

Existing Data

The materials used by the companies are generally well documented, as there is price for all materials and components. The material data is often included in ERP systems. There is still a large variation in how well the material data is transferred within the company from the customer order to the database and in many cases manual work is applied to transfer the information. There are no global (or even national) naming systems agreed on, which would help exchanging the material data digitally.

The environmental data regarding any product or operation comes from the earlier phases of the production chain, called upstream. Besides the upstream data, depending on the scope of the environmental evaluation, also the rest of the life cycle of a product can be evaluated. This could include the process of taking the products in use, the use phase and everything that happens in the end of life of the product.

The companies in the shipbuilding value chain have very different amounts of environmental data and are in different stages of environmental maturity and understanding. Some material producers have published many EPDs, some companies have evaluated some of their products and some have made calculations based on generic (average) data available in commercial and open source databases. The value chains in the ship industry are fairly long, and therefore linking the environmental data throughout the entire value chain would bring benefits for all value chain members. However, producing the environmental data always has a price and there is a question of how to make it (financially) beneficial to provide environmental data.

To include in the life-cycle assessment of a ship all or substantial portion of its materials is not an easily reachable goal as the data would have to cover a large number of (partial) products from several suppliers. Instead, it is easier for the value chain member companies to concentrate on obtaining the information as regards the main suppliers and product groups only. In particular, each company can try to resolve the environmental data coming from its immediate upstream partners based on e.g. the purchase information of bought products.

Data Sources

Several existing and theoretical data sources were identified during the interview process. Even though the information systems were in some cases quite unsupporting of the data collection process, the sustainability information was gathered from both inside of the organisation, bought from consultants and retrieved from contractors. In addition, other data sources such as EPDs and general databases had been recognized as vital information sources by some companies.

The acquisition of data was tedious at best. The information was usually not readily available and even if the knowledge on how to acquire new data was in some cases high, the level of manual labour concerning the gathering

and upkeep of LCA information about a single product was highly time-consuming. In one case, if readily made confirmed EPDs were not available, all products were manually calculated from their components and materials by the company to generate the LCA information required for the assessment. In the cases where EPDs were available, they usually resided in the web-pages of the producing company or in EPD databases, from where the information had to be transferred to the participating company's systems manually.

In most cases though the lack of data was accepted due to both the costs and the fact that the data was simply unavailable upstream of the network. In some cases, the problem of being environmentally friendly was bluntly described only as 'rhetoric to be used, when people start talking about costs'. In the light of this observation, it is fair to say that companies need a concrete driver, such as monetary compensation or legislation, to actually invest in environment conscious activities on a larger scale.

Social metrics, such as safety, health and wellbeing, ethics transparency and open communication, corporate governance, economic responsibility, and customer satisfaction were monitored in all companies. However, these were not brought up in the discussion of sustainability issues, except once. Clearly sustainability is most often understood as evaluating environmental impacts.

Internal Flow

Due to the siloing of data and information (see e.g. Fallmyr & Bygstad, 2014; Hylving & Bygstad, 2018; de Waal et al., 2019) in various information systems in many of the participating companies, intraorganisational interfaces concerning sustainability data have a tendency of being handled with manual labour.

In some cases where information system solutions in use were not all-covering ERPs but the sustainability information is stored in excel sheets and PDF formats. Hence the flow of the sustainability information was being restricted within the organisation making interorganisational information exchange cumbersome at best. In addition, the interfaces receiving new data concerning sustainability information were in most cases not connected to product information but rather were placed in separate information storages.

Some companies were quite active in the process of generation of new data. Yet that information tended to have a limited connection to the product information itself in IS level and was handled through manual work. Even though in many cases this manual work is not cumbersome, it is more susceptible to human errors and is not as updatable as automated flows of information.

DISCUSSION & CONCLUSION

All the companies involved were interested in sustainability and had a basic understanding of the topics, such as carbon footprint, LCA or EPD. Still the variation was great regarding the available LCA data and only one company had made EPDs. One of the biggest questions was how to make the management of sustainability information economically feasible. One of the companies had solved this by creating business around gathered environmental data.

The drivers for collecting and creating LCA data of a company's products are mainly requirements from their customers, legislation or finding ways to benefit from the data. The bigger companies will be subject to the CSRD reporting, which creates a need for understanding also the effects of their value chain and hence affects also the smaller companies. Small and more specified companies may have hindrances and obstacles in collecting environmental data, and replacing some of these in the shipbuilding network might be impossible. This makes it difficult to require more environmental data especially from small companies as it doesn't come without effort and cost.

The main challenges for the environmental information flow, were the complexity of the shipbuilding value chain, lack of good quality environmental data, motivation and cost of creating and operating environmental data, incoherency in naming and coding and not having systems within and between companies, which would enable automatic information flow.

Even though the companies were interested in implementing the sustainability information exploitation to the business processes, their levels of knowledge, data, data sources, and information system capability vary immensely. In many of the companies' information system renewal projects were started and the results should be visible in the coming 1–2 years.

The tendency of the data to be available only from some sources was seen as challenging and even demoralising for the whole sustainability development process. While the company might have been active in environmental issues, the lack of information from their contractors conflicted with their mission of bringing accurate sustainability information about their products.

The lack of uniformity in what and how the sustainability information within the network and the field should be gathered was seen problematic. The call for standardisation and common practices of naming, data gathering and delivery processes for enhanced automation repeated during the interviews.

The internal flow was often broken and a lot of manual labour was required to transfer the information gathered from the (sub-)contractors to the actual product or service information. The automation and interconnectivity of the ISs seemed to be lacking in many cases.

In addition to technical and operational solutions, collaborative social interaction among companies can provide means to enhance sustainability information flow within the network of companies. Information sharing and development initiatives can power joint company sustainability and the capabilities for responding to systemic challenges and reporting requirements. Sustainability information flow within the maritime industry networks requires collective actions and coordinated activities by a wide range of collaborators to achieve requirements and objectives of the ship. We acknowledge the importance of an authentic collaboration and knowledge transfer among partners for effective sustainability information flow.

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REFERENCES

Baraldi, E., Gressetvold, E., & Harrison, D. (2012). Resource interaction in inter-organizational networks: Foundations, comparison, and a research agenda. Journal of Business Research, 65(2), 266–276.

CSI Awards 2023 (November 30th, 2023), Home - Cruise Ship Interiors Awards, https://cruiseshipinteriors-awards.com/.

Directive 2022/2464, Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting (Text with EEA relevance).

European Committee for Standardization (2019). Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products, (European Standard No. EN 15804:2012+A2:2019).

Fallmyr, T., & Bygstad, B. (2014). Enterprise architecture practice and organizational agility: An exploratory study. In 2014 47th Hawaii International Conference on System Sciences (pp. 3788–3797). IEEE.

Haaja, E. & Saarni, J. (2023) Bringing Sustainability to Shipbuilding Through Supplier Integration – Findings from SusCon-project, CCR Insights 1/2023, Turku School of Economics, University of Turku 2023.

Han, H., Lee, M. J., & Kim, W. (2018). Antecedents of green loyalty in the cruise industry: Sustainable development and environmental management. Business Strategy and the Environment, 27(3), 323–335.

Hylving, L., & Bygstad, B. (2018). Responding to enterprise architecture initiatives: loyalty, voice and exit. In Hawaii International Conference on System Sciences 2018 (HICSS-51).

International Maritime Organisation (2023). Resolution MEPC.379(80) (adopted on 7 July 2023) 2023 Guidelines for the Development of the Inventory of Hazardous Materials. International Maritime Organisation, 2023.

International Organization for Standardization (2006a). Environmental labels and declarations, (ISO Standard No. 14025:2006).

International Organization for Standardization (2006b). Environmental management, Life cycle assessment, Principles and framework (ISO Standard No. 14040:2006).

International Organization for Standardization (2006c). Environmental management, Life cycle assessment, Requirements and guidelines, (ISO Standard No. 14044:2006).

IPCC (2023). Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1–34.

Jokinen, L., Palonen, T., Kalliomäki, H., Apostol, O., & Heikkilä, K. (2020). Forward-looking sustainability agency for developing future cruise ships. Sustainability, 12(22), 9644.

Jokinen, L., Mäkelä, M., Heikkilä, K., Apostol, O., Kalliomäki, H., & Saarni, J. (2022). Creating futures images for sustainable cruise ships: Insights on collaborative foresight for sustainability enhancement. Futures, 135, 102873.

Meyer Turku (2022). Sustainable Shipbuilding, Sustainability report 2022. Meyer Turku Oy 2022. Available at https://www.meyerturku.fi/en/05_sustainability/meyer_turku_sustainability_report_2022_web.pdf.

Odobaša, R., & Marošević, K. (2023). Expected Contributions of the European Corporate Sustainability Reporting Directive (CSRD) to the Sustainable Development of the European Union. Eu and Comparative Law Issues and Challenges Series (ECLIC), 7, 593–612.

Regulation 2020/852. Regulation of the European Parliament and the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088.

Ramoa, C. E. D. A., Flores, L. C. D. S., & Herle, F. B. (2020). Environmental sustainability: A strategic value in guiding cruise industry management. Journal of Hospitality and Tourism Insights, 3(2), 229–251.

Svensson, P. (2023). Implications of the CSRD on sustainability reporting: the need for digital maturity. Master's thesis, Kungliga Tekniska högskolan, Stockholm, Sweden.

Strandhagen, J. W., Buer, S. V., Semini, M., Alfnes, E., & Strandhagen, J. O. (2022). Sustainability challenges and how Industry 4.0 technologies can address them: a case study of a shipbuilding supply chain. Production Planning & Control, 33(9–10), 995–1010.

de Waal, A., Weaver, M., Day, T., & van der Heijden, B. (2019). Silo-busting: Overcoming the greatest threat to organizational performance. Sustainability, 11(23), 6860.

World Resources Institute and World Business Council for Sustainable Development (2011). Product Life Cycle Accounting and Reporting Standard.