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Adopting Systems Thinking and Systems Oriented Design Approaches to Make Industrial Organizations Aware of Novel Insights Related to the Sustainable Transition

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Abstract: Industrial organizations require action to be taken transversally in their hierarchy to align with the sustainable transition. Digitalization and systems disciplines may support these organizations in this regard. This paper presents how to bring the attention of top-management, engineering-management, and engineers to the implication of the sustainable transition. By means of tools and methods within systems disciplines, this work presents how to intermingle multiple silo's thinking across the organizational hierarchy and enhance rapid learning processes of new insights.

Keywords: Sustainable Transition, Systems Thinking, Systems Oriented Design

1 Introduction

National decision-makers are aligning their strategies and action plans with the international vision about the sustainable transition (United Nations, 2015a; United Nations, 2015b; Huttunen et al., 2022; Markard et al., 2012; Köhler et al., 2019; Norwegian Ministry of Climate and Environment, 2020). Industrial organizations are responsible about large quantities of Green House Gasses (GHG) emissions and are expected to reduce the environmental impact of their activities and processes while developing products, systems and services (Mehmood et al., 2024)(Markard et al., 2012). Rethinking the current practices require significant measures across the entire organization's hierarchy from top management to engineering level. Top management requires to assess and evaluate new scenarios and how they will affect the business. Engineers implement the new processes in their practices. However, altering managerial and engineering practices at the expected rapid pace is not trivial. There is a need to convey transversally in the organization hierarchy the implications of the sustainable transition for their business activity and their daily operations. The rapid enforcement of the sustainable policies, the related short-term deadlines, and the respective implications create, at the same time, potential opportunities and challenges for industrial organization. System disciplines, such as systems engineering, system thinking and systems-oriented design, are valuable methods that may support to overcome the mentioned challenges.

This paper showcases how tools and methods within systems engineering, systems thinking and system-oriented design may bring the attention of top-management, engineering-management, and engineers to the implication of the sustainable transition in Norway. The paper is based on a workshop related to a Norwegian industrial-research driven project. The paper extends the work of (Giudici et al., 2023) by presenting the findings with relative discussions. The objectives of this work are: i) explore the implications of the sustainable transition for Norwegian industrial organizations and ii) promote sustainable engineering decisions while developing products.

2 Background: the H-SEIF project

The Human System Engineering Innovation Framework (H-SEIF) is a Norwegian university industrial collaboration funded by the regional research fund, the Research Council of Norway, and industrial partners. The project aims to increase the competence of the industry partners for how to develop technologies suitable for humans and improve early-phase decisions by deploying digitization and (relatively) big data. The project entangles at its essence a system thinking and system engineering approach. It aims at building a systematic approach to systems development, such that the industry is capable of coping with the rapidly evolving socio-technical interactions. This project envisioned the need for "*developing a culture that fosters innovation applicable for humans*" (Dudani 2020) asserting that a fusion of system engineering with design thinking theories, centered on humans, could form the basis of the new framework. The "(…) *main goal is to create a framework for developing innovation using methods and tools combining design thinking and system thinking*" (Dudani 2020) (Kjørstad, 2022).

The H-SEIF is divided into two consecutive parts: Technology with Empathy (H-SEIF1) and the value of Big Data and Digitalization (H-SEIF2). The first part of the H-SEIF lasted from 2017 and 2020. "*The objective of the H-SEIF project is to develop the System Engineering toolbox to create concrete, tangible improvements for Norwegian companies and* *industries*” (Dudani 2020) (Kjørstad, 2022). In her work, Kjørstad (2022) adopts the H-SEIF approach to develop a new-energy subsea system. To this aim, the validation phase of the developing system was explored at the early stages turning competence in system thinking, system of design, and system engineering into valuable industrial results.

The second part of the H-SEIF strengthens its focus on how early project stages can benefit from (big) data and digitalization. Selecting appropriate strategies and methodologies to deploy data-driven decisions is fundamental to exploring breakthrough innovations. The academic foundation of the H-SEIF conceptualized and designed research approaches to support research-industry collaborations (Ali et al, 2022). For instance, Langen et al. (2022) adopted an innovative research-based approach for an industrial case study, an automated parking system. That study merged human-centered design, system engineering, and data-science principles to create a conceptual Data Sensemaking framework. Within the same context, Ali et al. (2023) studied how conceptual modelling and data science could be combined to improve the reliability of the same automated systems. They retrieved, collected, analyzed, and further conceptualized data from the system’s maintenance operations and weather conditions to assist the practitioners in performing their maintenance operations.

3 System disciplines, tools and methods

3.1 Systems Engineering tools and methods

Systems are composed by one or multiple constituents and the interactions between them (Backlund, 2000). The International Council of Systems Engineering (INCOSE) define Systems Engineering (SE) as a “*Transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods*” (Sillitto et al., 2019). Yet the same council presents in its Vision 2025 how systems engineering may facilitate aspects such as industrial automation and the sustainable transition (Beihoff et al., 2014). The systems engineering discipline studies systems, and systems of systems, within a wide variety of domains (Dahmann and Baldwin, 2008). Understanding such systems and systems-of-systems requires a detailed comprehension of technical and human factors and their potential interactions (Snowden & Boone, 2007).

Among others, two strategic tools used by systems engineers are the PESTEL framework and roadmapping. Developed by Gupta (2013), the PESTEL framework is a multi-faced approach capable to deal with multiple perspectives simultaneously. The perspectives comprehended in the PESTEL framework are: Political, Economic, Social, Technical, Environmental and Legal. This framework is widely adopted by organizations to depict potential opportunities and challenges from past, present and future scenarios (Gupta, 2013). Roadmap is a scheduling tool capable to support the journey towards the accomplishment of a goal within a given timeframe. After the goal to be achieved in envisioned, it is possible to set the action plan with relative time-schedule. Roadmaps may support projects in observing the evolvement of the action plan to potential alternatives in case obstacles and threats appears during the course of the work (Phaal et al., 2004).

3.2 Systems Thinking and Systems Oriented Design

When dealing with complex systems, or complex system of systems, system thinking approaches may support to map in an unstructured and unpredictable way the exploration of the intended system with creativity without altering the system's complexity. System thinking comprehends multiple tools to investigate the system complexity, such as system dynamics and gigamapping. Dynamic thinking enables the comprehension of the dynamic behaviours of the system's constituents' interactions (Bonnema & Broenik, 2016; Wettre et al., 2019). The gigamapping support the exploration of system's components (from mega to micro constituents), functionalities, ownerships, and finally supports the comprehension of un-explored patterns within the system of interest (Sevaldson, 2011). System Oriented Design is capable to navigate very complex problems in an agile way depicting potential tensions and not-sufficiently understood interactions. System Oriented Design approach consists of the following steps as suggested by the (Sevaldson, 2013).

Table1: System Oriented Design

<table>
<tr><td rowspan="7">System Oriented Design</td><td colspan="2">Gigamap</td></tr>
<tr><td rowspan="3">ZIP</td><td>Zoom</td></tr>
<tr><td>Idea</td></tr>
<tr><td>Problem</td></tr>
<tr><td colspan="2">Design</td></tr>
<tr><td colspan="2">Impact</td></tr>
<tr><td colspan="2">Reflect</td></tr>
</table>

The gigamapping is a descriptive process. The ZIP step may shift from the previous descriptive process to a more generative process by analyzing the map and finding the ZIP aspects of interest. Such aspects can be further investigated by generating new concepts, identify points of leverage where interventions can be designed or identify holes in the sensemaking process, that needs to be further elaborated. Impact Analysis, or Impact and Threshold (IMP), is a low threshold level analysis to investigate concepts, ideas, interventions and depict whether further analysis may be conducted (based on its value within the process). The reflection step brings the assessment and evaluation of the system boundaries with relevant criteria for inclusion/ exclusion (Midgley, 2000).

4 Methodology

On the 29th of November 2023, a seminar was held at the University of South Eastern Norway (USN) in Norway. The topic of the seminar was "Data for a Sustainable Future". The seminar was a one-day event divided into two sessions, in the morning and afternoon. A combined approach of system science's tools and methods have been adopted in this work. Table 2 shows the structure of the seminar.

Table 2: Seminar structure.

Session 1		Session 2
Key Note Speakers	Panel Discussion	Workshop

4.1 Session 1

Five keynote speakers took place in this session. The selection of the speakers followed the PESTEL framework. A panel discussion concluded the first session. In the panel discussion the speakers presented a roadmap about the potential opportunities and challenges for Norwegian industrial organizations to better align with the sustainable transition without compromising their competitiveness in the global market. The presentations showed the implications of the sustainable transition for industrial organization using a combination of roadmap and PESTEL framework.

Table 3: Session 1 structure.

Presentation	PESTEL Perspective
1	Political, Legal, Environmental
2	Economic, Legal, Environmental
3	Social, Legal, Environmental
4	Technical, Economical, Environmental
5	Technical, Environmental
Pannel Discussion	Roadmapping towards sustainable transition: opportunities and challenges for industrial organizations

4.2 Session 2

The Session 2 comprehended a workshop with hands-on activities. The workshop aimed to reflect on the previous session and apply what was learned in a co-creation session using industrial cases. The workshop was led by three facilitators and two context navigators. The two cases were based on context from two cases from two H-SEIF's partners. One of the facilitators briefly introduced the workshop. After that, the two context navigators presented each case by explaining the overall problem without going into details. The short presentation of the case studies ensured to have time for questions and discussions from the attendees. The attendees were divided in five groups of, approximately, six people. Then, one of the facilitators asked to each group to select a case study and have a visual dialog by co-creating a Gigamap. The dialog aimed to bring the sustainable perspective on the case study. After the participants got confident with their case study, they were asked to design an intervention in their case to spur in-depth discussion related to the sustainability topic. Such early design task aims to stimulate discussions in working groups that may lead to observing new aspects, or not obvious ones, within the case study (Sevaldson, 2022).

4.2.1 Case 1

This case is based on the value chain of plastic. A brief excursus from cradle to grave about the supply chain of plastics was explained to the participants. During the explanation of the case attention was given to the end-of-life processes, namely re-using, mechanical recycling, and chemical recycling with relative opportunities and challenges from the industrial perspective. The context navigator wished to get valuable insights for the ongoing project related to the case.

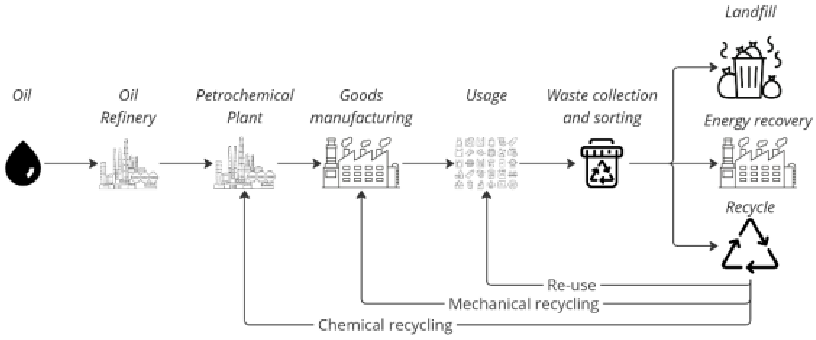

Figure 1 Case 1 Plastic value chain. Image credit Baard Røsvik. Reproduced with permission of the author.

4.2.2 Case 2

This case is based on the future installation of offshore hydrogen-producing stations storing energy from offshore wind farms. These hydrogen stations provide a stable renewable energy supply and the production of green hydrogen (Strange et al., 2023). The technicalities of the operation and some of the key stakeholders were briefly introduced using an illustration as seen in Figure 2. As in Case 1, the context navigator explained the technicalities of the case scenario. The context navigator aimed to explore the learning process and how seminar attendees bring in the case study the content of Session 1.

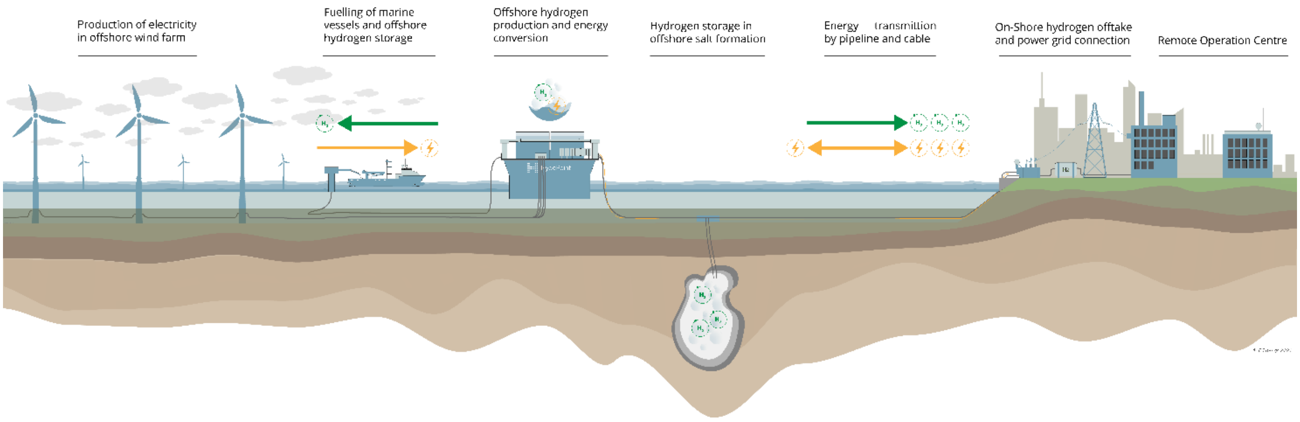

Figure 2 Case 2 hydrogen case study. Image credit: Espen Strange (Strange et al., 2023). Under attribution CC-BY-NC-ND 4.0 International License (https://creativecommons.org/licenses/by-nc-nd/4.0/)

5 Results

The content of session 1 can be resumed as follows: Norway is in line with international organizations, namely the United Nations and European Union, to reduce the GHG by 55% within 2030 and reach carbon neutrality within 2050. The enforcement of policies such as the Transparency act (Forbrukertilsynet, 2022), the EU taxonomy (EU, 2020) and Corporate Sustainability Reporting Directive (EU, 2023) contribute to the carbon neutrality vision. These policies requests accurate reporting assessments from industrial organizations regarding their practices and operations. Mangers and engineers need to assess and evaluate the environmental and social impact of their activities and alter the same towards more sustainable ones. Sustainability can be integrated inside the practices of the organization, especially in the development of products, systems or services, by improving resource management and product life-cycle management. Peculiar attention to these aspects should be given at early phase of product development where it has been recognized the highest impact for the whole life-cycle of the product, system or service. The use of (big) data and digitalization may support the integration of sustainability in the product life-cycle and yet explore ground-breaking innovations in a competitive way especially during the development and operations of products, systems and services. By means of the same tools, such products, systems or services can be operated in a way to reduce their environmental sustainable impact. Data related to environmental sustainability are needed to provide more sustainable decision-making. To collect such extensive sustainable data, especially when dealing with complex systems or systems of systems, there is the need to establish a collaborative customer-supplier relation where data are transparently communicated over the supply chain. This customer-supplier relation enhances easier traceability of environmental activities and the related reporting across the supply chain, namely GHG emissions, Scope 1, 2 and 3.

Between session 1 and session 2, the authors collected positive feedbacks, by informal qualitative assessments, from the attendees. Both managers (of any level) and engineers, express a positive opinion and interest related to the presentations and the related content. This can be defined as a positive result of the organization's session and how the PESTEL and Roadmap tools support the organization of session 1.

In session 2 five groups were working on the two study cases by means of SOD approach. The SOD is a mindset aimed at utilizing the combination of system thinking and design thinking in a practical oriented-design driven approach to investigate the complexity of systems. The process outlined in the SOD steps, are rarely followed linearly and furthermore they are adaptable in their nature, to allow the selection of the most suitable design methods appropriate for the complex care and/or process (Sevaldson, 2022b). The nature of complexity and systems thinking leads us to jump back and forth as the insights grow while working with the different steps. In the workshop the groups started to map the complexity of the case system applying a sustainability perspective. It was a fairly short session so the map was not extensive enough to need a ZIP process. Therefore after the initial mapping, the groups designed an intervention based on the discussions emerged through the mapping. They were assessing the relative impact of the intervention on the System. Finally, the groups made reflections based on the early morning discussions (Session 1) as well as the group work (Session 2). Table 2 resume the outcome for each group.

Table 2: Results of the workshop

Group	Case Study	Intervention	Objective	Direct implications	Indirect implications	Reflection on the intervention
1	Nr. 2	Produced energy for transportation purposes	Transportation at lower energy impact	Environmental	Social Economical	1.Sustainability as a tool for company 2.End-user involvement 3.Sustainability as collaborative approach
2	Nr. 2	Reuse of oil rig as a hydrogen facility Deployment of autonomous vessels from rig to on shore	1.Economic savings to be invested in sustainable economic activities 2.Improved safety Reduced environmental risks	Environmental Social Economic		1.Sustainability as a transdisciplinary need in the whole company 2.Economic perspective of sustainability
3	Nr. 1	Tag in manufacturing process to track plastic consumption and reuse	1.Comply with regulations 2.Improving reporting 2.Social awareness 3.Economical benefits	Environmental Social Economic		Data collection add complexity Data quality as priority
4	Nr. 1	Processes in Manufacturing	1.Investigation on how to include recycled material 2.Improved reporting during manufacturing	Environmental	Social Economical	1.Sustainability as a company mindset 2.System thinking to look at all the problem instead to a narrowed solution
5	Nr. 2	Dynamic tool to assess energy demand, energy price, and supply-chain data management	1.Improve understanding of the overall supply-chain	Environment Economic	Social	1.Holistic perspective 2.Useful to share specific insights

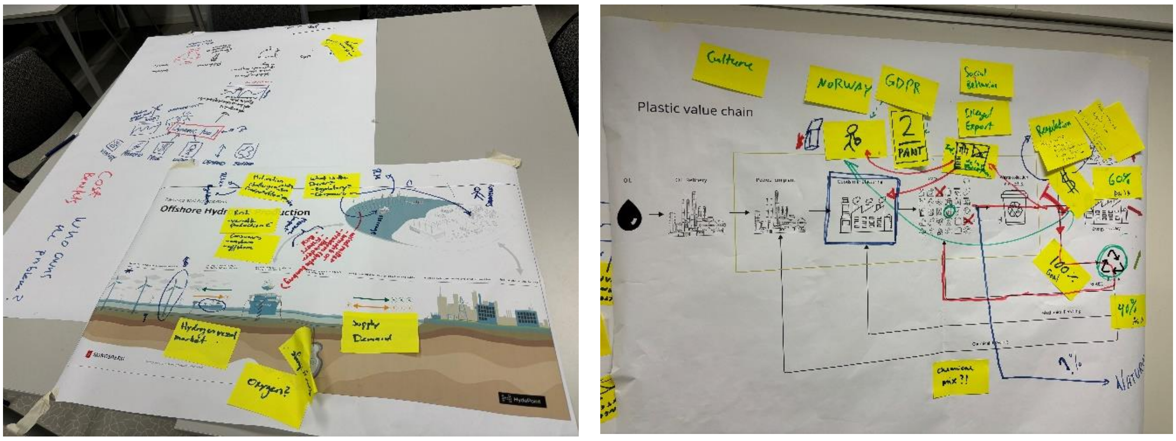

Figure 3. Gigamapping of case studies (nr.1 on right side, nr. 2 on left side).

6 Discussions

Top-management, engineering-management, and engineers were the main audience of this seminar. Managers and engineers are among silo-thinkers (Wettre et al., 2019) and are dislocated at different organization's hierarchy. The silo-thinking approach makes difficult to convey the same message across multiple silo-thinking (Wettre et al., 2019). This was a challenge related to the organization of the seminar. Systems approaches were adopted to overcome such challenge and bridge the silos-thinking in both sessions.

In session 1, PESTEL and roadmap frameworks provided to the audience the understanding of the implications related to the sustainable transition for the Norway industrial sector. Management, top and engineering ones, got an holistic view about the upcoming regulations, reporting schemes and how organizations' employees need to re-think and re-design their practices towards the sustainable transition. Recent research activity showed interest in this regard (Gaza et al.; 2024; Roustaei et al., 2024; Muller & Giudici, 2024; Giudici et al., 2024a; Giudici et al., 2024b; Giudici, 2024c).

Notably, there were multiple commonalities among the different speeches. The common aspects include: i) the need to environmental and social data; ii) better data-driven engineering decisions; iii) establish a collaborative environment between customers and suppliers; iv) more comprehensive assessment and evaluation of GHG emissions Scope 1, 2 and 3; v) a culture capable to attract new generation in industrial organization.

In session 2, the attendees digested the content of the previous session thought the use of a System Oriented Design approach, specifically the ZIP. There was observed an enthusiastic level of engagement from the attendees. The attendees openly and creatively reflected and discussed how to implement sustainability interventions in the two case studies. Given the study case, participants where actively jumping from topic to topic related to the case study. The jumping conversation helps to overcome the silos-thinking challenge enlarging the possibility to co-creatively exploring the case study and related intervention (Wettre et al., 2022). All the groups working in session 2 were able to successfully integrate discuss and reflect interventions focused directly or indirectly related to the sustainability aspects (environmental, social, economical). Thus, the SOD approach gave the possibility to co-create on the holistic perspective of the case study and to zoom on specific intervention looking on how data-driven solutions may overcome potential tensions and implement the environmental sustainability aspect in the case study.

The learning by doing process offered by the system oriented design introduced to the participants a way to work holistically with complexity and, at the same time, work in a design oriented practical way rather than focusing on technical silo-based thinking. The combination of such system discipline with data-driven approaches may supports the integration of the human dimension into the human-machine autonomous interaction (Nelson & Stolterman 2014)(Evergreen , 2023).

7 Concluding remarks

The presented case study is based on the implications of the sustainable transition in Norway. Systems disciplines and approaches may support industrial organizations while aligning their strategies towards the sustainable transition. At the same time these systems approaches can be adopted to support reason-driven and data-driven decision making. However, the results presented in this work are based on a single workshop. Further research is required to assess and evaluate the usefulness of the presented methodology.

In this work, common challenges were observed, specifically on the need from industrial organization to improve the data-driven decision making related to environmental (as well as social) sustainability. Such data are essential to assess and evaluate the practices of organizations related to GHG Scope 1, 2 and 3. This is of particular interest for the assessment of GHG Scope 3. GHG Scope 3 relies on the data shared between customers and suppliers. The interaction between customer-suppliers may be a potential challenge for retrieve the needed information. Establishing a cooperative and collaborative environment may support organizations, independently from their role (e.g. customer or supplier), to discuss and overcome these challenges. Organizations, characterized by different size and sector, may face similar difficulties that can be mitigated using similar methodologies, methods and processes. The presented systems engineering, systems thinking and systems oriented design tools and methods may help in exploring, assessing and evaluating the potential tensions and data-driven sustainability interventions while developing and operating socio-technical systems.

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