THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Perceived impacts of higher levels of automation within the European inland waterway transport: a socio-technical system evaluation

RANA SAHA

Department of Mechanics and Maritime Sciences

CHALMERS UNIVERSITY OF TECHNOLOGY

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RANA SAHA

Department of Mechanics and Maritime Sciences
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

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Abstract

This licentiate thesis presents cumulative findings from ongoing research analyzing the potential impacts of higher Levels of Automation (LOA) on stakeholder interactions within an Inland Waterway Transport (IWT) using Socio-Technical System (STS) frameworks. It has investigated three co-related research issues in three papers using different system theory methods.

The findings of the thesis suggest that with increasing LOA, the level of uncertainty in the resiliency of the STS is high given the near logarithmic growth of technology, artificial intelligence (AI) and machine learning (ML) which will have a profound impact upon the IWT ecosystem. Multiple actors are responsible for implementing foreseeable changes in the IWT STS. There are multiple roles and tasks/functions that are expected to evolve in this emerging system and being considered while designing futuristic system. There are gaps within the existing European IWT STS that need to be addressed for a smoother transition towards higher LOAs. The first step of defining the gaps is an in-depth analysis of current *work as done* (WAD) in order to elucidate on how to evolve to a *work as imagined* (WAI). As LOAs emerge in an operational setting the higher the level of system complexity will become. Illumination of WAI with standardization and becoming independent of human intervention at operational level can, perhaps, resolve these complexities. Yet, there will be necessity of human presence in the loop but more on supervisory and management level.

The future research work will investigate the preparedness of IWT STS from a user perspective, focusing on emerging concept of 'shift of command' towards Remote Operating Center (ROC) and ROC operators. It will also have the opportunity to investigate preparedness of IWT STS from maritime education and training (to build up the skillsets), legal (to enable and regulate the autonomous IWT), technical (to ensure safer than before), and business case (to make it feasible and sustainable) perspectives.

Keywords: Autonomous Shipping, Inland Waterway Transport, Socio-Technical System, Work as Done, Work as Imagined, Stakeholder Analysis.

Appended publications

Paper A

Saha, R., Lundh, M., & MacKinnon, S. N. (2023, October). The shift toward autonomous European inland waterway shipping: Identifying the gaps in the emerging socio-technical system. In Journal of Physics: Conference Series (Vol. 2618, No. 1, p. 012016). IOP Publishing.

Paper B

Saha, R., MacKinnon, S. N., & Lundh, M. (2025). Mapping the current socio-technical system of European inland waterway transportation: a benchmark for the integration of automation and digitalization. (Under review)

Paper C

Saha, R., Lundh, M., & MacKinnon, S. N. (2025). Evaluating stakeholders' interactions for future autonomous European inland waterway transport: an ethnographic approach. (Under review)

Additional publications and reports

Technical Report:

Saha R. (2023). Description of the Artificial Intelligence/Human- Automation Interactions model for data collection, processing and distribution. Deliverable 3.3 of the project AUTOBarge (European Training and Research Network on Autonomous Barges for Smart Inland Shipping). Gothenburg, Sweden.

Peer Reviewed Conference Abstract:

Saha, R., Lundh, M., & MacKinnon, S. N. (2024). Stakeholders' preparedness for autonomous inland waterway transport in a European socio-technical system. Extended abstract presented at Swedish Transport Research Conference (STRC) 2024, 16 October 2024, Gothenburg, Sweden.

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To *Dipa* & *Hridita* – persons by my heart!

Contents

List of Figures

List of Tables

Acronyms

AI	Artificial Intelligence
ANT	Actor Network Theory
CONOPS	Concepts of Operations
EC	European Commission
EIWT	European Inland Waterway Transport
HTI	Human Technology Interaction
HAT	Human Automation Technology
IMO	International Maritime Organization
IWW	Inland Waterways
LOA	Level of Automation
ML	Machine Learning
ROC	Remote Operating Center
STS	Socio Technical System
WAD	Work as Done
WAI	Work as Imagined
MET	Maritime Education and Training
CPE	Continuing Professional Education

1. Introduction

Compared to land-based transportation, waterborne transportation is more cost effective and environmentally friendly and is considered as the most sustainable means of transporting goods within connected business regions such as Europe (Alias & Zum Felde, 2022; Galieriková & Sosedová, 2016; Sys et al., 2020). This is consistent with a European Union (EU) vision of shifting mobility from land to waterborne transport (European Commission (EC), 2020). Exploiting digital and artificial intelligent (AI) systems may be the foundation for creating a multimodal system which integrates human and technological resources into a seamless logistical chain within a European Inland Waterway Transport (EIWT). In these regards, large investment has been made (AutoBarge, 2021; Bolbot et al., 2020; Gkoumas et al., 2021) to introduce higher level of automation (LOA) and digitalization with a long-term vision of operating the inland barges from a remote operation centre (ROC). However, the socio-technical system (STS) which describes the EIWT has received less research attention (Saha et al., 2023). An STS consists of both human and technology as its fundamental cornerstones (Cooper & Foster, 1971). With the introduction of higher LOA, the IWT STS is perceived to be shifting from a 'human centric system' towards a 'human beside and/or human behind system' where concepts of operations (CONOPS) will shift from a 'human' to 'technology' centred framework (Saha et al., 2023).

1.1 Increasing presence of higher levels of automation within the EIWT ecosystem

The process of introducing higher LOA gained more acceptance and integration into transport chain following the COVID19 pandemic (Kurt & Aymelek, 2022). The industry has now recognised the economic and operational opportunities for deploying higher LOAs to increase commercial competitiveness, to become safer and efficient, and contribute to an overall greening of the industry (Kongsberg Maritime, 2017; Rolls-Royce, 2018). Further economic advantages will soon be realised as shore supervision/remote vessel control protocols are developed. These operational disruptions will require further innovation related to digitalization, automation and AI (Verberght & Van Hassel, 2019) before the full potential can be realised (Aylward, 2020).

Every industrial evolution features emergent disruptive technologies, changing work as done (WAD), procedures and the organisation of work (Hollnagel, 2017a). AI, the Internet of Things (IoT), Big Data Analytics (BDA), Machine Learning (ML) and cloud computing (Aiello et al. 2020; Schwab 2016) have created a new era within the shipping industry. However, to be a viable business model, the integrated logistics must work.

1.2 Understanding a socio- technical system bounded by ¨fuzzy¨ terms of reference

For a theory to have broad utility it must follow the virtues (criteria) of a 'good' theory, including uniqueness, parsimony, conservation, generalizability, fecundity, internal consistency, empirical riskiness, and abstraction, which apply to all research methods (Wacker, 1998). Typically, research begins with a working theory and then empirical data are collected to test a hypothesis.

The research undertaken in this work has a focus on technologies, human competencies and system elements yet to be clearly defined and operational only under the most controlled and/or preconceived circumstances. Therefore, these problems will be studied using a Systems Theory (Von Bertalanffy, 1972; Wacker, 1998) approach. This research employs a socially constructed lens to describe the elements of the system and how they interact to 'get work done'. To gather wider views and acceptance for a futuristic system of Autonomous IWT system, it is important to investigate the existing IWT system involving and evaluating all stakeholders from this socio-technical aspect.

1.3 Research objectives

The IWT STS has not been investigated thoroughly (Amodeo, 2020), especially certainly not in a European context (Saha et al., 2023). As this mode of transport has many activities and stakeholders, particularly when an intermodal context is considered, an increasing utilization of digitalized automation and technologies including machine learning (ML) and artificial intelligence (AI), the problem to understand how safety, efficiency and sustainability becomes much more complex. Work as Imagined (WAI) and work as done (WAD) will continuously be redefined. This is a wicked problem!

The aim of this thesis is to understand the impact of automation and its influence upon future operations within the EIWT system. When considering the EIWT system in an era of higher LOA, this STS will undergo changes in technologies and procedures, and these will have an impact upon the training and competencies of seafarers.

1.4 Research Questions

To achieve these objectives, the following research questions, were undertaken considered:

RQ1. How are the stakeholders impacted (or might be impacted) by emerging technologies related to the introduction of higher LOAs within the EIWT system?

RQ2. How is the current socio-technical system describing a baseline/benchmark to consider how future work might change within EIWT system deploying increasing LOAs?

RQ3. What are the perceptions of EIWT stakeholders regarding how socio-technical systems are impacted by the implementation of new technologies and changing roles operational roles?

1.5 AUTOBarge project

The work reported in this Licentiate was undertaken under the auspices of the *European Training and Research Network on Autonomous Barges for Smart Inland Shipping* (AUTOBarge). The papers presented in this licentiate contributed to outcomes described in Work Package 3 (see *Figure 1*) of the project. Work Package 3 objectives focused analyses of socio-technical, economic and legal aspects towards safe and efficient implementation of autonomous inland shipping (AutoBarge, 2021). Three papers from AUTOBarge are appended to this thesis and represents a stepwise approach to conceptualising STS framework that include four subsystems from which the proposed research questions were addressed.

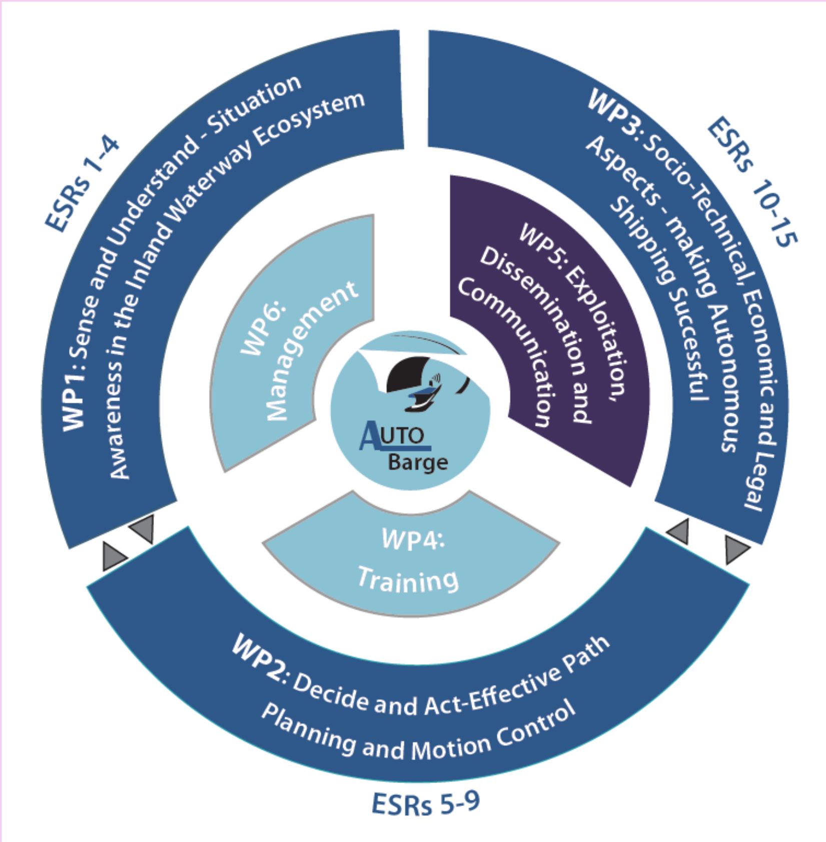


Figure 1: AUTOBarge Work Packages

1.6 Appended Papers

A. Saha, R., Lundh, M., & MacKinnon, S. N. (2023, October). The shift toward autonomous European inland waterway shipping: Identifying the gaps in the emerging socio-technical system. In Journal *of Physics: Conference Series* (Vol. 2618, No. 1, p. 012016). IOP Publishing.

Paper A studies the perceived gaps in evolving IWT STS with higher LOA. To do so, it examines the role of existing stakeholder and technology using Change Agent Infrastructure (CHAI) analysis (Berlin et al., 2021) to analyse the integration of intervention by automation and digitalization within current IWT STS.

B. Saha, R., MacKinnon, S. N., & Lundh, M. (2024). Mapping the current socio-technical system of European inland waterway transportation: a benchmark for the integration of automation and digitalization. (Under review for a journal)

Paper B mapped the existing EIWT STS and current gaps of it with the motivation of benchmarking the integration of higher LOA. Consulting with 6 subject matter experts and using actor network theory approach, this paper proposed the mapping exercise of the present IWT STS as WAD.

C. Saha, R., Lundh, M., & MacKinnon, S. N. (2024). Evaluating stakeholders' interaction for future autonomous European inland waterway transport: an ethnographic approach. (Under review for a journal)

Using a 6-phase thematic analysis (Braun et al., 2018) of 29 IWT stakeholders' interviews **Paper C** mapped both present (WAD) EIWT STS for conventional operation, and foreseeable (WAI) EIWT STS for two scenarios: a. manned remote control, and b. unmanned remote-control operations. The paper identifies organization of IWT STS, gaps and opportunities for all scenarios. It also highlights foreseeable shift in role & responsibility, and the necessity for standardization and digitalized collaboration from user aspects.

2. Theoretical framework

This section provides an overview of the theoretical frameworks considered in this research with a review of the theory and concepts that define their utility and application within this research context.

2.1 Characteristics of today's EIWT STS

STS studies consider a system as a 'whole organization', investigating the actors through micro to macro levels (Trist, 1981). Actors within then EIWT STS have both localized micro-level interactions within the system at regional and national territories as well as extended macro-level interactions within a European level creating unique characteristics of EIWT. There are two dimensions. On one side- there is an ongoing shortage of crew (CCNR, 2024; Lednický & Dávid, 2010; Pauwelyn & Turf, 2022), an old fleet with a large number of family-owned vessels (CCNR, 2024; Notteboom, 2007), and growing climate uncertainties e.g., low draft in dry seasons (Bernardini et al., 2018; van Dorsser et al., 2020). Meanwhile, there is continuous increase in investment for automation and digitalisation via several new projects and commercial initiatives (Gkoumas et al., 2021). Moreover, there is strong demand from the society for greening in shipping thus an extended focus from the European Commission to shift cargo from road to rail and waterways via the 'green deal' (European Commission, 2019).

Again, potential business model shows small margin of return, so single boat owners or small barge companies will face economic challenges to move towards higher LOA without justifying return on investment. In this circumstances, besides economic and legal aspects, socio-technical aspects also require an in-depth analysis for successful implication of Autonomous IWT in a safe and efficient manner (AutoBarge, 2021) which is not yet got adequate focus by researchers (Amodeo, 2020).

2.1.1 IWT stakeholders

There are several actors and tools that altogether form the IWT STS. From a system perspective, the stakeholders of IWT STS can be divided into four sub systems: **1.** Technical subsystem describe 'what' the system is doing, **2.** Personnel subsystem detailed 'who' operates the system, **3.** Work design subsystem describe 'how' the system is functioning, and **4.** the Environment clarifies 'external inputs and expectations' to ensure effective functioning of the system. The technical subsystem relies on the personnel sub system since they are the 'operator' of that system. Similarly, personnel sub system is governed or guided by the 'work design sub system' which is influenced by the environments.

2.2 System theory

System theory draws the fundamental conceptual framework for this thesis. A system is a combination of several interdependent interactive system components to which combinedly achieve the system goal where 'whole is greater than the sum of its parts' (Bertalanffy, 1968; Skyttner, 2001, 2005). For conceptualizing the thesis work, IWT system is considered as a complex system where the components are distributed widely and in an unorganized way that require deeper investigation prior to harmonised. System theory characterized the system features by describing the interactions between and among different components (Bertalanffy, 1968; Wilkinson, 2011). In this context, IWT system is an example of 'open loop system' where the components are at the same time independent and interdependent depending on their activities and therefore regarded as a complex system. For example, within IWT system, barges operate based on planned routes and schedules but mostly without real-time feedback or adjustments.

Employing system theory for IWT involves examining the complex interactions and relationships within a complex STS. It will facilitate getting a holistic perspective of the system and its subsystems by analysing stakeholders' dynamics, system boundaries, interrelation, adaptability and resilience of the system components (Freeman, 2010; Hendrick & Kleiner, 2001; Meadows, 2008). That is how system theory can provide a concrete foundation for understanding how subsystems function within complex systems as IWT, highlighting the need for an integrated approach to system design and management.

2.2.1 Socio technical system (STS)

STS is a branch of general system theory. STS frameworks are increasingly being used within human factors research to analyse the task and functions (Aylward, 2020; Costa et al., 2018; da Conceição et al., 2017; de Vries, 2017; Praetorius, 2014) and improve design and safety features (Andersson et al., 2011; de Vries & Bligård, 2019). An STS is an 'integrated whole' incorporating all active and interactive components of the system (Bertalanffy, 1968; Skyttner, 2001). The STS framework is developed, based on ‘social’ and ‘technical’ components of the system, to understand the system and its enhanced performances. Sociotechnical framework also systematically analyses ‘human factors’ within the system performance (Grech et al., 2008).

Here is an incorrect general perception of ‘autonomous shipping’ considering it as an independent and self-sufficient where the challenges are entirely technology centric. This results into a complete overlooking of the ‘social’ components and only focusing on ‘technical’ components.

Eventually, the socio-technical aspects have not drawn enough attention while IWT business is preparing for the introduction of higher LOA. The fact is that, although higher LOA is likely to reduce direct engagement of humans in various operational functions as they do today, it is still most unlikely that human functions within the system will completely disappear within the concepts of operations. Rather, their roles and functions need to be redefined within the system.

Being a goal driven system, STS can be described by several subsystems. For the appended papers within this thesis, IWT STS is distributed into four subsystems (Hendrick & Kleiner, 2001) as detailed in section 2.1.1. This model includes all the human and non-human components of a system gathering holistic view from all the stakeholders.

2.2.2 Actor network theory (ANT)

Complex issues are usually socio-technical thus require holistic review of its actor's relationship using ANT framework to clarify social perspectives of their system (Iyamu & Sekgweleo, 2013; Latour, 1987, 2007). Within IWT STS there are both human and non-human actors exits, and they act, interact and interplay simultaneously.

ANT were employed into this study to identify the system elements (Latour, 2007). ANT is a method rather than a theory itself and is considered as an effective tool to evaluate the introduction of disruptive technologies (Seuwou et al., 2016) such as higher LOA facilitating unmanned autonomous operation. ANT focuses on interactions between human (social) and non-human (technical) entities and shift of their network (Callon, 1999; Dankert, 2012; Iyamu & Sekgweleo, 2013).

Of course, there are other method to analyse complex STS such as FRAM (Functional Resonance Analysis Method) which looks more into the functions (Hollnagel, 2017b) or stakeholder theory focusing on value creation from an organizational aspect (Gilbert & Rasche, 2008; Parmar et al., 2010). However, ANT found to be an effective tool to analyse stakeholders' interactions within complex IWT STS (Kaghan & Bowker, 2001). It will provide 'holistic overview' visualizing actors interaction with an overarching evaluation which is very important to define and design futuristic stakeholder interactions. Collaborative Decision making (CDM) can be ideal here to combine all stakeholder's inputs (Zaraté et al., 2008) to make the best choice to serve the system's objective. Predictably, collective decisions differ from individual opinions but still represent a collective view.

2.3 Concept of Operations

As this research will look at how changes in work as done occur in an emerging IWT The structure of this research inquiry deploys a process broadly described as a CONOPS (Fairley & Thayer, 1997). CONOPS refers to a document or plan that describes the characteristics of a proposed system from the viewpoints of the stakeholders that will be included in the system. CONOPS generally evolve from a concept or an existing emergent system and is used to identify both quantitative and qualitative elements to all participants. It is the identification of these capacities that hopefully allows the system to achieve a desired end state.

2.4 Automation and Human Factors

There are several taxonomical explanations of automation. From human factors aspects, automation can be explained as partial or complete removal of human functions (by machine/technology) which can vary depending on the technical advancement i.e. based on LOA (Parasuraman et al., 2000). In maritime, presently Integrated Automation Systems (IAS) is widely used for streamlining various shipboard operations including propulsion, power management, cargo handling, ensuring maximum reliability and safety (Dagkinis et al., 2022). However, these systems are not anymore considered as advanced LOA due to technical advancement in this domain.

2.4.1 Levels of Automation (LOA)

IMO introduce Maritime Autonomous Surface Ship (MASS) as their strategic focus to integrate ongoing advancement on automation and digitalization within their regulatory scopes. IMO defines MASS *as a ship which, to a varying degree, can operate independently of human interaction* (IMO, 2018). To elaborate it further, IMO also introduce 4 LOA to explain different mode of automation and human involvement in the loop.

LOA in maritime context refer to degree of which control of operation is delegated to automation or human operators. This classification is essential to understand evolving landscape of maritime automation, particularly towards higher LOA with remote control operation. There are several frameworks for explaining LOA in shipping context which all are broadly aligned with the definition of 4 degrees of LOA provided by International Maritime Organization (IMO) (IMO, 2018; Saha, 2021). However, a recent article by Rødseth et al., (2022) argues the levels can be categorized into a matrix that distinguishes between full autonomy and constrained autonomy, reflecting varying degrees of human control and automation. In anyway, presence and functionality of human within the loop is increasingly being focused while defining autonomy for shipping operations (Poornikoo & Øvergård, 2022; Rødseth, 2019).

Table 1 provides a synchronized framework of different LOA provided by United Nations (UN) maritime regulatory authority IMO, European pioneer in IWT regulation CCNR, Norwegian Forum of Autonomous Ship (NFAS), Classification society LIyod's Register (LR), technological innovator ABB (ABB, 2018; CCNR, 2022; IMO, 2018; Lloyd's Register, 2017; Rødseth & Nordahl, 2017).

For the purpose of this thesis, LOA is considered following IMO 4 LOA where level 1 (Manned control vessel) is considered as lower LOA and level 2 & 3 (Manned and unmanned remote control) is considered as higher LOA. Level 4 is not considered for investigation.

Table 1: Different LOA synchronized with IMO references

IMO, 2018	*CCNR, 2022*	*LR, 2017*	*NFAS, 2017*	*ABB, 2018*
	0: No automation	AL (Autonomy level) 0: manual ship	Direct control	No Autonomy.
1: Ship with automated processes and decision support	1: Steering assistance	AL1: On-board decision support	Decision support	Assistance with or control subtasks
			Automated bridge	
2: Remotely controlled ship with seafarers on board	2: Partial automation	AL2: On & off-board decision support	Periodically unmanned	Occasional autonomy in certain situations
		AL3: 'Active' human on the loop	Remote control	
3: Remotely controlled ship without seafarers on board	3: Conditional automation	AL4: human on the loop, operator/ supervisory	Automatic	Limited autonomy in certain situations
	4: High Automation	AL5: fully autonomous, rarely supervised	Constrained autonomous	System in full control in certain situations
4: Fully autonomous ship	5: Autonomous = Full automation	AL6: fully autonomous, unsupervised	Fully autonomous	Autonomous operation in all situations

2.4.2 Human Technology interactions (HTI)

HTI within the framework of LOA focuses the dynamic relationship between human operators and automated systems. As automation becomes increasingly prevalent, understanding this interaction is crucial for optimizing system performance and ensuring safe and efficient operation to achieve ultimate user satisfaction.

Earlier, HTI refers to the design and implementation of interactive human automation systems that facilitate user engagement by providing usability and functionality, ensuring users can easily and effectively utilize technology to perform their task (Thüring & Mahlke, 2007). However, with advanced automation and active presence of ML, AI, this definition requires further explanations particularly due to the replacement of human functionality by non-human actors.

2.4.3 HTI in different LOA

With the increasing LOA, the interactions between humans and technology will evolve and may create a very different HTI by redefining the role and the tasks of both human and technology in new ways. Therefore, researchers are focusing on Human Automation Teaming (HAT) research for effective integration of future autonomous system (GOODS, 2024; Sheridan & Parasuraman, 2005). While the focus on LOA and HTI is essential for improving HAT, it is also important to consider the potential drawbacks of over-reliance on automation, which can lead to skill degradation and reduced situational awareness among users. Presently, with the presence of lower LOA, balancing automation with human oversight remains a critical challenge in the field.

As illustrated in section 4.2 of Paper A, there is a strong corelation between different LOA and role of human within the system. LOA emphasis presence of human categorizing the interaction between humans and machines, emphasizing that no system is fully autonomous (Roth & Pritchett, 2018). Different LOA levels also influence user trust, workload, and system performance, demanding tailored designs for specific applications (Roth & Pritchett, 2018). Precise LOA frameworks are required to enhance human-system performance and guide effective human-automation design. Within this thesis, HTI is considered at two different steps within LOA.

2.4.3.1 HTI at Lower LOA

Lower LOA is already having sufficient presence within different mode of transport operation for information acquisition, analysis, and application (Janssen et al., 2019; Parasuraman et al., 2000). Aviation (Valdés et al., 2018) and road transport (Alessandrini & Stam, 2018; Parent, 2007) have more advancement on using automation in operation comparing with waterborne transport. HTI at lower LOA is more predictable as we already have many known technologies either readily available or in the development process. Presence of human is still vital in this level not only due to regulatory barrier also due to technological limitation. Therefore, Human Centered Design (HCD) approach is still vital to enhance safety at lower LOA (Grech & Lutzhoft, 2016; Soper et al., 2023).

2.4.3.2 HTI at higher LOA

HTI at higher LOA covers remote control operations with or without human presence onboard. Human Beside Design (HBD[1]) and Human Behind Design (HBD[2]) are the new concept for these two modes of vessel operation consecutively. There is still a limited implication of this in shipping domain. Again, these are mainly within autonomous underwater vehicle (AUV) or underwater surface vessel (USV) (Sarda & Dhanak, 2016). Therefore, functions at this LOA are still considered more as a 'predictions' rather than a solid 'framework'. That possess difficulties towards defining IWT STS for HTI at higher LOA. Ethnographical approach is employed to address this barrier.

2.5 WAD vs WAI

WAD and WAI are widely used concept to differentiate peoples actual work and expected work within similar system framework (Hollnagel & Clay-Williams, 2022) and frequently referred while discussing about safe work management in various domain such as medical care (Blandford et al., 2014) or emergency response (de Carvalho et al., 2018) or pilotage and VTS (Vessel Traffic Services) operation (de Vries, 2017). WAD refers to how a task or function is performed as of now within known circumstances whereas WAI represents stakeholders explicit or implicit assumption of how task or function will be performed within foreseeable circumstances (Hollnagel, 2012, 2017c). This thesis work considers an STS approach of evaluating WAD and WAI with changes in LOA. As LOA increase in complexity due to the introduction of new technologies or the roles of stakeholders within the system will change (Hollnagel, 2017c). It is anticipated that the role of human will evolve and either replace or redefined for different functions. Therefore, role of human in the presence of higher LOA is also required clarifications as approaches within this thesis.

3. Methodology

To address the proposed research goals, it was decided to use a systems approach to better understand how the EIWT system will address the strengths, weakness, opportunities and threats regarding how it will adapt in the light of emerging technologies and operational changes.

Systems theory is the interdisciplinary study of a system (i.e. cohesive groups of interrelated, interdependent components that can be natural or artificial. Every system has boundaries, is influenced by its context, defined by its structure, function and role, and expressed through its relations with other systems. A system is "more than the sum of its parts" especially when viewed within a socially constructed context (Von Bertalanffy, 1972). This chapter will describe the general methodological approaches grounded in ethnographic and socio-technical theories (as summarized in *Table 2*).

Table 2: Summary of methodological approaches

Research goal	Objective	research theme (see section 1.4)	Concept	Variables & operationalisation
Perceived impact of higher LOA within EIWT STS	Analyzing the current phenomenon and pattern (WAD) to 'sense' the future (WAI)	RQ1. Gaps and challenges	'Work as Imagined' from 'Work as Done'	Variables: different Level of Automations Operationalisation: perceived views of current system and interactions
	To get a perceived view of future IWT STS in the presence of advanced automation	RQ2. System readiness	Defining a 'common ground' based on Actor network theory	Variable: Current Stakeholders, and foreseeable future stakeholders Operationalisation: current stakeholders interaction mapping exercise
	studying an 'ethnography of the future' considering the current circumstances in the IWT system to a large extent	RQ3. Perceived impacts	Shifting of HCD to HBD[1] and/or HBD[2]	Variable: role of human in different Levels of automation Operationalisation: perceived views on role of human in future operation

The outcomes of these studies were to evaluate the existing interactions among IWT stakeholders (WAD) and look into the future (WAI) based on current stakeholders' interactions. It is important to investigate the IWT STS from a 'holistic view' (Nurani, 2008) to ensure effective interactions among the stakeholders in an autonomous era. *Table 2* listed research objectives at current stage of the research and detailed how they are conceptualized and operationalised.

All three appended papers within this thesis have some relationship with the AUTOBarge objectives. Paper A and B focused on current IWT STS i.e. WAD with a vision of introducing higher LOA i.e. implementing WAI. In both papers, solid findings from current IWT STS are considered to develop 'futuristic observation'. Paper C focused on futuristic framework i.e. WAI. Existing stakeholders and their present interactions both were used to create strategic proposals for future IWT STS i.e. WAI.

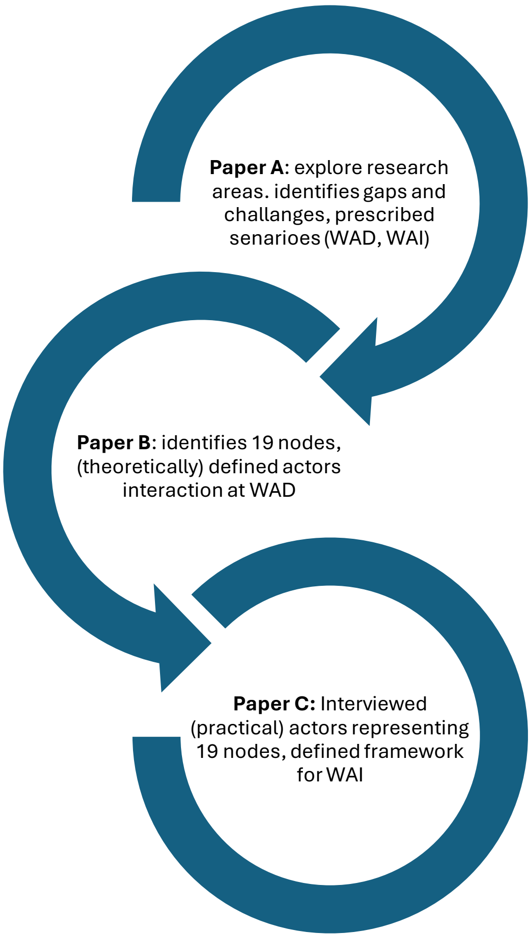


Figure 2: Research Objective and Approaches

3.1 Experimental design and data sets

Figure 2 describes an overview of the research approaches in line with the research goal and objectives of the thesis. The research program to date was designed to answer three research questions consecutively. RQ1 explores the research area identifying the actors´ roles whereas RQ2 identifies actors' distribution in current setup (WAD) to achieve efficient collaborations among those actors. finally, RQ3 will answer the best data coordination framework for future (WAI) by reevaluating the actors' roles considering their current work organizational framework and anticipated transformations to those. Combining the answers to these three RQs will serve as the expected framework describing the impacts of higher LOA in HTI for EIWT STS ensuring smother stakeholder interactions. However, this is yet to be analysed further to zoom into several other dimensions (as detailed in section 6.1) which is aimed to be covered during post licentiate studies.

3.1.1 Research ethics

All data collection ensured participant anonymity in respect to personal and professional information and was in compliance with the EU General Data Protection Regulation (GDPR).

3.2 Paper designs / procedures

This section provides an overview of methodological approach and procedures followed for all 3 appended papers in this thesis. For detailed understanding, reviewing the papers is recommended.

3.2.1 Paper A

Approach

This paper analyses roles of stakeholder and technology within emerging presence of higher LOA with an aim of mapping the gaps and challenges employing Change Agent Infrastructure (CHAI) analysis. This is a procedural step-by-step analysis to analyse the stakeholder's perspectives to characterize human factors integration of intervention in a work design system (Berlin et al., 2016, 2021). CHAI analysis is built on the concepts of the 'actor network theory' (Berlin et al., 2021) and assist with a better understanding of the likely changes with the introduction of automated technologies and higher degrees of automation and digitalization into the EIWT STS for Inland Waterway (IWW) STS (Saha et al., 2023). CHAI analysis acknowledges ‘both human and nonhuman artifacts’ as possible actors (Berlin et al., 2021) the same we did in this study.

Data collection and analysis

CHAI analysis follows 6 step procedures starting with identifying the system stakeholders (actors) and their roles with the intervention of higher LOA. This was done by literature reviews followed by unstructured interview with 5 expert academicians from nautical science domain. Then actors/role and roles/actor were evaluated in a qualitative way to determine if the current role distribution was ideal.

3.2.2 Paper B

Approach

This paper aims at benchmarking the current IWT STS (WAD) visioning the perceived impact of higher LOA. Here, using the system theory and STS theory approach, IWT stakeholders were systematically categorised the IWT stakeholders in 19 different nodes under 4 subsystems considering the whole research field (IWT) as a system as detailed into *Table 5*. All the elements i.e., various actors and tools enabling the current operation within the IWT system belong to any of these 19 nodes. Using ANT principle, a mapping exercise is done to describe how these nodes are interacting at WAD and eventually to identify where are the gaps in current interactions.

Samples

Initial contents were summarized based on literature reviews. To validate, the contents were discussed (Slocumb & Cole, 1991) via unstructured and semi-structured interviews in a reiterative process. Six Subject Matter Experts (SMEs) were chosen via ‘purposive sampling’ (Tongco, 2007) considering their domain expertise combining maritime expertise and research activities. The demographics are detailed in the paper (as appendix 1).

Analysis

STS framework evaluates influence of the environment towards other subsystems (work *design, personnel* and *technical)* in a soft system framework (Berlin, 2011; Kirwan, 2000). Using this Systems analytical approach the data collection was undertaken in two rounds of one-to-one interviews. A. unstructured interview covering one hour open ended discussion with SMEs to define the interactions among 4 subsystems and their nodes. B. The follow-up rounds engaged SMEs in a semi-structured interview (Wood, 1997) to review the synthesized from previous interviews and eventually revised to describe the current IWT STS i.e. WAD.

3.2.3 Paper C

Approach

This paper examines the WAD with an aim of defining and designing the framework of future stakeholders' interactions within EIWT system. An ethnographic approach was employed to gather a 'holistic' view from the whole system. It was done by a. initial questionnaires and follow up interviews, b. unstructured observations onboard inland barge and during interviews.

Samples

Primary data from the 31 online questionnaires and semi-structured interviews with 29 of those 31 stakeholders representing all the 19 nodes under 4 different subsystems were collected to ensure collective representation of the whole IWT system. An extensive search for industry stakeholders following three stages of different approaches were employed to reach to these informants who have an average of 12 years of experience within IWT segments and are from 7 different EIWT leading countries.

Analysis

The questionaries and follow up interview were detailing actors' interactions in three operational scenarios: a. current IWT operation, b. manned remote-control operation, and c. unmanned remote control operation.

Informants elaborated on their existing and perceived roles within these scenarios. This provides a holistic overview of current and future IWT and facilitate generating a thematic concept showing future IWT stakeholders 'interaction method' for autonomous Inland shipping. *Table 3* shows an overview of the analysis process for this paper.

Table 3: Research approach for Paper C

Data source	***Data set***	***Method***	***Result***
a. Primary inputs on questionaries,	Excel sheet created digitally	Thematic analysis using Nvivo software	4.1: WAD- summary/overview as Figure 2 in Paper C
b. Interview transcription	(thick) interview data, transcribed		4.2: WAI – summary/overview as Figure 3 in Paper C

4. Results

This chapter summarize the relevant results from all 3 appended papers pertinent to answering the research questions.

4.1 Paper A

Following the evaluation of the actor's role, Paper A summarizes that there are barriers to introducing higher LOA and digitalization. The result identifies that multiple actors will act as the 'receivers' of the changes due to higher LOA and 'regulatory bodies will be the actors with key roles to drive towards these changes.

Table 4: CHAI analysis (adapted and revised from Saha et al., 2023)

ACTORS	Initiators	Sponsors	Convincers	Change Owners	Subjects / Receivers	Blockers	Solution builders	Documenters
shipowner		investor				less interested to move for the changes		
technology developers							main backhand who develops, test, and verify the reliability of the changes	
regulatory bodies	talking with the stakeholders and outside	they may not be involved actively always		can enable it in a national / European level		they are pretty slow to allow/ amend the change		document handler
crew / seafarer					have to deal with the changes			
port operators (agents)					have to adapt their work culture in some degree			
Port authority								document/data handler

ACTORS	Initiators	Sponsors	Convincers	Change Owners	Subjects / Receivers	Blockers	Solution builders	Documenters
suppliers					have to adapt their work culture in some degree			
society (the people)		demand sustainable water neighbourhood						
researcher	investigating and engaging the society		providing findings of their works					
insurance company				can legitimate it within their mandates				
company (personnel)					have to adapt their work culture in some degree			
Cargo owner					Are they Ready to pay?			
Political leadership				Often Have different motive				
Activist and associations			Influencer or lobbying group					

As presented in *Table 4,* there are five receivers (who are actors from different nodes from the ***technical*** subsystem and ***personnel*** subsystem) have to act, and more importantly, have to collaborate to adapt to forthcoming changes effectively. According to the CHAI method, '*actors who are subjects to the problem, or are receivers of the change, will have their operations directly affected, either by the problem and/or the outcomes of the change project*'.

Besides, there are also three (***P1, E3, E5***) 'sponsors' who '*are not directly active in the project but support keeping it on the agenda'*, and three (***P5, E3, E5***) 'change owners' who '*have the* *legitimate ownership of the problem, the mission to solve it, and the mandate to determine when and if it has been solved'.* On the other hand, regulators (***E5***) have the most (5) roles as an actor. It will eventually slow down the change process which is often noticed. There is always criticism from technology developers and innovators (W2) that regulation is not ready to serve the latest technical advancement when it is ready.

4.2 Paper B

Paper B identifies 19 different nodes distributing the IWT STS into 4 different subsystems: technical, personnel, work design and environment. While mapping the interactions within these subsystems and their nodes, this paper also identifies gaps within the current way of interactions visioning future introduction of higher LOA. *Table 5* listed all the subsystem and its nodes along with example of actors under each node.

As explained in section 4.2 of Paper B, for this study, gap is explained as '*a discontinuity between the nodes of a system that prohibits 'perfect' functioning/interactions between and among the system components'*. A gap can exist between sub systems or between a subsystem and a node of another sub system. Further, an interaction refers to 'more than communication' rather a 'combination of communication, collaboration, relation, contact, exchange, dealing' to perform actions and functions within a complex STS. All the nodes interact between and among themselves to enable proper functioning of the system.

This mapping exercise facilitates identifying the sociotechnical gaps within current IWT STS WAD. The aim here was benchmarking the system changes with higher LOA. As detailed in section 4.3 of this paper, there are several gaps within WAD.

- There are no two-way interactions between personnel subsystem and the environment. Two nodes from the technical subsystem (T1: inland barge & T3: support system) individually can serve as the 'bridge' to cover the interaction gaps between the environment and personnel subsystem.
- A necessary interaction between E-W2 (environment-innovator/technology developers) is missing preventing smother integration of advanced automation within current IWT STS.
- Technical subsystem has the most outward integrations whereas environment has most inward interactions. Nodes within the personnel subsystem are currently scattered and stand alone in nature.

Table 5: System boundaries in IWT STS (based on Paper B)

	NODES	*Example of Actors & Tools*
TECHNICAL SUBSYSTEM (T)	**T1**. Inland vessel: the inland barge	Operation + owned/charter vessel (dual role) = operator
	T2. Port infrastructure (technical mechanism)	terminal operator, stevedores
	T3. Supporting Operation/ control stations	bridge operator, lock operator, Vessel Traffic Service, Shore Control Centre
	T4. Navigational and cargo operational components	mooring system, crane system, navigational & operational components producer
	T5. Machinery and bunker operational components	maintenance service provider fuel/propulsion power supplier
PERSONNEL SUB SYSTEM (P) **Operator for --->**	**P1**. owner: legal owner of the barge	ship owner
	P2. onboard operators	skippers
	P3. Shore side (port and company) assistants	pilot agent customs police/security (inc. cyber security)
	P4. regular service: supply and logistics service providers	ship supply (food, spare, consumable) providers other regular logistic service provider
	P5. irregular /non periodic service	insurance classification society
WORK DESIGN SUBSYSTEM (W) **regulator/ guide for-->**	**W1.** international and national regulations, safety guidelines	flag & port state controls
	W2. advanced technical supports	innovators (in operation, supply chain, services, etc): (unmanned machinery space, B-zero: unmanned bridge concept, satellite, digital twin, etc)
	W3. intermodal and hinterland connections	truck terminals, operators, inland container depot
THE **E**NVIRONMENT (E) **Influencer of --->**	**E1.** inland waterways	(national/ regional) inland waterway authority
	E2. port arena	port authority (owner & policy maker)
	E3. Society	people living around, political leadership: Municipality administration
	E4. Funder / financer	Ship financial institution (bank/fund/investment company)
	E5. Regulatory authority	National authority international authority (IMO, EMSA)
	E6. Associations (interest groups) and activists	Associations (covering members who are IWT stakeholders) IWT worker Unions Green movements

4.3 Paper C

Summarizing the feedback from IWT stakeholders, this paper identifies gaps within current and future IWT STS. And it also describes challenges towards introducing higher LOA into IWT STS. Finally, evaluating interactions at both WAD and WAI, Paper C argues that the future ways of interactions will be more comprehensive, structured, real time engaging all stakeholders within a ‘common ground’ to ensure safe, efficient and effective stakeholder interactions within future IWT STS. Both remote operational (manned and unmanned) scenarios were identified as WAI.

This paper identifies gaps in both current (WAD) and future (WAI) systems. Gaps in current system are unstructured communication, scattered actors, lack of data & data clarity, no real time synchronization, limitation on data handling, human centric business, conventional industry behaviour, non-competitive business case, non-unified regulatory requirements, missing collaborative ‘common ground'. Mixed traffic operation, operators’ acceptance, manning level, are identified as challenge specifically for manned remote-control operation. Other identified challenges are reliable communications, financing, regulations, vessel owners trust, standardized organisation, missing common communication channel, human empathy, closed IWT industry, skilled workforce, and business case.

Paper C also identifies different areas existing of collaborations from different dimensions: a. with the line of business, b. within external forum and working groups, c. within supervisory operations, d. local and regional level.

Figure 3 shows an overview of the results of these 3 papers and how the thesis outcomes are sketches.

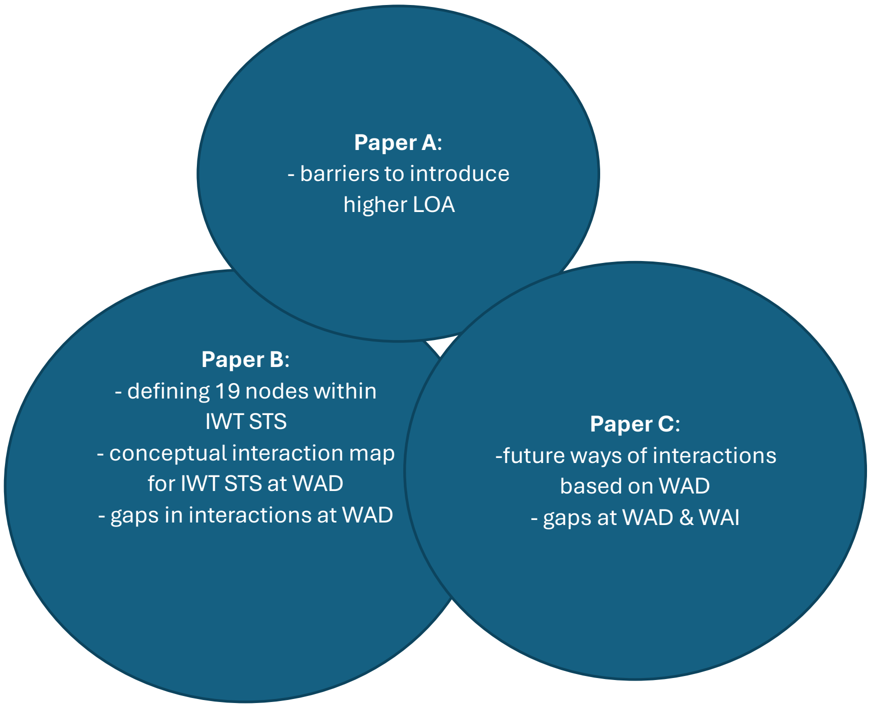


Figure 3: overview of results from appended papers

5. Discussion

With rapid developments of higher LOA and associated artefacts in the EIWT maritime operations there is an opportunity to make the EIWT industry safer, greener, sustainable and efficient. The challenge to answering the proposed research questions (see Section 1.4) is that the industry is trying to grasp how systems, operational demands and technologies, which do not physically and operationally exist, but many stakeholders have views about how introducing higher LOA will impact today's practices (WAD) into the future (WAI).

The three appended papers all reveal that WAD will be disrupted from the introduction of higher LOAs in the EIWT system. There is almost complete agreement amongst all the respondents that this information will influence stakeholders' thoughts about WAI and will have an impact on conceptualizing, designing, and finally how the new system, its actors, technology and CONOPS with emerge to meet the modern challenges on this transportation chain. *Table 6* provides an overview of how the appended papers support the general research questions of this Licentiate.

Table 6: Overview of research approaches

Research Goal	Licentiate research Questions	Appended article relationship	Objectives	Method	Data set
Perceived impact of higher LOA within EIWT STS	RQ1. Gaps and challenges	A and C	identifying the 'Gaps' at WAD that will hinder WAI	CHAI	SMEs, Stake-holders interview
		B and C	Identifying the collaboration points/common ground	thematic analysis, ethnographic study	SMEs, Stake-holders interview
		C	identifying gaps within WAI	ethnographic study	Stake-holders interview
	RQ2. System readiness	A and B	evaluating actors (both human and machine) role for safe, efficient, and environment-friendly operation	CHAI, thematic analysis	Literatures, SMEs
		C	evaluating system preparedness for WAI	ethnographic study	Stake-holders interview
	RQ3. Perceived impacts	C	identifying shift in design and operation for remote navigation	ethnographic study	Stake-holders interview
		C	Proposing actors' interactions strategies for HTI at Autonomous operations in Inland Waterways within EU	ethnographic study	Stake-holders interview

5.1 Addressing RQ1- Gaps and challenges

It is very important to consider existing realities from WAD (Paper A). There are existing gaps within IWT STS which need to be addressed to prepare the EIWT STS for future autonomous driven activity, which are considered in Paper B. There are also foreseeable gaps in future IWT STS (WAI) based on current system analysis considered in Paper C. There are multiple barriers that were identified in this body of work and are discussed in detail in this section.

5.1.1 Incompletely defined regulatory system

As identified in Paper A & C and by several other researchers (Li & Yuen, 2022; Saha, 2021) there is always a disagreement between technological development and how this is regulator to adapt to new technical advancements. The technology developer see regulation as the showstopper. Whereas Regulators say, they prefer to modify regulation only once the technology proved itself. Critical to these opposing views, how can technology prove them if they are not allowed to be used in operations? (as highlighted in section 4.2.3.3 of Paper C)

The industry needs regulatory support, but the regulatory body is unwilling to change unless they see successful examples. This creates a real problem and a huge barrier to move towards higher LOA effectively. Both parties need to work in parallel to create a framework on how they can address the continuous technical development by regulations despite being tested in commercial operations. Goal based regulatory scope (Hamann & Peschmann, 2013; Skjong, 2005) with close collaborations between regulatory and innovators stakeholders could be one way to address this issue. It will shorten the typically long implementation times.

5.1.2 Yet to be defined sustainable business models

Compared to land-based transportation, waterborne transportation is more cost effective and environmentally friendly and is considered as the most sustainable means of transporting goods within connected business regions such as Europe (Alias & Zum Felde, 2022; Galieriková & Sosedová, 2016; Sys et al., 2020). However, the introduction of higher levels of automation, driven by sound AI and ML can create innovative business models and economic solutions. However, a widely usable proven business case is still missing thus slowing down the progression towards advances in automation development in the European inland shipping.

We need to revise current business patterns and practices in an innovative way to adapt with the perceived (and perhaps expected) changes within the system. As discussed in section 5.3 of Paper C, one example of such innovative business model could be a collaborative stakeholder's approach where various stakeholders collaborate to achieve common goals.

Such collaboration can bring scattered IWT actors under one umbrella. Some examples for such collaboration could be several carriers creating alliances to operate a single 24/7 operations team or a ROC team. Another possibility could be ROCs collaborating with an autonomous crane or mooring service providers to offer an attractive and 'all inclusive' business case. This example also could influence a more improved intermodal logistics network/system. Increased trust, open and fair business policy, continuous collaboration within different clusters, open single window for sharing much more data, active working groups for information and knowledge sharing are prerequisite for such collaborative approach (see Section 5.3 of Paper C).

5.1.3 Communication uncertainties

Future technologies available for communication (e.g. VHF surrogates, sensor/data transmission) remain unknown. There are two aspects that need to be considered: developing standard industry framework for communication and solving technical uncertainties (e.g. data stability and cybersecurity).

Within the current EIWT sector, communication is not well organized and mostly not synchronized within actor networks. Most of the individual actors and small entrepreneurs rely on telephone and email communication without traceability, important in the decision-making process (see Section 4.1.4 in Paper C). Having a clear, stable communication with real time feed in a redundant way is technically crucial for remote operation of the barges. It is not only for smoother functioning of the system or solving legal liability issues but also to train and develop the system further with actual operational data. Actors' communication should be standardized in a digitalized platform such as single window enabling smoother and real time exchange of data. However, there are concerns that open communications and data transmissions may impact business model security and competitive advantages for some entities.

5.2 Addressing RQ2- System readiness

This RQ is answered by providing future directions benchmarking the current system i.e. WAD. Papers A and B evaluate the role of most elements (human and machine) identified by the participants. Paper C extended that research further by analysing industry stakeholder insights considering foreseeable changes in their future operations. Aside from the obvious changes in technology which are forthcoming with higher LOA, there are both positive and negative opinions suggested by the human actors within current STS.

5.2.1 Actors restructuring

Several actors are not prepared for the introduction of higher LOA and digitalization (refer to *Table 4*). Actors are not aligned in an organized or systematic manner (refer to Paper B) thus are not able to interact efficiently within current system. It will be further critical with the intervention of higher LOA (Paper C) replacing several current human roles i.e. Skipper or crane operator by technology. Therefore, restructuring the actor network is required to adapt with the new system functionalities provided from higher LOA.

5.2.2 New ways of interaction

While the system is in operation, the current interactions are not ‘perfect’ (Paper B), it's not ready to adapt with the impacts of higher LOA (Paper B, Paper C). Therefore, a new system facilitating effective ways of actors (both human and machine) interactions at WAI will emerge. Standardized, real time synchronized, and redundant thus highly reliable communication engaging all stakeholders in a ‘common ground’ is expected to be the key to new ways of interactions.

5.2.3 Learning from WAD and preparing for WAI

WAI is generally different from what it is planned (Hollnagel, 2017c). There are identified gaps regarding actor’s interactions (refer to Papers A & B). Moreover, there are also gaps relating to WAD that are preventing smoother integration of higher LOA such as described in Section 4.3 of Paper B. On the other hand, there is also foreseeable gaps at WAI as most of the stakeholders identified in Paper C. Current actors’ network are not ready to adapt to the increasing presence of automation and digitalization as identified by the CHAI analysis in

Paper A. Within the EIWT, higher LOA will not completely replace the current socio-technical system, rather it will revise the system to adjust and adapt with advanced automation. Most of the existing actors will still have actions to perform enabling smother system at WAI.

5.3 Addressing RQ3: Perceived impacts

This RQ has been answered from two aspects: a. perceived impact on the emergent system, and b. perceived impact on the EIWT. Much of these findings are addressed in Paper C, however, Papers A and B contribute to these thoughts.

5.3.1 Perceived impact on STS

It is not yet clear whether higher LOA will act as a disruption to the existing system, or it will simply improve the existing system. Since operations within the current EIWT STS are already somewhat impacted by lower LOA.

As revealed in Paper C, out of 4 subsystems of the EIWT STS defined in the study, actors contributing to the discussion in two subsystems (Technical and Personnel) are less confident and unsure about their roles from a WAI perspective. Actors discussing the other two subsystems (Work design and the Environment) shows more confidence in how future work might be done and are more receptive to change. A main frustration expressed by many of the actors was that the felt removed from the development loop. This is a clear violation by some stakeholders of not incorporating user knowledge and needs in a UCD framework of development. However, all actors consider advanced automation and remote operation as a future reality.

5.3.1.1 Shift in roles: Function of the ROC and ROC operators

The EIWT actors' roles will change as LOA increase in complexity and operational control. There is a likely probability that most of the human actors will shift towards supervisory tasks and activities whereas technologies will take on operational activities, such as navigation and data management. While concepts of operational control are still being discussed, this thesis takes a view that a ROC will become the centre of the hub and wheel. As suggested at section 5.4 of Paper C, the design of this installation can either be novel or simply a mimic of those operations on board (i.e. similar layout, HMI design and equipment functionalities. Likely, some technical functions will become less transparent to the ROC operator compared to a bridge's officer of the watch, as AI will be performed in the background to the visual output presented to the operator.

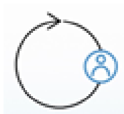
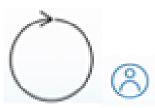
5.3.1.1.1 Emerging actors: remote operation centre operators

Expectedly with the shift of operations to a shore-based entity, the ROC operator (ROCO) is expected to be the new centre of the operation instead of the vessel master. Besides potential legal dilemma of whether a ROCO is a master or seafarer there is also uncertainty regarding what are the roles and responsibility of a ROCO (Sharma, 2023). Depending on functionalities ROC could have multiple human operators with different responsibilities. Here, most of the conventional task of current master and crew will be transferred to ROCO for a remote-controlled vessel (Sharma, 2023).

5.3.1.2 Shift in design and interaction

While shifting from the current conventional to future autonomous shipping, a HCD approach is expected to drive a 'paradigm shift' towards HBD[1] or HBD[2] (see Paper A, Section 4.2). This explains the actors' roles in the collaborative decision-making process to achieve operational and system objectives. This concept is based on the expectations that machines will continuously replace or redefine human roles with the implementation of higher LOA. *Table 7* provides a conceptual summary of interactions for these design approaches.

Table 7: Foreseeable shift in design and ways of interactions (H=Human, M=Machine)

Mode of operation	Current low LOA	Manned RC	Unmanned RC
Design approach	HCD (H in the center of the loop)	HBD[1] (H on the loop)	HBD[2] (H out of the loop)
Visualisation			
Human role in the loop	Centred	Beside	Behind
Role of human	Operation	supervision and emergency response	Machine guided supervision
Forms of interactions	H-H, H-M-H	H-M-M, M-M, M-H-M,	M-M, M-M-H

5.3.2 Perceived impact on EIWT

Europe has invested a considerable amount of financial and technical resources to improve and optimize waterborne transport by shifting cargo from road and rail to the waterways (European Commission, 2019; Gkoumas et al., 2021; Oloruntobi et al., 2023). Although, research focusing on socio-technical aspects is mostly missing (Amodeo, 2020; Saha et al., 2023).

EIWT industry has been traditionally a family owned 'stand-alone' business. It was and still for many is a floating home for many of the stakeholders. Communication generally take place in a 'closed loop' where human actors have known each other for longer time and therefore have strong trust and comfort on communicating in informal ways i.e. telephone and emails rather than in a system like single window. Moving towards higher LOA may result in a loss of local knowledge, customs and practices, which may have a net effect of decreased safety.

6. Conclusions

Autonomous shipping is the future but the pathway how increasing LOA towards fully autonomous EIWT system is long and winding. This work attempts to identify the roles of human and technologies within this emerging socio-technical system. During this evolution these elements will evolve and change. The gaps and barriers have been identified and will need to be considered as the industry moves forward. Participants interviewed over the course of this work have provided opinions and insights. Some remain sceptical that such a transportation system will ever evolve, while others remain much more optimistic. It is universally agreed that whatever autonomous technologies are introduced, system safety must be maintained, if not improved. Furthermore, sustainable business models must emerge to justify further research and development in this mode of transport.

7. Future research directions

The current research has focused on achieving better insight into the utility of applying Systems Theory research frameworks to study the wicked problem(s) of how the current EIWT STS may evolve and adapt to future technological developments related to increasing LOA. This work has included a mapping of actors and technologies within the current system and served as a benchmark to describe what the future system may be described.

Future research in this doctoral programme of research proposes to use a similar methodological approach in a similar manner to study remote operations centres, like those currently used in Scandinavia, for the ferry and goods transportation, typically in well defined, nationally controlled waterways.

While this setting is more mature, from a technical and operational point of view, compared to the IWT sector, it will face similar challenges to adopting to new concepts of operations, new technologies, operator competencies and regulatory changes. However, given these higher levels of technical, system and human integration levels might provide a more ecologically valid test space to:

1. Describe the emergent transitions to higher LOAs in the IWT sector based through a lens of WAD to a WAI perspective.
2. Define the gaps within the STS that could impact upon the resiliency of the system.
3. Study, compare and contrast more matured and better operationally defined (CONOPS) systems using higher LOAs. These might serve as suitable surrogate examples for IWT/coastal waterways.

These analyses should provide insights to the socio-technical organisation of remote operations working with higher (LOAs), regulatory reform and directions for institutionalised maritime education and training (MET) and continuing professional education (CPE).

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