TURUN YLIOPISTO
UNIVERSITY OF TURKU

The Human-Centric Knowledge Management System in a Complex Environment

Pengcheng Ni

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ABSTRACT

In the shipbuilding industry, research on human-centric knowledge management systems is lacking. For a long time, shipbuilding has been considered a labour-intensive sector. However, the digital revolution is ongoing in the European shipbuilding industry and we cannot rely on the traditional way of running businesses. It is necessary to pay attention to the management of knowledge assets to maintain strong competitiveness in the global market. Knowledge management, as an interdisciplinary field, contributes to the study of the knowledge asset in knowledge-intensive organizations. However, many modern firms are not treating knowledge assets as a competitive advantage in the operation of their organizations. Knowledge, as an invisible asset, needs to be managed systematically, and knowledge management now plays a pivotal role in different organizations. Therefore, this thesis examines knowledge management through the architecture of a knowledge management system. This work employs a multi-method approach to build a human-centric knowledge management system for shipbuilding. The result shows that such a system is suitable for the European shipbuilding industry. The system is decoupled, which means we need to follow a sequence of design parameters when implementing it. Additionally, the dissertation finds that tacit knowledge has a vital role in the human-centric knowledge management system in shipbuilding. This evaluation uses a systems engineering approach to explore the system's architecture and applies a multi-method knowledge management system to construct it. The process can serve as a significant reference for other architectures in knowledge-intensive industries.

KEYWORDS: knowledge management, knowledge management system, human-centric shipbuilding industry, complex environment

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TIIVISTELMÄ

Laivanrakennusteollisuudessa ihmiskeskeisen tiedonhallintajärjestelmän tutkimus on vähäistä. Laivanrakennusta on pitkään pidetty työvoimavaltaisena teollisuudenalana. Digitaalinen vallankumous on kuitenkin käynnissä Euroopan laivanrakennusteollisuudessa. Emme voi luottaa perinteiseen tapaan hoitaa liiketoimintaa. On tarpeen kiinnittää huomiota tietoresurssien hallintaan vahvan kilpailukyvyn ylläpitämiseksi globaaleilla markkinoilla. Tiedonhallinta monitieteisenä alana edistää tietoresurssien tutkimusta tietointensiivisissä organisaatioissa. Monet nykyaikaiset yritykset eivät käsittele tietoresursseja kilpailuetuna organisaatioidensa toiminnassa. Tietoa, organisaatioiden näkymätöntä voimavaraa, on hallittava systemaattisesti. Siksi tässä opinnäytetyössä tarkastellaan tiedonhallintaa tiedonhallintajärjestelmän arkkitehtuurin kautta. Tiedonhallinta on nykyään keskeisessä roolissa eri organisaatioissa. Tässä tutkimuksessa sovelletaan monimenetelmätutkimusta ihmiskeskeisen tiedonhallintajärjestelmän rakentamiseen laivanrakennuksessa. Tulos osoittaa, että ihmiskeskeinen tiedonhallintajärjestelmä sopii Euroopan laivanrakennusteollisuudelle. Järjestelmä on irrotettu, mikä tarkoittaa, että meidän on noudatettava suunnitteluparametrien järjestystä ihmiskeskeisen tiedonhallintajärjestelmän toteutuksessa. Lisäksi tutkimuksessa havaitaan, että hiljaisella tiedolla on keskeinen rooli ihmiskeskeisessä tiedonhallintajärjestelmässä laivanrakennuksessa. Tässä tutkimuksessa käytetään järjestelmäsuunnittelun lähestymistapaa järjestelmän arkkitehtuurin tutkimiseen ja sovelletaan monimenetelmäistä tiedonhallintajärjestelmää sen rakentamiseen. Prosessi voi toimia merkittävänä referenssinä muille tietointensiivisten teollisuudenalojen arkkitehtuureille.

ASIASANAT: tietämyksenhallinta, tietämyksenhallintajärjestelmä , ihmiskeskeinen laivanrakennusteollisuus , monimutkainen ympäristö

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Abbreviations

AD	axiomatic design
AI	artificial intelligence
CoP	community of practice
DP	design parameter
FR	functional requirement
IT	information technology
KM	knowledge management
KMS	knowledge management system
PLM	product lifecycle management
RP	research purpose
RQ	research question
SE	systems engineering
SECI	socialization, externalization, combination, internalization
SEUS	Smart European Shipbuilding

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Ni, P., Kantola, J. (2024). Taxonomy of knowledge management systems in a complex environment. In: Vesa Salminen (eds) *Human Factors, Business Management and Society*. *AHFE (2024) International Conference*. AHFE Open Access, vol 135. AHFE International, USA. http://doi.org/10.54941/ahfe1004933

II Pengcheng Ni. (2024). Can Knowledge Management Be Appropriate for Shipbuilding?: Based on Typology and the Seven C's Model. *Journal of Knowledge Management Practice*, 24(4). https://doi.org/10.62477/jkmp.v24i4.461

III Ni, P., & Kantola, J. (2025). Exploring The Factors Influencing Knowledge Management Strategy in the European Shipbuilding Industry: A Pilot Study. *Journal of Knowledge Management Practice*, 25(6). https://doi.org/10.62477/jkmp.v25i6.595

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Pengcheng Ni is the principal author of all the papers. Professor Jussi Kantola supports the study.

Declaration of AI Use

AI-assisted tools were used solely for language editing, including improving clarity, readability, and academic style. These tools were not utilized to generate ideas, research interpretations, or theoretical content. I am fully responsible for the accuracy and originality of all scholarly content presented in this thesis. The research design, analysis, interpretation, and conclusions are entirely my own work.

1 Introduction

A human-centric knowledge management system (KMS) in a complex environment emphasizes three core points, which are the KMS, the complex environment, and human-centric factors. Digitalization and computational technologies can create significant stakeholder value through cyber-physical systems and digital twins, but their effective adoption in the European shipbuilding industry demands substantial changes to existing tools and practices (Gaspar et al., 2023). The KMS can play a pivotal role in promoting technical improvement and application, thereby strengthening the competitiveness of the European shipbuilding industry.

Knowledge management (KM) has been studied since the last century. During that period, the *knowledge worker* concept was initially proposed by Drucker (1959), who emphasized the importance of knowledge in organizations, drawing on his book *Landmarks of Tomorrow*. Scholarly interest in the concept of knowledge management emerged in the 1990s, marking the beginning of efforts to articulate and define its theoretical foundations (Maciá-Lillo et al., 2025). KM is an interdisciplinary subject, with many researchers working to develop the subject in different fields. The rapid proliferation of KM within the global business landscape has prompted scholars to interpret and synthesize the extensive and heterogeneous corpus of contemporary research (Mukarram et al., 2025).

"Knowledge" is the core of KM and now plays a pivotal role, with modern organizations making it a vital asset. We therefore need to address KM issues in a complex environment, which means KM must manage knowledge assets across heterogeneous parts that connect in complex ways, creating significant uncertainties. KM represents a contemporary organizational perspective that emphasizes the systematic sharing and utilization of a firm's intellectual and creative resources (Corso et al., 2003). In practice, KM manages knowledge assets within an organization with different stakeholders, and a KMS aims to facilitate KM work by modelling KM activities in light of the internal and external environment. Building on the foundational definitions of KMSs proposed by Alavi and Leidner (2001) and Corso et al. (2003), KMSs can be understood as encompassing both knowledge management practices (KM practices)—that is, the methods and techniques that facilitate organizational processes of knowledge creation, storage, and transfer—and tools (KM tools), which refer to the specific IT-based systems designed to support and operationalize these practices (Centobelli, Cerchione, & Esposito, 2017).

KM has experienced several significant developments. Important milestones in the field occurred in the 20th century and continued into the 21st. Several definitions of KM were proposed during this period, and KM concepts have been applied in different sectors. From traditional industries to new ones, KM is becoming increasingly interdisciplinary, drawing on the characteristics of different fields to achieve a common KM goal. This interdisciplinary aspect can also introduce vagueness into KM. Researchers across fields offer different explanations of KM from various perspectives. In this thesis, we will discuss KM and its application in shipbuilding, with a focus on a human-centric KMS in a complex environment. Such an environment involves complex knowledge asset management. Examples include the knowledge-intensive education system, shipbuilding industry, complex construction system, and so on. In this work, shipbuilding serves as a case study that contributes to the architecture of a human-centric KMS.

The human-centric KMS is a concept involving the architecture of a KMS based on a core of human-centric factors. This study focuses on the knowledge processed and created by human beings, and it is evident that a KMS is based on human-centric activities. Margaret Cavendish, a natural philosopher, argued that all parts of nature retain a degree of self-awareness and an inherent form of self-knowledge (Cavendish, 1666/2001). Her metaphysical and epistemological views are close to explanations from modern neuroscience. This means that knowledge is not unique to humans. For example, sonar is undeniably a form of perception, but its mechanisms differ so radically from human senses that we have no grounds to assume its subjective character resembles anything humans can perceive or imagine (Nagel, 1974). This helps us understand that different parts of nature have self-knowledge and consciousness. However, there are other related ideas in which knowledge is defined as a justified true belief based on epistemology. For example, the mind has been conceived as a non-physical substance that distinguishes human beings from the rest of the material world (Descartes, 1641/1996). Although modern neuroscience has refuted this claim, the idea of differentiating humans from other beings in nature has profoundly impacted modern KM.

This thesis aims to show that it is undeniable that all things in the world possess their own knowledge; however, animal knowledge can be understood as apt belief, in contrast to the more demanding form of reflective knowledge characteristic of humans (Sosa, 2007). Therefore, certain types of knowledge are uniquely human. For example, personal knowledge is based on memory, which derives from an individual’s experience. This offers an interesting interpretation. As adults, if we imagine our lives at a very young age, most of us may have lost that memory. You cannot create any emotional connection with that period. When you listen to a story about you at a very young age from your parents, it seems like a new one for you. This memory has gone. However, your self-awareness remains unchanged. This is called *qualia*, as proposed by Lewis (1929/1956): "There are recognizable qualitative characters of the given, which may be repeated in different experiences, and are thus a sort of universals; I call these 'qualia'" (p. 121). From my point of view, tacit knowledge develops based on the defined qualia. Therefore, you cannot remember your life at a very young age now. This is due to your self-identity relying on memory. The idea of pure awareness from Eastern philosophies can also support the two forms of existing, which are memory and self-awareness. This means a separation between the two. Knowledge is derived from an individual's unique experience. If the mind receives no input whatsoever, then knowledge would lack any real content and would be entirely arbitrary, for there would be nothing external to which it must correspond (Lewis, 1929/1956).

Knowledge originates from previous experiences; humans can possess the conditions for forming new knowledge. Therefore, this study takes the origin of knowledge from humans as the foundation of knowledge management, thus giving rise to the research theme of a human-centric KM. Furthermore, individual knowledge contains tacit knowledge that cannot be easily transferred. Organizational knowledge relies on organizational memory; it is derived from knowledge from different individuals. Therefore, KM in a complex environment should be approached from the human-centric perspective, although it can be stored and used by other living and non-living things. The final KMS in the dissertation emphasizes three key points, which are the human-centric factor, the decoupled KMS, and the complex environment.

Unlike mass production sectors such as the automotive and aerospace industries, shipbuilding involves a highly customized production process (Yilmaz et al., 2025). Tacit knowledge gained during negotiation directly influences order outcomes. Concurrently, uncertainties contribute to the complexity of the European shipbuilding industry. Building on key insights from general management and project-based literature, complexity can be understood as consisting of four primary dimensions: diversity, interdependence, dynamism, and uncertainty (De Toni & Pessot, 2021). The European shipbuilding industry is thus considered a human-centric complex environment in this work.

Organizational sustainability is increasingly shaped by the adoption of engaged and decentralized digital technologies, the emergence of intelligent knowledge systems, and the cognitive transformation taking place within contemporary work environments (Alzeiby et al., 2026). KM has experienced several developments. Currently, it is connected to artificial intelligence (AI), which aims to improve its efficiency. Although AI cannot possess reflective awareness, it can still support humans in KM activities. Furthermore, it offers the possibility of explicitly displaying implicit knowledge. From a KM perspective, the development of human society involves summarizing, generalizing, and developing existing knowledge, then creating new knowledge to enrich human civilization. Therefore, whether at the macro or micro level, we face the challenge of managing knowledge effectively. To do so, we must first understand it sufficiently—along with all relevant factors—to assess its current state, as well as addressing issues, identifying and creating opportunities related to knowledge, and implementing the necessary changes to achieve desired outcomes (Wiig, 1998). Therefore, a system for integrating the process is vital for KM.

1.1 Research gap and suggestions

The research on KM is enormous and spans different fields. However, only a limited number of publications study KMSs. Many reflect the exploration of KM but ignore KMSs. Others examine KMSs; however, there is no complete work illustrating the process leading from KM to a KMS. KMSs can result in the success of organizations; however, once organizations recognized that knowledge could meaningfully influence performance and warranted more effective management, many struggled to determine how to begin, largely because the inadequate structuring and presentation of knowledge have been identified as a major barrier to implementing knowledge management (Rajesh, Pugazhendhi, & Ganesh, 2011). It is meaningful to introduce the KMS at the organizational management level. There are also a restricted number of studies about transferring KM to a KMS based on an organizational management level.

Given this, research should start with a background on KM and then apply the concept to KMSs. No work introduces the architecture of KMSs. The introduction of a workflow-based architecture model for KMSs can facilitate their architecture across various fields. This speeds up the development of the KMSs in different scenarios. Current studies of KMSs do not reveal how the human-centric factors operate within the system. Most publications focus on the technical level. Notwithstanding that this is a vital aspect, the importance of the organizational level cannot be underestimated.

There are a restricted number of studies of a human-centric KMS. This thesis suggests that it is valuable to pay attention to the architecture of human-centric KMSs. Shipbuilding, as a knowledge-intensive industry, is insufficiently addressed in previous research. Industrial environments function as sociotechnical systems characterized by continuous interactions among society, people, and technology, shaping nearly all dimensions of human life and work (Ribeiro, Nakano, & Muniz

Jr., 2024). A KMS focusing on the human-centric perspective is thus important for the European shipbuilding industry. However, there is a research gap between KMSs and shipbuilding. Currently, there is limited work on shipbuilding related to KMSs. Therefore, this dissertation suggests that conducting research about human-centric KMSs in shipbuilding is necessary.

How do technology and humans work together for KM in a complex environment? Although early document management systems were mistakenly regarded by uninformed users as “KMSs” the growing recognition that KM must extend beyond organizing and providing access to documentation towards enabling the creation and sharing of new knowledge prompted the search for collaborative platforms that better support knowledge workers (Ardichvili, 2002). However, there are a limited number of publications on KMSs that focus on the collaborative networks between technology and humans.

This thesis analyses the different KMSs in shipbuilding from a technological aspect. No study about the human-centric KMS in the context of European shipbuilding currently aligns with Industry 5.0 in the shipbuilding industry. Research related to three key parts, which are the human-centric part, KMS, and the complex environment, needs to be integrated to fulfil the new needs in the era of Industry 5.0.

1.2 Research purpose

KM is a vague concept in many fields. Providing a precise definition of KM is challenging, as the literature offers no universally accepted or unified interpretation of the concept (Egbu, 2004). One of the reasons for this is that KM can be considered an interdisciplinary subject, which means that it applies in different sectors. Furthermore, the knowledge asset is an intellectual asset, differing from real ones. In addition, compared with other subjects, KM has experienced decades of development. Those reasons lead to the problem of defining KM based on a unified explanation. The vagueness can affect the systematic study of KM. Given that the problem exists in academia, this thesis starts by defining KM and then creating the taxonomy of the KMS.

KM has made a great impact on firms. Today’s manufacturing sector operates in an environment characterized by intense global competition, in addition to rapidly shifting markets, fluctuating customer demands, and increasing economic and technological uncertainties (De Lima et al., 2023). The notion of project capability pertains to the experiential insights, managerial competencies, and specialized knowledge base within an organization that are indispensable for planning, organizing, and executing projects successfully (Alves & De Carvalho, 2025). A firm can strengthen its strategic, innovative, and marketing capabilities through the systematic creation, storage, and efficient dissemination of knowledge (Chatterjee, Chaudhuri, & Vrontis, 2022).

KM is playing an increasingly vital role, especially in knowledge-intensive industries. Traditional industries are experiencing tremendous revolutions. For example, in the shipbuilding industry, the knowledge asset has a pivotal role in the industry. Effective project management relies both on the accumulation of organizational knowledge and on the development of individual and collective competencies that enable projects to be executed successfully (Kasvi, Vartiainen, & Hailikari, 2003). With the development of information technology (IT) and AI, a growing number of workers are being replaced by robots and e-platforms. Shipyards are increasingly relying on the management of knowledge assets for enhancing or stabilizing competitiveness in the global market; therefore, the shipbuilding industry forms the case study for this research. The work aims to explore KM in the shipbuilding industry, and will contribute to the architecture of a human-centric KMS in a complex environment.

A KMS, the system which is designed for KM activities, has the advantage of coordinating the transmission of knowledge in order to improve overall competitiveness. KM is a systematic approach focused on collecting, sharing, and effectively utilizing knowledge within an organization (Tsirakis et al., 2025). Currently, many companies face the challenges of KM. One of the major problems is that they do not know how to conduct KM systematically. In addition to technical knowledge, the system must have all the administrative and organizational types deemed necessary for “smoothing” the user’s work (Barthes & Tacla, 2001). Knowledge is separated in organizations. For example, as noted by the Smart European Shipbuilding (SEUS) project, there are many issues related to KM in the shipbuilding industry. There are many barriers to the transmission of knowledge in organizations. Different types of knowledge exist in various departments; therefore, the need to build a KMS for shipbuilding is strong. Based on the aforesaid situations, my study aims at constructing a KMS for European shipbuilding.

Human-centric theory is the core of a KMS. Knowledge is a human’s intellectual asset, which differs from information. The advent of Industry 5.0 signifies a transformative shift wherein humans and machines collaborate synergistically to enhance the efficiency and effectiveness of industrial production processes (Adel, 2022). KM also encompasses employees’ tacit knowledge—which has not yet been formally articulated in organizational processes or systems—because people, alongside information technologies and related infrastructures, constitute an essential foundation of KM efforts (Mmatloa & Venter, 2025). The fundamental value of knowledge is its role in serving human needs. Individuals within organizations have been identified as key contributors to the facilitation of knowledge exchange (Bordas, Le Masson, & Weil, 2025). Humans create and deliver knowledge. Human resources can be considered an important carrier of intellectual capital. Addressing education, training, and the continuous processes of re-skilling and up-skilling is critical for managing the digital transformation in industrial sectors, as the availability of highly qualified human capital is essential for its successful implementation (European Commission, 2021).

Humans play a vital role in KM in industrial sectors by producing a digital form of KM. Humans' involvement and contributions can lead to the success of KM, although other factors can affect the final result. If we focus on European shipbuilding, human resources occupy a considerable part of the total resources. This is due to the characteristics of shipbuilding, which is considered a workforce-intensive industry. Contemporaneously, the failure of transferring knowledge is largely caused by human-related factors. In light of this, the study will concentrate on exploring the human-related factors in the KMS for shipbuilding. Simultaneously, it takes human-related factors into account in the development of the KMS, emphasizing the human-centric architecture.

A complex environment is frequently linked to certain key words (e.g., high risk, complex internal relationship network, complex external network). In highly complex environments, project managers and team members must comprehend diverse factors, establish connections, and foster collaboration among them (Ramadhan, Iyiola, & Alzubi, 2024). A lot of knowledge is exchanged and generated during communication. Organizations today face environments that are highly complex, uncertain, and subject to rapid transformation (Ameer, Gnan, & Oppedisano, 2025). The conduct of KM in a complex environment is very difficult. Today's knowledge managers are confronted with ambitious challenges and issues of increasing complexity (Bolisani & Damiani, 2010). In light of this situation, it is useful to study a human-centric KMS within the context of a complex environment. From a KM perspective, knowledge-intensive organizations can be defined as a complex environment. When we use the richness of knowledge to measure the complexity of an industry, those operating in complex environments often have to deal with a high volume of different types of knowledge.

There is a paucity of research on KM between technology and humans in a complex environment; therefore, it is critical to build a KMS to systematize the different dimensions (e.g., dissemination, application, and innovation) of knowledge by technology and human resources in different industries. The purpose of this thesis is to systematize human-centric KM activities in a complex environment. The study explores the architecture of a human-centric KMS in the European shipbuilding industry by building one to improve the competitiveness of this sector in a complex environment.

1.3 Research questions

KM plays a pivotal role in industries. A KMS has a great significance in maintaining high competitiveness in knowledge-intensive industries. IT and AI are currently undergoing a rapid deployment period. Part of the work can be replaced by AI. However, the transition of tacit knowledge still relies on human beings. Therefore, it is meaningful to explore a KMS based on human- and technology-related factors. In my research, shipbuilding, as a case study, contributes to the architecture of a human-centric KMS. The main research question (RQ) is:

RQ1: How can we build a human-centric KMS in a complex environment?

To address the main question, four secondary RQs guide the architecture of a human-centric KMS in a complex environment.

In order to explore the process of a KMS by different dimensions, the study employs the taxonomy method to construct the workflow model of a KMS in a complex environment. Based on the aforesaid aim, the thesis proposes RQ1.1.

RQ1.1: What is the taxonomy of KMSs in a complex environment?

Key objectives in the maritime industry—such as developing efficient routes and networks, managing transportation costs, and enhancing service performance and quality—are heavily reliant on effective knowledge management (Ding & Lee, 2024). However, there is a restricted number of publications that analyse the feasibility of a KMS for shipbuilding. The shipbuilding industry is highly competitive and global in nature, with Europe, China, South Korea, and Japan acting as its principal players (Alfnes et al., 2021). The necessity of evaluating the feasibility of conducting KM is high. The following research question aims to fill this gap in the field.

RQ1.2: Is KM appropriate for the European shipbuilding?

The KMS comprises several factors, but the interaction between KMS and those factors is ambiguous. For the sake of identifying the relationship among them, the research question outlined below is proposed.

RQ1.3: What are the key factors of KM in the European shipbuilding?

The architecture of a KMS lacks studies. The system architecture is prevalent in many systems (e.g., IT, transportation, and mechanical systems, etc.); however, there is a paucity of research on the architecture of KMSs in the context of the organizational management level. Contemporary KM practices predominantly focus on static repositories and structured procedural documentation, yet they often lack mechanisms for real-time interactivity and adaptability—features that are essential in dynamic maintenance contexts (Mao, Scheffer, & Majumdar, 2025). Owing to this setting, the following research question is outlined for developing the architecture of the KMS in a systematic way.

RQ1.4: What is the architecture of the human-centric KMS in the European shipbuilding industry?

1.4 Human-centric design and KM studies in different fields

KM is widely studied in different subjects. When searching Scopus and ScienceDirect to collect publications on KM and KMSs, a huge number of papers appear. However, the aims of KM in different fields differ. For example, in shrimp farming, innovation capacity is primarily shaped by how well organizations manage to integrate and balance two key processes: exploring new knowledge and leveraging the existing knowledge (Zaragoza-Sáez & González-Illescas, 2026). The importance of KM is obvious in the software industry. Given that the software industry is characterized by rapid and continuous technological progress, short innovation cycles, and intense market competition, ensuring the efficient and timely dissemination of knowledge throughout the supply chain becomes critically important (Kang, Altmann, & Hong, 2025). The definitions of KM are decided by the aims and functional needs of industries. In healthcare, KM encompasses a structured approach to generating, disseminating, contextualizing, and utilizing clinical and operational knowledge to support informed decision-making and improve the quality of care (Mukherjee et al., 2025). Furthermore, higher education, as a knowledge-intensive industry, also pays attention to KM. KM within higher education institutions has been the subject of extensive scholarly investigation, owing to its pivotal role in promoting innovation and improving organizational effectiveness (Gurler, Bhatti, & Sari, 2025).

Aside from the aforesaid industries, KM is also discussed in arts and crafts organizations, where artisans' specialized knowledge, distinctive skills, and embodied creative capabilities function as essential organizational resources that significantly contribute to a competitive advantage by enabling the production of exclusive, handcrafted artefacts that are difficult to imitate (Manfredi Latilla et al., 2019). Tacit knowledge therefore plays a pivotal role. Furthermore, implementing comprehensive KM practices is essential for strengthening sustainable performance in manufacturing small and medium-sized enterprises (Al Koliby et al., 2025). Within the transportation sector, effective KM is vital for sustaining operational efficiency, ensuring safety, and supporting the strategic management of assets (Amaram et al., 2026).

KM studies in various industries consistently emphasize human-centric design. Innovation and sustainability have opened up a new era of KM. The evolving vision of the manufacturing sector, illustrated by initiatives such as Industry 5.0, is moving beyond the traditional emphasis on technology-driven and economically focused growth associated with extractive and consumption-oriented models, towards a more transformative and long-term perspective that prioritizes human well-being, sustainability, resilience, and human-centric development (Stjepandić et al., 2025). Human-centric design needs to be incorporated into KM in the context of a complex environment.

1.5 Research approach adopted for the study

In this thesis, a mixed-method research design consisting of quantitative and qualitative analysis was utilized in conjunction with different forms of surveys. In addition, the axiomatic design approach was applied to the architecture of the KMS. The following graph shows the structure of the research, consisting of the primary research question and four secondary RQs each linked to an article. A summary of all the articles and the insights into the research topic will be presented in this dissertation.

This thesis uses the European shipbuilding industry as the case study for the architecture of a KMS. The result can be a good reference for KM in the European shipbuilding industry; however, the process of the research can also reflect the general architecture of KMSs in other industries (e.g., the education industry). Figure 1 shows the framework of the whole thesis by presenting the relationships between the main RQ and the four secondary RQs.

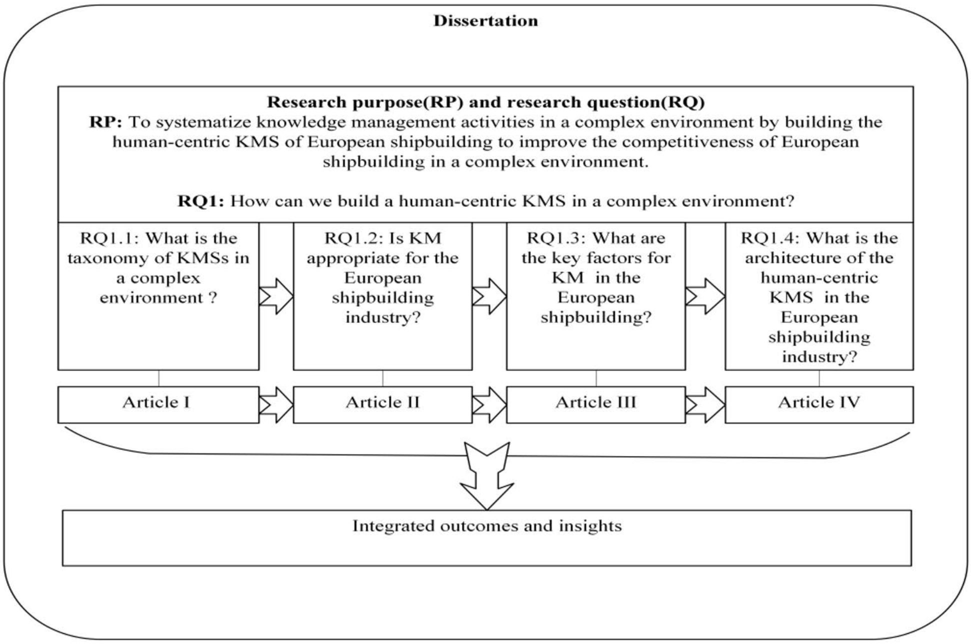

Figure 1. The lifecycle of the study of a human-centric KMS in the European shipbuilding industry

RQ1.1 provides the foundation for building the human-centric KMS in shipbuilding. RQ1.2 and RQ1.3 cover the preparation for building the system from a KM strategy perspective. RQ1.4 refers to the architecture of the human-centric KMS in European shipbuilding industry. They connect to form the complete process of developing the architecture of the system.

1.6 Dissertation structure

Table 1 shows the components of articles in the study. It consists of the title of each article, as well as its aims, the research questions, and the methods applied.

Table 1. Components of each article

Articles	Objectives	Research questions	Data collection and method of analysis
Article I: Taxonomy of Knowledge Management Systems in a Complex Environment (Ni & Kantola, 2024)	The study aims to examine the use of a taxonomy to delineate the shared characteristics of a KMS within the complex context of the Smart European Shipbuilding (SEUS) project.	What is the taxonomy of KMSs in a complex environment?	The taxonomy is applied as the foundation of the architecture of the human-centric KMS.
Article II: Can Knowledge Management Be Appropriate for Shipbuilding?: Based on Typology and the Seven C's Model (Ni, 2024)	The study aims to determine the feasibility of implementing systematic knowledge management in the European shipbuilding industry.	Is KM appropriate for the European shipbuilding industry?	The seven C's model is applied to analyse the feasibility of implementing KM in shipbuilding.
Article III: Exploring The Factors Influencing Knowledge Management Strategy in the European Shipbuilding Industry: A Pilot Study (Ni & Kantola, 2025)	The study aims to identify the factors that can affect the knowledge management strategy in the European shipbuilding industry.	What are the key factors for KM in the European shipbuilding?	A questionnaire survey is conducted in the external environment of the SEUS project as part of a multiple linear regression to confirm the key factors for conducting KM in European shipbuilding.
Article IV: Modelling Human-centric Knowledge Management Systems Based on a Shipbuilding Project (Ni & Kantola, in press)	The study presents the architecture of a knowledge management system model for a shipbuilding project.	What is the architecture of the human-centric KMS in the European shipbuilding industry?	Different surveys are conducted as part of the qualitative analysis to inform the architecture of a human-centric KMS in European shipbuilding.

2 Theoretical Foundation

2.1 Systems engineering

There are an enormous number of studies of systems engineering (SE), which is widely used in the software engineering field. Contemporary systems are becoming increasingly complex due to the interplay among hardware, software, and electronics, as well as end users (Santos, Martins, & Molléri, 2025). This approach is also applied in the space engineering field, as introduced by NASA. Implementing SE from the earliest phases of the space product lifecycle facilitates the fulfilment of stakeholders' functional, physical, and operational performance requirements (Rodríguez et al., 2025). However, SE can not only contribute to the aforesaid subjects, but also support the architecture of a human-centric KMS in shipbuilding by systematizing the process of the architecture. The application of SE in business can be a good reference for other fields.

The V-model plays an important role in SE. It forms a valuable reference for the architecture of the human-centric KMS in shipbuilding. The *NASA Systems Engineering Handbook* provides a detailed introduction to SE, which is useful for this study. SE is a structured and rigorous approach that governs the design, development, management, operation, and eventual decommissioning of an integrated collection of elements whose combined functioning yields outcomes unattainable by the individual components alone (United States, 2007).

2.2 Axiomatic design

Axiomatic design (AD) is an approach proposed by Suh (1990), and its description can also be found in the book *Design Engineering and Science* by Suh, Cavique, and Foley (2021). It was introduced to solve manufacturing problems. When designing a complex system, integration is a central issue for the designers. Contemporary designers must adopt an integrated, multidisciplinary approach to ensure effective collaboration and problem-solving (Kröpfl et al., 2025). Different functional requirements (FRs) can create high possibilities for the failure of the system. Manufacturing task design entails meeting multiple concurrent requirements, which underscores the need for a systematic ergonomics assessment framework (Arkouli et al., 2024). Therefore, AD is regarded as one of the most promising strategies for addressing complex problem-solving within manufacturing systems (Kose et al., 2023). The purpose of applying AD in system development is to establish a scientific foundation for design and to improve design processes by leveraging theories grounded in logical and rational principles, supported by systematic tools (Palleti, Joseph, & Silva, 2018). The conduct of AD follows two main axioms which are explained in the book *Design Engineering and Science* by Suh, Cavique, and Foley (2021). These two axioms are the *independence axiom* and the *information axiom*.

1. The *independence axiom* means that each functional requirement ought to be kept independent. They do not affect each other.
2. The *information axiom* emphasizes that we need to use the least information to design the system, to maintain its robustness.

By introducing two fundamental axioms applicable to all design problems, AD shifted the discipline from a practice driven by experience and best-practice guidelines to one grounded in scientific principles (Rauch & Brown, 2021).

According to Suh, Cavique, and Foley (2021), the AD approach follows the two axioms and four-domain design process. We know that the standard AD approach contains four domains (i.e., customer domain, functional domain, physical domain, and process domain). During the design, we need to follow the sequence of four domains, from the customer domain to the process one. We need to confirm the customer's needs and then build the system based on those (see Figure 2). Additionally, we have to set the restrictions for the system before collecting the customer needs.

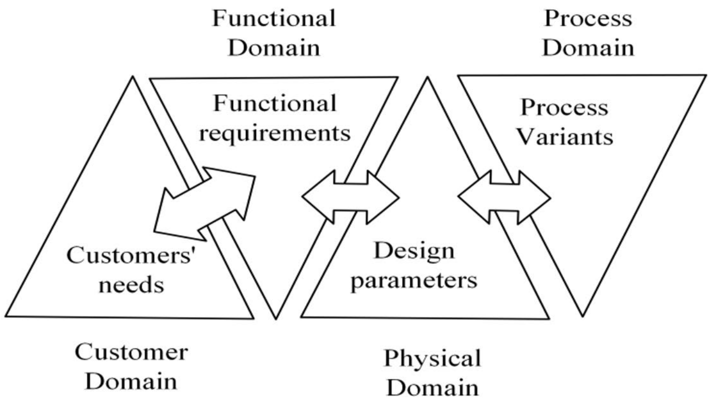

Figure 2. The four domains of axiomatic design

Note. Redrawn based on Suh, Cavique, and Foley (2021). *Design Engineering and Science*. Springer.

According to Suh, Cavique, and Foley (2021), Figure 2 shows four domains matched with four parts of our human-centric KMS in shipbuilding (i.e., customer needs, functional requirements, design parameters, process variables). The initial functional requirements are based on the customers' needs. The design parameter (DP) is generated based on the design of the functional requirement (FR). The highest FRs confirm the highest DPs. Then the FRs and DPs can be decomposed according to design needs. The design goes back and forth between adjacent domains, which is called *zigzagging* according to Suh, Cavique, and Foley (2021).

2.3 The SECI model and KM dimensions

The model was introduced to develop the process of knowledge transfer, which illustrates the socialization, externalization, combination, internalization (SECI) model of knowledge in the context of knowledge-related activities (Nonaka, Toyama, & Konno, 2000). The SECI model outlines a dynamic process through which organizations circulate and expand knowledge internally and externally, aiming to optimize and generate added value from existing organizational knowledge (Anshari & Hamdan, 2022). The dynamic theory of knowledge creation posits that the interactive interplay between tacit and explicit knowledge generates a continuous and productive flow of activities, ultimately enabling the creation, dissemination, and utilization of valuable knowledge (Piątkowska et al., 2025). The SECI model provides a method for transferring tacit knowledge into implicit knowledge by a four-step spiral loop. The SECI model, consisting of socialization, externalization, combination, and internalization phases, instructs organizations on how to manage the tacit knowledge in an effective way.

The SECI model has been used in different fields. It is a significant reference for KM. The SECI model integrates both tacit and explicit forms of knowledge to describe the processes of knowledge creation, dissemination, and utilization (Neft, Kappler, & Smolnik, 2025). Knowledge is externalized into explicit forms, combined into structured systems, and ultimately internalized by individuals as new tacit understanding (Summerscales, 2024). In this thesis, the SECI model is utilized as the foundation of the human-centric KMS in a complex environment. Article I applies the SECI model for developing the taxonomy of a KMS in a complex environment. Furthermore, many factors promote the application of the SECI model in KM in knowledge-intensive industries. Team trust emerges as a key factor that may serve as an antecedent to the SECI process (Baldé, Ferreira, & Maynard, 2018). The SECI model also relates closely to the process dimensions of KM. To visualize the basic workflow of the KMS, the study presents a diagram based on the SECI model (see Figure 3).

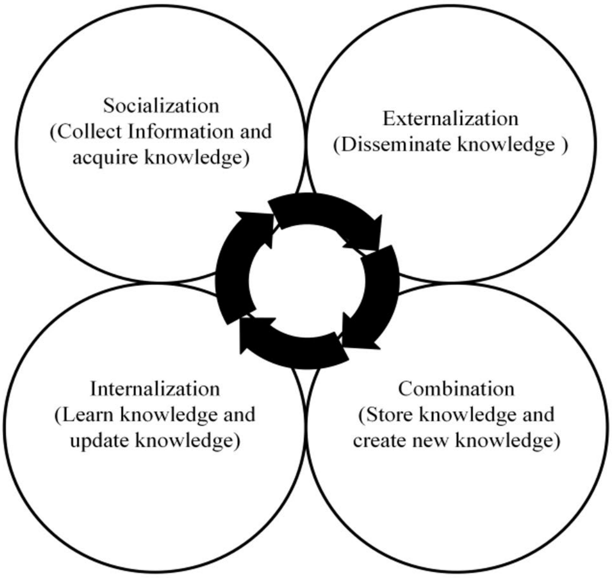

Figure 3. A KMS conceptual model based on the SECI model

Note. Redrawn based on Nonaka, Toyama, and Konno (2000). "SECI, Ba and Leadership: A Unified Model of Dynamic Knowledge Creation." *Long Range Planning*, 33.

Figure 3 shows that there are four blocks matched with socialization, externalization, combination, and internalization from the SECI model (Nonaka, Toyama, & Konno, 2000). This study proposes the KMS workflow model based on the SECI model. The first stage is socialization. The KMS starts by collecting information from formal and informal occasions and then processes it into knowledge, which is considered the know-what level. The second stage is externalization. It emphasizes disseminating the knowledge to a group or team. The third stage is combination, which means that we need to save the knowledge as an organizational and personal asset and use it for knowledge creation. The final one is internalization. This stage involves the know-how level, which means understanding and learning the knowledge.

Acquiring knowledge is the first step and the vital one for introducing knowledge into a system. Internal knowledge management aligns organizational structures with learning processes to co-create opportunities, while external efforts focus on acquiring knowledge to enhance internal capabilities (Alves & De Carvalho, 2025). The processes of acquiring and disseminating knowledge play a critical role in shaping an organization's competitive advantage (Nguyen Tran & Ngo Thi, 2025).

Knowledge transfer plays a pivotal in the human-centric KMS. It enables organizational units to learn from one another, thereby enhancing their overall performance (Standaert & Andries, 2026). It facilitates the effective use and application of existing knowledge to serve the organization's objectives (Ajith Kumar, & Ganesh, 2009). It is part of the externalization phase, which is characterized by the dissemination of knowledge.

Knowledge creation is a complex, multidimensional phenomenon encompassing organizational behaviour, leadership, and technology, as well as human dynamics, environmental factors, strategic considerations, and the interplay among these domains (Kao & Wu, 2016). When the knowledge is collected and shared, the new knowledge can be created. This involves the combination phase.

Using knowledge is an important step in the human-centric KMS in shipbuilding. The use and implementation of knowledge are widely acknowledged as essential resources in the field of management, particularly in the context of globalization and digitalization (Almalki & Al-Shammari, 2025). The current European shipbuilding industry relies on efficient knowledge usage to create an irreplaceable position in the global market. Knowledge utilization refers to the application and exploitation of knowledge in ways that generate new value for the organization (Chaudhary et al., 2025). This refers to the internalization phase. The organization absorbs new knowledge and uses it to create new value.

2.4 Human-centric factors in KM

Human-centric factors are always closely attached to tacit knowledge in KM. Knowledge exists in various forms, some of which are relatively easy to acquire while others are more complex. Among these, the two most widely recognized categories are tacit and explicit knowledge (Shahzad & Soroya, 2024). Tacit knowledge is a significant concept in KM and KMSs. KM involves transforming tacit knowledge into explicit knowledge and facilitating its dissemination within the organization (Chidambaranathan & Swarooprani, 2017). Tacit knowledge is proposed and described in detail in the book *Personal Knowledge: Towards a Post-critical Philosophy* by Polanyi, who states "We can know more than we can tell" (Polanyi, 1966, p. 4). This opens a door for knowing tacit knowledge. However, Henry (n.d.) explains that the expression tacit knowledge, although grammatically smoother than tacit knowing, can perpetuate the misunderstanding that Polanyi was referring to a mysterious or esoteric type of knowledge set in contrast to explicit knowledge.

Collins (2010) describes three types of tacit knowledge: “relational,” “somatic,” and “collective” (pp. 85, 99, 119). Tacit knowledge is embedded within individuals, including employees, managers, leaders, and consultants (Dutta and Kumar, 2022). Tacit knowledge consists of intangible, undocumented forms of understanding, encompassing subjective, cognitive, and experiential learning such as insights, skills, accumulated experiences, and expertise (Kanyundo, Chipeta, & Chawinga, 2023). In the architecture of a human-centric KMS, tacit knowledge is emphasized. In the human-centric KMS in the European shipbuilding industry, tacit knowledge management plays an important role. At the individual level, trust and a sense of psychological safety within the work environment are essential for facilitating the sharing of tacit knowledge (Shahzad, Chilba, & Arslan, 2024). Within a KMS, the articulation of tacit knowledge enables the systematic capture, preservation, and dissemination of individual insights and expertise across the organization (Zaoui Seghroucheni, Lazaar, & Al Achhab, 2025). The study of tacit knowledge management is worth pursuing in the future, especially its development in the context of AI. Currently, AI can provide explicit knowledge. However, it cannot replace humans in the fields that need tacit knowledge.

3 Methods

3.1 The method for building the KMS

This thesis uses the AD method, which was derived from Suh (1990), to build the human-centric KMS in shipbuilding. The AD approach is considered a systematic approach to building a system. The process of AD matches with SE theory and can be utilized by combining a SE approach. This study starts with the definition of the KMS. Then it continues by confirming the restrictions of the system by exploring the scope and key factors, collecting the customer needs, constructing the FRs, confirming the DPs, and building and identifying the system. AD introduces the standard process of building the system. The AD approach is widely employed in the mechanical engineering field. Comparably, AD can be implemented in healthcare systems, the economy, government, and so on. Therefore, AD applies to various complex systems.

Here, the study introduces the process of conducting AD derived from the book *Design Engineering and Science* by Suh, Cavique, and Foley (2021). There are four connected design domains in AD, which are the customer, functional, physical, and process domains. They have a strict sequence. All the design solutions start from the customer domain, which means that we need to explore the customer needs first. Indeed, this thesis combines the SE approach and the AD approach. We must have an initial plan before designing the system, which means that we need to know some basic information. For example, what is the aim, what is the system boundary, and what are the restrictions of each component of the system? Therefore, in Figure 4, the work summarizes the multi-method design workflow. In Figure 4, the AD approach and SE are considered a parallel and integrated parts of the whole design process.

3.1.1 The V-model design of the human-centric KMS

In this part, the study introduces the V-model design approach to a KMS, which means that it combines the V-model design workflow and the needs of the architecture of KMSs. During this period, the AD approach derived from Suh (1990) is embedded into the design model (see Figure 4). The V-model is a traditional software development methodology that places strong emphasis on quality through systematic verification and validation activities (Pavlíčková et al., 2024).

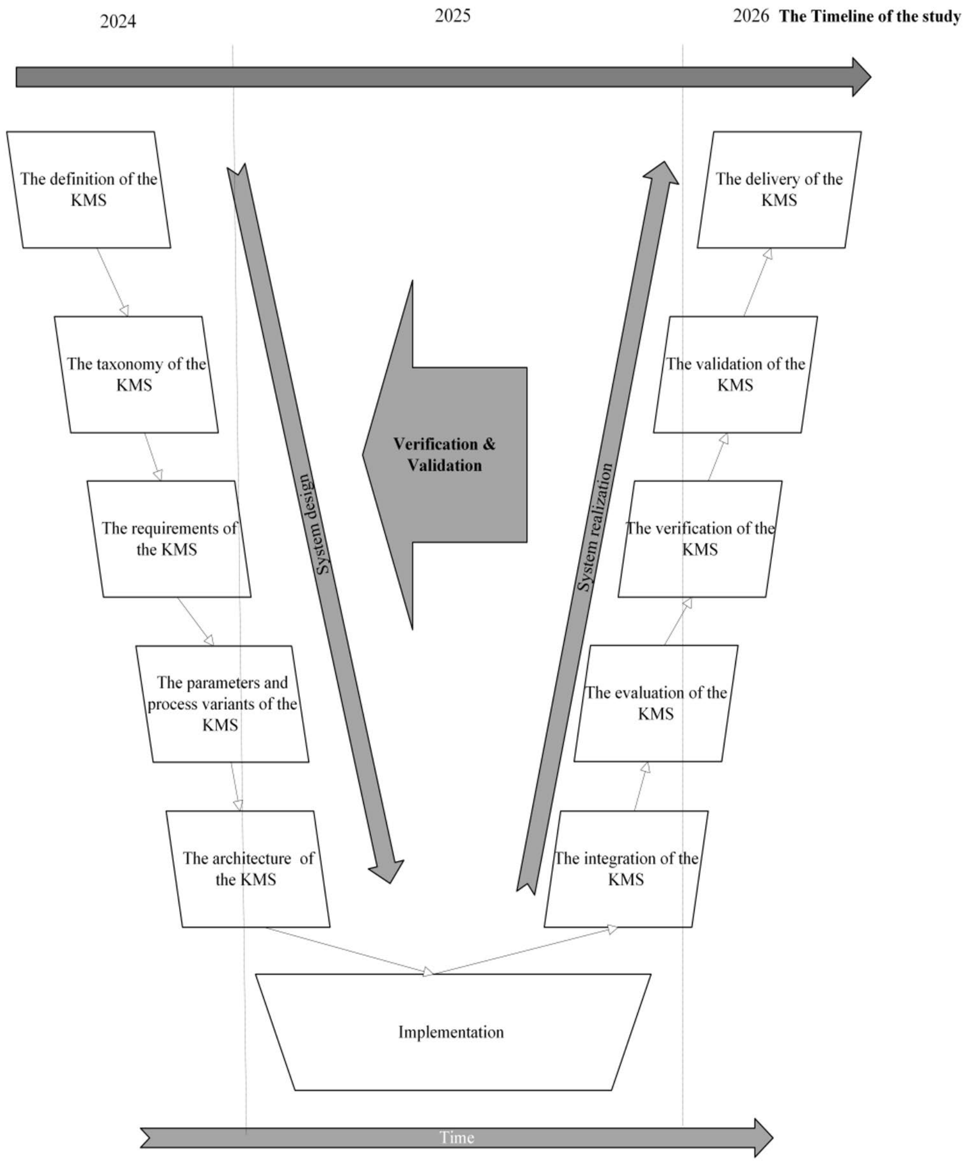

Figure 4. The human-centric KMS design V-model

Note. Redrawn based on Puik and van Osch (2024). Connecting the V-Model and Axiomatic Design; An Analysis How Systems Engineering Methodologies Relate. In: E. Puik, D. S. Cochran, J. T. Foley, P. Foith-Förster (eds.) *Proceedings of the 15th International Conference on Axiomatic Design 2023*. Lecture Notes in Networks and Systems, vol 849. Springer.

The V-model, as a part of SE, has been widely used in software engineering. Although different versions of the V-model exist, the basic steps and aim remain the same.

In Figure 4, there are 11 steps in the lifecycle of finishing the KMS. The study referred to the theory of SE from NASA systems engineering (United States, 2007), the AD approach from Suh (1990), and the description from Suh, Cavique, and Foley (2021). At the same time, it takes into account the needs and characteristics of human-centric KMSs.

1. The first step: KMS definition. During this phase, the study advises the system designer to confirm the aim and scope of the system. It is vital to know what the internal and external environments of the system are.
2. The second step: the taxonomy of the KMS, which presents the general workflow of the system, highlighted by key nodes of the system.
3. The third step: the requirements of the KMS. The study collects the customer needs, and then constructs the table of FRs.
4. The fourth step: the parameters and process variants of the KMS. We convert the FRs into DPs by the zigzag process. In this step, the necessary decomposition needs to be built. This is the projection between FRs and DPs. We also need to confirm the process variables among all the parts. It can be represented by arrows and explained by text.
5. The fifth step: the architecture of the KMS. This involves combining all the parts and finalizing the architecture of the KMS.
6. The sixth step: the implementation of the system. From this step, the system design process goes up. The implementation step means that it starts to check all the requirements and expectations from customers and prepares for the final delivery.
7. The seventh step: the KMS integration. This step aims to combine all the parts into a whole system.
8. The eighth step: the KMS evaluation. This step aims at using a design matrix to identify the connections among different parts.
9. The ninth step: this step aims at identifying all the components in the KMS.

10. The 10th step: this is aimed at validating the final KMS from the customer's perspective. Verification and validation can be viewed as complementary processes of analytical decomposition and integrative reconstruction. Verification breaks down system requirements into manageable, testable units of code, whereas validation focuses on integrating these components to ensure that the assembled system functions as intended in its final form (Pavlíčková et al., 2024).
11. The last step is the delivery of the final KMS to the customers.

3.1.2 The taxonomy of the initial development of the human-centric KMS

The concept of the taxonomy of the KMS has been presented in Article I. The term taxonomy, derived from the Greek words *taxis* (order) and *nomos* (law), was coined by the Swiss botanist A. P. de Candolle and is widely used in biology to classify organisms (Encyclopaedia Britannica, 2026).The primary aim of a taxonomic proposal is to formally establish and describe previously unrecognized elements of biodiversity (Dvořák et al., 2025). However, it is also applied in many other fields as an important method of classification. For example, findings from publications were integrated into a taxonomy that systematizes the characteristics of real-time anomaly detection (Stahmann, Nebel, & Janiesch, 2025). Regarding KM, it is employed for classifying the KM activities. It is vital for the human-centric KMS because it is a basic and essential part of the whole system as its core.

The taxonomy of the human-centric KMS leads to the final human-centric KMS model. In Figure 5, the study shows the application of taxonomy in KM in a complex environment.

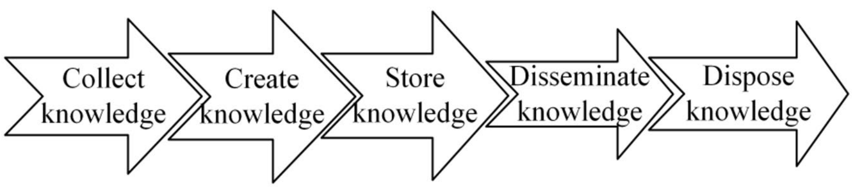

Figure 5. Conceptual taxonomy model of KM in a complex environment

Figure 5 shows basic classes of KMSs. KM is an organized and intentional process through which an organization acquires, shares, and applies knowledge in order to connect knowledge holders with those who need it and, ultimately, to strengthen performance and support innovation (Tsirakis et al., 2025). It is generated based on KM activities in a complex environment. The five steps connect, forming the basis of the KMS. The last step of the system is the disposing of knowledge. It denotes that the knowledge portal needs to be updated to remove the outdated knowledge. The human-centric KMS uses a structural way to illustrate the input, output, and process based on the taxonomy of the KM in a complex environment.

3.2 The method for exploring key factors of the system

In this thesis, quantitative analysis is used to confirm the key factors for conducting the human-centric KMS. The association between the variables in the model can follow either a linear or a non-linear pattern (Öztürk & Başar, 2022). In Article III, the study presents a linear regression method applied to confirm the key factors of the system. The literature review aims to collect the related factors that are considered potentially important for the KMS. Second, this work proposes seven hypotheses which influence the KM in shipbuilding. Their relation can be explained by the multiple linear regression formula. The next step is collecting the research data through a questionnaire survey focusing on the European shipbuilding industry where all the participants have work experience in European shipbuilding. Before the questionnaire survey, the background of the research and the definition of KM and KMS are introduced. The introduction can help participants understand the topic of the survey, to ensure its effectiveness. Then the data are collected and analysed by SPSS. The quantitative analysis shows that the process factor has a great significance on the KM. Other factors affect KM indirectly. The key factors can provide a direction for designing the architecture of a human-centric KMS. The advantages of the key factors investigation are summarized below.

1. The key factors can instruct the data collection in the final architecture of the KMS. It is related to the requirements of the KMS in the human-centric KMS design V-model.
2. The key factors can contribute to the final model of a human-centric KMS by focusing on its key factors.
3. The key factors can help us understand the internal relations among different parts of the system.

A multiple linear regression formula for KM is constructed for confirming the key factors and their relations with KM.

$$\mathcal{Y} = \beta_0 + \beta_1 \mathcal{X}_1 + \cdots \beta_n \mathcal{X}_n + \mathcal{E}$$

$\mathcal{Y}$: dependent variable which is effective knowledge management
$\mathcal{X}_n$: independent variables which are key factors of knowledge management
β_1: parameters
$\mathcal{E}$: error

3.3 The method for exploring components of the system qualitatively

Article IV focuses on the architecture of the KMS. A multi-method approach was applied in this paper. This consisted of two methods (i.e., AD derived from Suh [1990], and qualitative analysis). Qualitative content analysis is widely employed by researchers across diverse disciplines as a methodological approach to social inquiry on a global scale (Boller et al., 2026). A short literature review was conducted to confirm the theme and design the survey. The qualitative analysis was a longitudinal study. The survey lasted for 32 months and included workshops, interviews, questionnaires, and periodic meetings. The content was encoded by themes. Any inconsistencies in the coding process were addressed through collaborative discussion until a shared interpretation was reached, thereby enhancing the reliability of the analysis (Shahiwala & Rahul, 2025). Thematic analysis is a qualitative approach used to identify, interpret, and systematically describe recurring patterns or themes within a dataset (Braun & Clarke, 2006). Furthermore, the different forms of surveys can ensure that the data are wide and complete. The data were collected during the period of project work, promoting a complete and reliable triangulation.

The study method in Article IV is shown in Figure 6. Figure 6 depicts how the aforesaid process relates to the whole system design process.

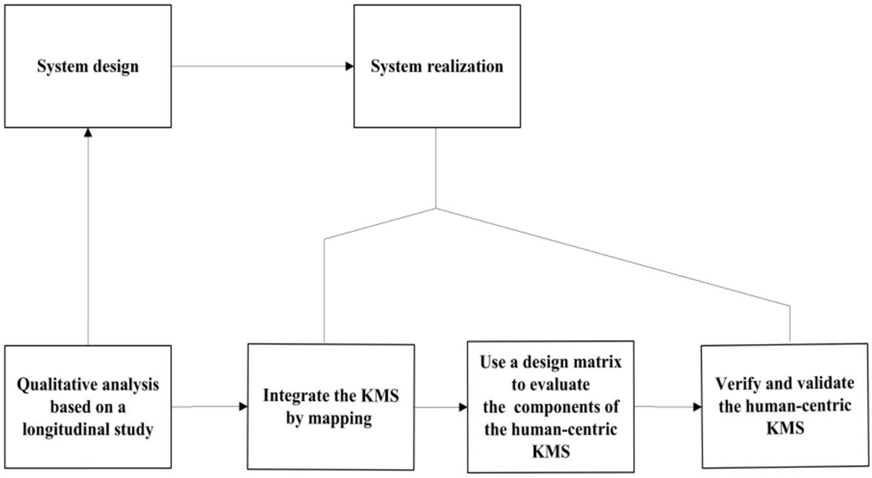

Figure 6. The system realization methodology in a human-centric KMS

Through the four steps of the research process, the study builds the final human-centric KMS. In the meantime, each step matches those in the human-centric knowledge management system design V-model.

There are four steps for achieving the system realization process. A longitudinal study is used to confirm the components of the system. This is part of the system design phase in the human-centric KMS design V-model. The second step is integrating the KMS. This is linked to the KMS integration in the human-centric KMS design V-model. The third step is utilizing a design matrix to evaluate all the components of the system. The fourth is verifying and validating the system. The final system is delivered to a group of experts in the European shipbuilding industry. Based on their comments, the project finalizes the model and delivers the final human-centric KMS. This is part of the system realization step in the human-centric KMS design V-model. The system is constructed over the second to the fourth step.

4 Summary of Included Articles

The study contributes to the KM in the European shipbuilding industry by systematizing and facilitating the KM activities in shipbuilding. In addition, the human-centric concept is embedded into the KMS in shipbuilding. The four articles work together to explain the architecture of human-centric KMS in shipbuilding. The first paper explains the taxonomy of KM in a complex environment. It outlines the core and foundation of the research. The rest explain the feasibility and potential factors, and lead to the final architecture of the KMS. Table 2 shows the essential results of each article.

Table 2. The essential results of each article

Articles	Titles	Essential results
Article I (Ni & Kantola, 2024)	Taxonomy of Knowledge Management Systems in a Complex Environment	The results show that the different types of knowledge and different dimensions of KM can work with different tools under the same system. In the meantime, the workflow of a KMS in a complex environment can form the comprehensive groundwork for the study.
Article II (Ni, 2024)	Can Knowledge Management Be Appropriate for Shipbuilding?: Based on Typology and the Seven C's Model	The paper reviews KM definitions in different fields and introduces the seven C's model to evaluate the feasibility of KM in shipbuilding. The result shows that KM is appropriate for the shipbuilding industry.
Article III (Ni & Kantola, 2025)	Exploring The Factors Influencing Knowledge Management Strategy in the European Shipbuilding Industry: A Pilot Study	The paper explores the potential key factors through quantitative analysis. It reveals that the process factor affects the KM strategy directly. Other factors impact the KM strategy indirectly.
Article IV (Ni & Kantola, in press)	Modelling Human-centric Knowledge Management Systems Based on a Shipbuilding Project	The paper presents the final architecture of human-centric KMS in shipbuilding. It shows that the KMS system is a decoupled design. In addition, tacit knowledge plays a vital role in the human-centric KMS in European shipbuilding.

4.1 The application of a taxonomy in the KMS in shipbuilding

Article I describes the general taxonomy of a KMS in a complex environment in two aspects. The first aspect is process dimensions. The second is the knowledge dimensions. The taxonomy model of the KMS aims at classifying the KMS into different layers. Since KM is a comprehensive management subject, it involves various subjects, such as strategy management, information technology, quality management, and so on. It relates to distinct forms of knowledge and distinct stages of the KMS. Due to such circumstances, it is crucial to apply the taxonomy method to classify the operations of KM in the system. The architecture of the general taxonomy of a KMS demonstrates these advantages:

1. It gives a reference for the architecture of the human-centric KMS in shipbuilding by illustrating the tools and methods applied in different scenarios under the architecture.
2. The general KMS taxonomy connects different knowledge dimensions with process dimensions, to make them parts of the whole KMS.

Figure 7 shows the relation between the general KMS taxonomy and the system realization.

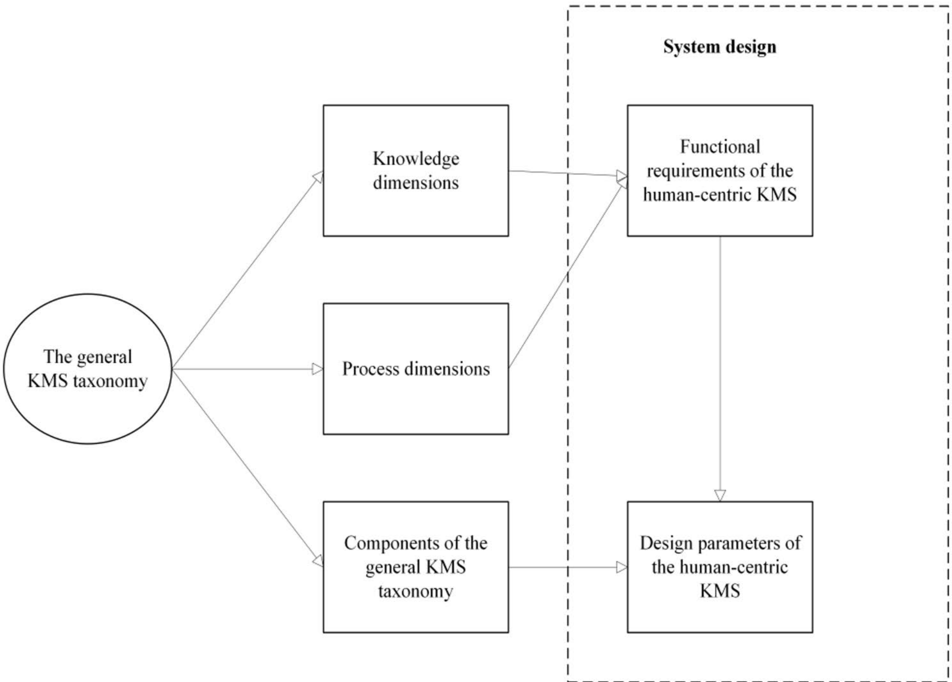

Figure 7. The relation between the general KMS taxonomy and the human-centric KMS in shipbuilding

Figure 7 shows how three parts of the general KMS taxonomy connect to the system design process by arrows. Knowledge and process dimensions refer to the functional requirements architecture. Components of the general KMS taxonomy relate to the architecture of DPs. They provide a good reference during the architecture of FRs and DPs.

4.2 The feasibility of applying KM in shipbuilding

Article II studies the feasibility of applying KM in shipbuilding by using the seven C's model conceived by Anders Örtenblad (Myers 2016). The results reveal that KM is very suitable for shipbuilding. A firm attains competitive advantage when it develops distinctive knowledge that enables it to operate more effectively or efficiently than its rivals (El Hachem, Harik, & Khoury, 2014). Article II presents a feasible analysis of the architecture of human-centric KMS in the shipbuilding industry. It evaluates the human-centric KMS from a strategy perspective and provides the foundation. Figure 8 shows how Article II contributes to the human-centric KMS study.

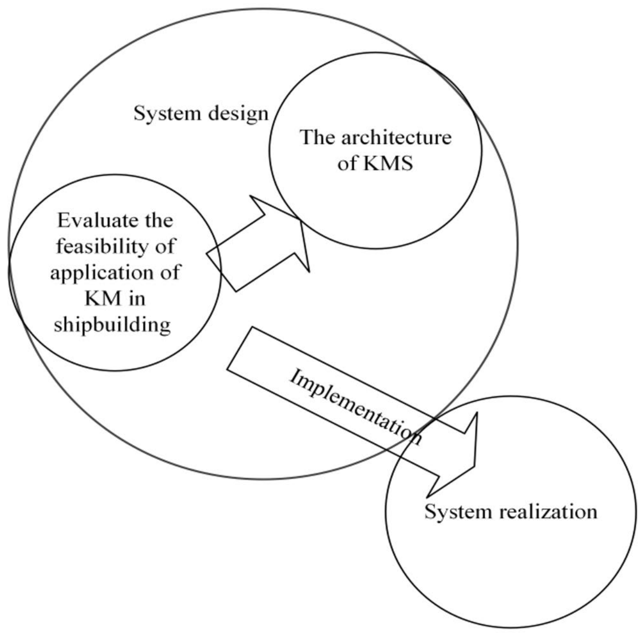

Figure 8. The relation between the feasibility of KM and the process of system architecture

In Figure 8, we can see that the evaluation of KMS feasibility and its architecture affect each other, and they work together as part of the system design to lead to system realization.

4.3 The process factor influences the KM strategy in shipbuilding

Article III studies the relation between potential key factors and KM. In organizational settings, the management of people, technologies, processes, products, and projects inherently involves handling the knowledge embedded in these components and continuously processed by employees across different roles and hierarchical levels (Nakash & Bolisani, 2025). The study finds that the process factor plays a vital role in KM, as it affects the KM directly. It reminds us that we need to focus on the process factor when developing the architecture of KMSs. The process here mainly refers to the lifecycle of shipbuilding. Different stages concentrate on different dimensions of knowledge. KM is embedded in the whole process of shipbuilding. Although the case is from the shipbuilding industry, the result can still be a reference for other knowledge-intensive industries. The outcome contributes to the KMS definition from a strategy perspective; in the meantime, it adds to the architecture of requirements of the system (see Figure 9).

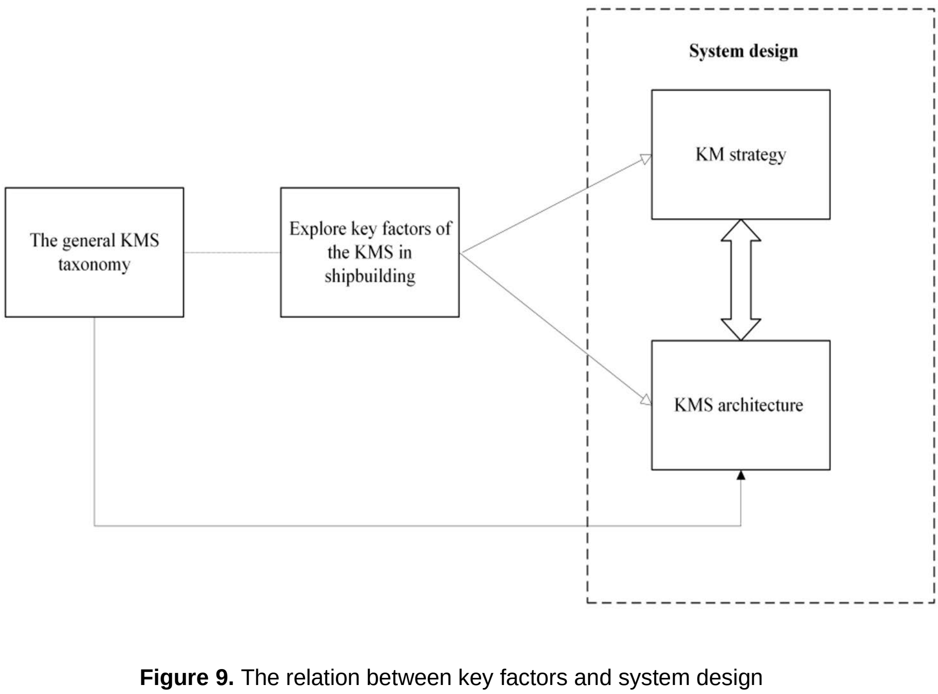

Figure 9. The relation between key factors and system design

Figure 9 reveals the relation between key factors and the system design process. Additionally, it reflects the relation with the general KMS taxonomy. How they work together to lead to the final system design is a valuable point in this figure.

We can see four process blocks in Figure 9. The initial two parts are the contributions to the system. Article III focuses on the key factors. It contributes to the final architecture of human-centric KMS in shipbuilding and KM strategy by providing a strong reference for the components of the system. In the meantime, the general KMS taxonomy contributes to the theme and also forms an essential foundation for in the architecture of the KMS.

4.4 The human-centric KMS in shipbuilding is a decoupled system

Article IV examines the architecture of a human-centric KMS in the European shipbuilding industry. According to Suh, Cavique, and Foley (2021), the result reveals a profound finding, which is that one DP in the human-centric KMS can affect multiple FRs simultaneously. Furthermore, from the design matrix in the human-centric KMS in the study, we can see that the human-centric KMS in shipbuilding is a decoupled system.

The reasons for this result are summarized as follows:

1. The human-centric KMS in the European shipbuilding industry is a system that contains technology as well as humans and social-related components. The components related to humans and technology are embedded in the system. It is difficult to keep all the FRs independent.
2. It differs from a mechanical system. The parts of human-centric KMS are connected and controlled by several parameters. Different stages of the project can affect each other directly or indirectly.

Figure 10 shows the contributions of Article IV to the human-centric KMS.

Figure 10 explains three aspects of the architecture of human-centric KMS. They are part of the system realization process, which leads to the finalization of the human-centric KMS in shipbuilding.

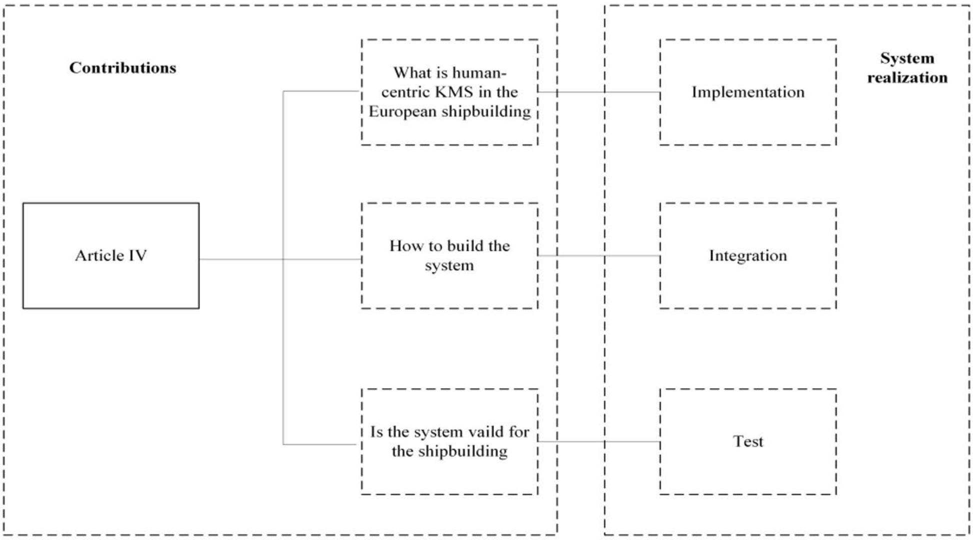

Figure 10. The relation between the architecture of the human-centric KMS in shipbuilding and system realization

Article IV focuses on the three parts linked to three main questions. The first is: what is a human-centric KMS in shipbuilding? This is explained in the discussion part. The second is: how can we build a human-centric KMS for shipbuilding? This is the core of the article, as described throughout. The third question is about the validation of the human-centric KMS in shipbuilding. Article IV adopts a design matrix based on Suh, Cavique, and Foley (2021) to identify the system and a face test to validate it. The study in Article IV leads to the realization of the KMS.

5 Results

5.1 The lifecycle of KM in shipbuilding

The study focuses on the lifecycle of KM in the European shipbuilding industry. It aims to determine what type of knowledge is used and how it moves at different stages of shipbuilding.

Figure 11 shows there are three phases in the European shipbuilding industry. Project preparation, construction, and delivery are presented on the horizontal axis. The vertical axis displays different degrees of interaction between human involvement and the technical perspective of KM.

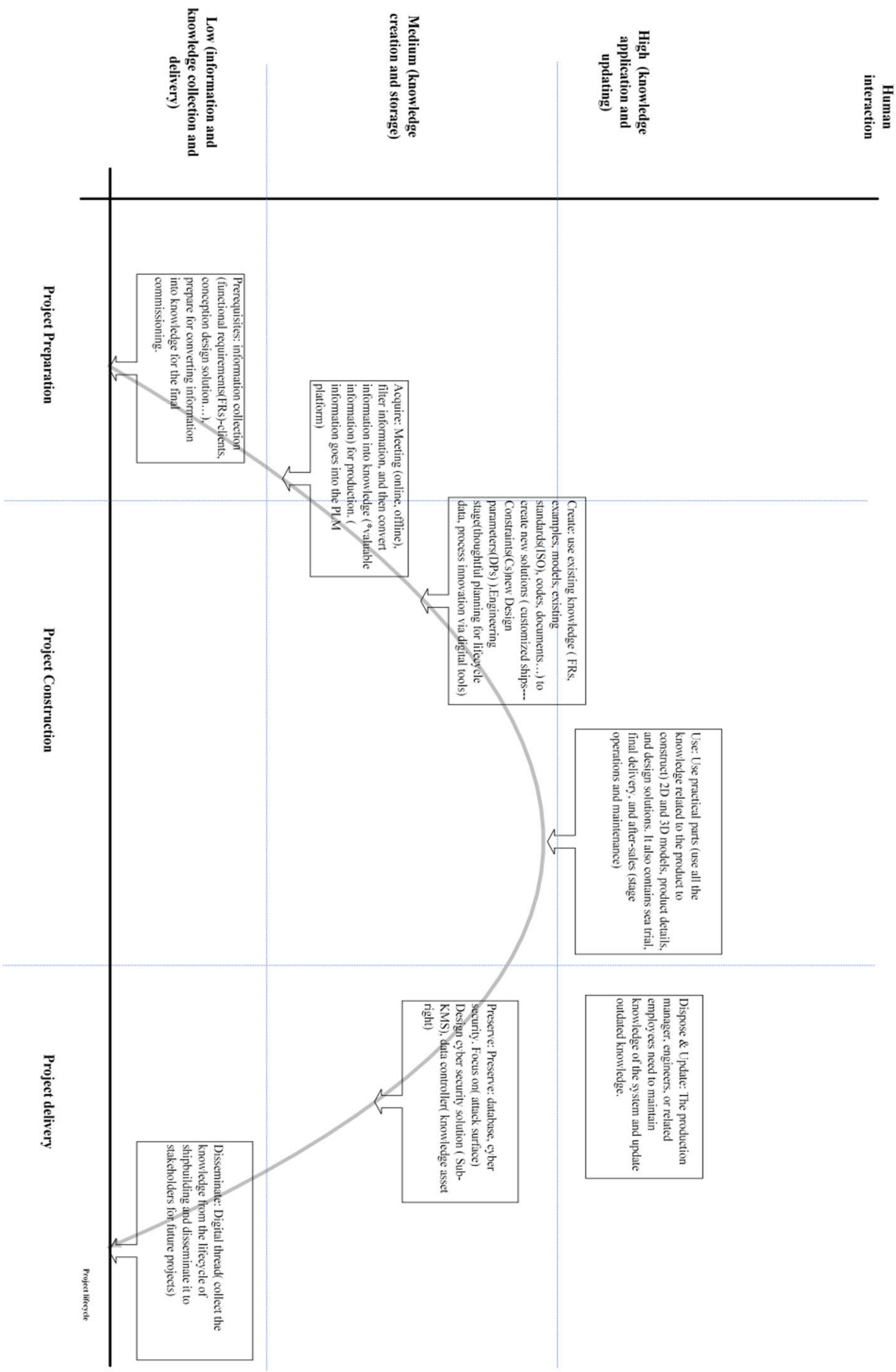

Figure 11. The lifecycle of KM in the European shipbuilding industry

Figure 11 shows that the project construction phase has the highest human interaction. This is due to the characteristics of the shipbuilding projects. People learn from each other. Junior workers learn from senior ones onsite, where a lot of tacit knowledge is transmitted. That tacit knowledge in shipyards is hard to encode. In other words, high human interaction sometimes means a large volume of tacit knowledge. For the project preparation and project delivery phases, shipyards pay more attention to procedural knowledge. However, this does not mean that they do not involve tacit knowledge. For example, negotiation needs a lot of tacit knowledge. But when we consider this as a part of the entire project preparation, the whole phase involves less human interaction than project construction. The engineer-to-order concept is very common in shipbuilding. The process follows this route from collecting information on the potential order to the delivery. Human-centric factors are embedded into the whole process in the European shipbuilding industry. Both explicit and tacit knowledge, produced through interactions among individuals and between humans and machines, have contributed to strengthening the overall competitiveness. This finding is closely aligned with the core focus of this doctoral dissertation, which examines human-centred knowledge management systems within complex environments.

Figure 11 displays the lifecycle of the KM activities in shipbuilding from the process dimensions of the KMS perspective. The process dimensions of the KMS are projected into a typical shipbuilding process and described below.

Prerequisites stage: during this stage, information is collected by the sales department and managers. The sales departments need to communicate with customers and introduce the information to the organization. Managers need to prepare for the orders by using old knowledge. During this stage, a large amount of explicit knowledge is collected, and some tacit knowledge is utilized and created.

Acquiring stage: the information needs to be evaluated and processed by the project members. They need to communicate with each other and develop a community of practice, as conceptualized by Lave and Wenger (1991). In apprenticeship, opportunities for learning are, more often than not, shaped by work practices rather than by strongly asymmetrical master–apprentice relationships (Lave & Wenger, 1991). In the context of the CoP, employees in shipyards with different backgrounds work together to prepare for new orders.

Creating knowledge: at this stage, new knowledge is created by communication, experience, coded information, and personal skills. New knowledge is generated for the new order.

Using knowledge: we use the knowledge to finish the order. During this phase, much tacit knowledge is utilized and transferred in shipyards. There are plenty of operations at the site, and a lot of modifications to the design happen.

Preserving knowledge: this aims at keeping the knowledge for future work, in order to reduce the time for construction. However, a lot of tacit knowledge is hard to encode.

Disseminating knowledge: knowledge needs to be communicated. It is beneficial for organizations to create new knowledge. However, it contains a lot of drawbacks. Knowledge assets can be leaked. This poses a risk for organizations. Generally, disseminating knowledge constitutes a key component of future work.

Finally, disposing of knowledge is considered the final step for KMS and a step in preparing for future projects.

5.2 The architecture of the human-centric KMS in the European shipbuilding

The study presents an architecture of the human-centric KMS in the European shipbuilding industry, which includes themes, FRs, customer needs, and DPs (see Table 3). The human-centric KMS in the European shipbuilding industry is in a complex environment due to external and internal uncertainties, which can affect KM for achieving high competitiveness in the ship market.

Table 3. The architecture of the human-centric KMS in European shipbuilding

Note. Adapted from Article IV (in press).

Theme	Customer needs	FRs	DPs
Manage knowledge at different stages	CN1	FR1	DP1
Manage tacit knowledge	CN2	FR2.1	DP2.1
		FR2.2	DP2.2
Use old knowledge	CN3	FR3.1	DP3.1
		FR3.2	DP3.2
		FR3.3	DP3.3
Keep connections	CN4	FR4.1	DP4.1

		FR4.2	DP4.2
Update knowledge	CN5	FR5	DP5
Manage tacit knowledge	CN6	FR6.1	DP6.1
		FR6.2	DP6.2
Manage knowledge at different stages	CN7	FR7	DP7
Take measures for document management	CN8	FR8	DP8
Update knowledge	CN9	FR9	DP9

Building on Suh, Cavique, and Foley (2021), Figure 12 illustrates the design matrix used in the study. The design matrix reveals the type of system being designed. The design matrix can help us understand the relationship between FRs and DPs to develop a suitable design solution. FRs are the functional components of the system. DPs are the solutions of the human-centric KMS. In the context of European shipbuilding, the work proposes a list of DPs leading to the system. Based on the architecture of FRs and DPs, the design matrix is presented in Figure 12. The human-centric KMS in the European shipbuilding industry is considered a decoupled system since some key FRs can be affected by the same DP. In reality, it reminds decision-makers working in the European shipbuilding industry to focus on the internal system structure, providing customized solutions based on system requirements and actual conditions.

		DP1	DP2		DP3			DP4		DP5	DP6		DP7	DP8	DP9
			DP2.1	DP2.2	DP3.1	DP3.2	DP3.3	DP4.1	DP4.2		DP6.1	DP6.2			
FR1		X													
FR2	FR2.1	0	X												
	FR2.2	0	0	X											
FR3	FR3.1	0	0	0	X										
	FR3.2	0	0	0	0	X									
	FR3.3	0	0	0	0	0	X								
FR4	FR4.1	0	0	0	0	0	0	X							
	FR4.2	0	0	0	0	0	0	0	X						
	FR5	0	0	0	0	0	0	0	0	X					
FR6	FR6.1	0	x	0	0	0	0	x	0	0	X				
	FR6.2	0	0	0	0	0	0	0	0	0	0	X			
FR7		0	0	0	0	0	0	0	0	0	0	0	X		
FR8		0	0	0	0	0	0	0	0	0	0	0	X	X	
FR9		x	0	0	0	0	0	0	0	0	0	0	0	0	X

Figure 12. The design matrix of the human-centric KMS in the European shipbuilding industry

Note. Reproduced from Article IV (in press), with permission.

Figure 13 shows the relations among different DPs. This is a part of the architecture of the human-centric KMS, which visualizes the collaboration between various DPs within the context of a shipyard. Different DPs are connected with each other by the actual needs of processing organizational knowledge. The arrows illustrate how the knowledge is transmitted in the organization. DP7 integrates differing DPs and leads to the KMS in the context of the European shipbuilding industry. DP9 coordinates the KM activities, which play an important role in the system.

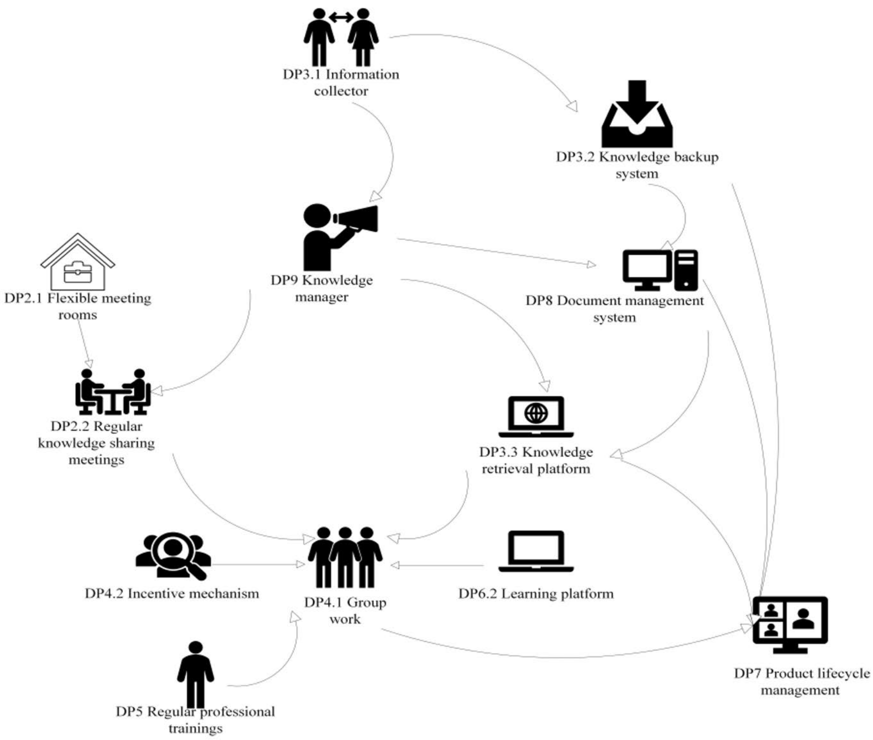

Figure 13. The collaboration network of DPs within the context of a shipyard

6 Discussion

6.1 Summary of integrated findings

This thesis shows that the human-centric KMS, as a decoupled system, is appropriate for facilitating KM in the shipbuilding industry. It can improve the core competitiveness of the European shipbuilding industry. The process factor, as a key factor in conducting KM in shipbuilding, needs to be emphasized. It can directly affect KM activities, as shown through the pilot study in the SEUS project. This work fills the research gap between human-centric KMS and shipbuilding. It also demonstrates that shipbuilding cannot be considered solely a traditional industry. With the development of IT and AI, shipyards need to conduct effective KM to enhance their competitiveness in the global market of shipbuilding. The era in which human capital was the critical competitive factor in the shipbuilding industry is obsolete. European shipbuilding should make knowledge an essential asset during the new Industry 5.0 era. The modern European shipbuilding industry is appropriately characterized as a knowledge-intensive industry. The findings from the lifecycle of KM in shipbuilding indicate that different stages of shipbuilding are associated with different types of knowledge; however, tacit and explicit knowledge both play vital roles in the KMS in shipbuilding. Shipyards therefore need to pay attention to the characteristics of different types of knowledge.

6.2 Synthesis and cohesion

This thesis utilizes approaches derived from systems engineering and design to build a human-centric KMS in shipbuilding, based on a general KMS taxonomy. Article I focuses on the taxonomy of KMSs, which serves as the foundation for human-centric KMS in shipbuilding. Article II concentrates on the feasibility of implementing KM in shipbuilding. Article III explores the key factors of KM from a strategy perspective. Article IV extends that content to the architecture of the human-centric KMS in European shipbuilding. Those works can not only advance the study of KMSs in European shipbuilding but also promote its research in other industries.

Consequently, understanding the architecture of KMSs is essential for applying it in shipbuilding and other knowledge-intensive industries.

6.3 Comparison with the literature

A search for “knowledge management” AND “shipbuilding” in Scopus and Web of Science yields only a few publications. The scope of the subject area is restricted to business, management, and accounting. Finally, 12 papers are retrieved. Some of the typical studies are selected and presented below.

Table 4 presents key related studies on KM in shipbuilding.

Table 4. The key information of the related literature on KM in shipbuilding

Author	Title of the publication	Key information
Cerezo-Narváez et al. (2021)	Knowledge as an Organizational Asset for Managing Complex Projects: The Case of Naval Platforms	This study introduces a comprehensive KM framework designed to support the management of complex projects in dynamic environments, where effective integration with risk management practices is essential.
Hosseini and Akhavan (2017)	A Model for Project Team Formation in Complex Engineering Projects Under Uncertainty: A Knowledge-sharing Approach	The well-established motivation–opportunity–ability (MOA) framework is employed to identify the key determinants of knowledge sharing during the process of team formation.
Halse (2014)	Global Value Chains in Shipbuilding: Governance and Knowledge Exchange	The core shipbuilding processes are examined to illuminate governance mechanisms and the dynamics of knowledge flow across global networks.

Based on the aforesaid literature, we find that the study is different from them in the aim of the design. The first publication focuses on the framework design of KM. This thesis concentrates on the architecture of a system based on the lifecycle of shipbuilding. The second publication pays attention to the knowledge sharing in the context of the shipbuilding industry; however, this work emphasizes the complete dimensions of KM. The third publication draws attention to the knowledge flow instead of studying the complete KMS, including the design parameters.

6.4 Theoretical implications

The conduct of KM in European shipbuilding has not been studied in a systematic way. This thesis aims to build a KMS to improve the performance of KM in the European shipbuilding industry. It is based on the current literature and the needs of the European shipbuilding industry. The first innovation of the theoretical part is that it applies a new V-model to design the study. This is a new version of the V-model in the KM field. According to Myers (2016), the Seven C's Model—conceived by Anders Örtenblad, the second innovation is that it develops the application of the seven C's model. It reflects that it is not necessary to fulfil all the parts of the model to confirm the feasibility of KM in the shipbuilding industry. The application of the model in shipbuilding pays attention to internal communication and connections with the external environment. This contributes to the development of the seven C's model. The third innovation is the multi-method application in the architecture of the KMS. A multi-method approach consisting of axiomatic design and qualitative analysis is proposed for the architecture. Thematic analysis, under the qualitative analysis, is used for confirming the components, and AD derived from Suh (1990) is utilized for connecting the components and building the system.

6.5 Practical implications

This thesis fills the research gap between human-centric KMS and shipbuilding. In the past, many works focused on KMSs and the architecture of the IT and software engineering networks. There are a few studies of KMSs that concentrate on the complete KM activities in the shipbuilding industry. Furthermore, the dissertation is a pioneer in KMS, centring on a human-centric perspective in the shipbuilding industry, and makes some significant contributions.

1. In the study, a new model of the human-centric KMS design V-model is developed. This model is used for explaining the process of architecture of human-centric KMS in shipbuilding from the SE perspective. The work adjusts the original V-model from SE and adapts it for the KM field.

2. A multi-method study is conducted in the thesis. This is used for building the human-centric KMS in shipbuilding by creating the components of the system qualitatively and confirming the architecture of the system by a systematic design approach.

3. The multiple linear regression analysis, as an empirical tool, confirms the key factors of the KMS.

4. The study proposes a reliable human-centric KMS for instructing the revolution of the current KM module in the European shipbuilding industry, to adapt to the demands of Industry 5.0 under the European Union policy framework.

6.6 Overarching limitations

Firstly, the study faces limitations arising from its research background. Our research object is European shipbuilding. Shipbuilding in different countries has its own characteristics and similarities. The limitation of this thesis is that it focuses on the regional shipbuilding industry. It would be useful to expand the scope to a larger region. The similarities are due to the cooperation and competition among different shipyards. These phenomena can be summarized as follows:

1. The mobility of skilled workers and experts can cause knowledge transfer among different organizations.
2. The global shipbuilding industry must follow relatively uniform standards.
3. The shipbuilding industry has an extensive range of material sources.

For these reasons, it would be meaningful to study KMSs in other regions and compare the results with European shipbuilding. In the meantime, the study sample is restricted to the SEUS project group. The data are stable and reliable, but it would still be valuable to expand the sample range with the following suggestions:

4. Different regions of Europe should have one shipyard participate in the research.
5. Different subcontractors should participate in the research.
6. It would be meaningful to collect the data from the external environment of the system. For example, the government, policy-makers, and other organizations do not directly oversee shipbuilding.

When the study scope is expanded to the Asian shipbuilding industry, the key factors of KM may include different factors. Due to the differences in internal and external environments, KMSs should be designed and deployed in different ways.

6.7 Future research

AI and IT have affected the European shipbuilding industry by improving the efficiency of KM from a KM perspective. However, there is no study on the relationship between those new technologies and humans. How they work together to change the form of KM of the European shipbuilding industry would be a valuable theme. The incorporation of generative AI into knowledge management introduces not only the practical challenges that dominate current research, but also a range of theoretical implications that warrant further examination (Kirchner et al., 2025). Future research can explore the interaction between AI and human-centric KM.

7 Validity

This study applies the quantitative and qualitative analysis methods. Article III reviews the KM literature to design an effective questionnaire. The questionnaire was sent to the group from the SEUS project. The selected participants have a highly relevant background in European shipbuilding, ensuring the data resource is reliable. Two people reviewed the result to prevent errors when entering the original data. Article IV utilizes a qualitative analysis. To maintain the high effectiveness of the original data, the work collected data from a group of experts with experience in European shipbuilding. The survey lasted 32 months to identify all potential KM themes in European shipbuilding. This maintained the high effectiveness of the original data.

In addition, triangulation was employed to improve the credibility and depth of the study. For example, it explored themes across various survey methods (e.g., periodic meetings, questionnaire surveys, workshops). Different investigators took part in the research. It also implemented verification and validation procedures to achieve high effectiveness. The verification step adopted the design matrix from axiomatic design. It aimed to evaluate whether the process meets the requirements of the design axiom. The SEUS project's experts performed the validation, with the goal of evaluating the final human-centric KMS in the European shipbuilding industry. The thesis meets the standards of scientific research validity. The result can be applied to European shipbuilding, and the process can serve as a reference for similar research themes.

8 Conclusions

Article I applied the taxonomy method to set a basis for the architecture of human-centric KMS. Article II used the seven C's model to evaluate the feasibility of building the KMS in the targeted field. Subsequently, the key factors were confirmed by a pilot study. Article III verified that the process is the direct key factor of the human-centric KMS in shipbuilding. Ultimately, Article IV utilized a multi-method examination to show what the human-centric KMS in shipbuilding is. The main finding is that the process is considered the key factor in constructing the human-centric KMS in shipbuilding, and that tacit knowledge plays a vital role in this process. Additionally, axiomatic design and systems engineering can be employed to build the architecture.

In this thesis, a multi-method approach combining axiomatic design and qualitative analysis is used to construct a human-centric KMS. This is the first practice of the multi-method approach applied in the architecture of human-centric KMS in shipbuilding. The method has significant implications for developing specific human-centric KMS within organizations through a similar system architecture process. The results can serve as a good reference for facilitating the KM process in the current European shipbuilding industry; however, it still has some limitations. The study is based on a specific group in Europe, so would be useful if it could be expanded to other regions. For example, the shipbuilding industry in Asia is growing rapidly. It would therefore be valuable to explore the human-centric KMS in Asia.

In addition, the architecture of the human-centric KMS can be applied to other system designs. The theories of KM and KMS can be a good reference for other knowledge-intensive industries. For future work, the study provides a good foundation for KM by taking into account the relationship between humans and AI technology. Human beings create knowledge and simultaneously hold a wide range of tacit knowledge, which is hard for AI to completely duplicate and utilize. Given the current development of AI technology, it would be valuable to explore the possibility of AI absorbing tacit knowledge and how AI and humans can work together as a system to improve KM across different knowledge-intensive industries.

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Turku, 26 February 2026

Pengcheng Ni

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