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Designing a survey framework to collect port stakeholders' insight regarding AI implementation: results from the Flemish context

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Abstract

Today, several research/initiatives exist in AI technology at the port operation. They mainly focus on solution development in a particular port and shipping industry domain. This scattered implementation leads to an unstructured overview of the port sector regarding AI innovation in use. Equally, this study aims to structure this overview for aligning stakeholders and AI providers toward implementation. In doing so, the first step would be collecting the port stakeholders' insight regarding AI implementation. This study develops a structured framework to collect the port stakeholders' insight through both desk and empirical research. Besides, an online survey is built based on the framework and sent to a target group of port stakeholders to collect their insight. The survey results show that a huge effort is needed to establish a structure for data exchange to increase the quality of data. Additionally, by highlighting the importance of data from specific stakeholders, developers can effectively convey the value proposition to these stakeholders. They can emphasize how utilizing this vital data can result in operational enhancements, cost reductions, improved decision-making, and competitive advantages. As an implication, alignment between port stakeholders and AI providers enhances the maturity level of the market in AI solutions by fostering collaboration, addressing industry-specific challenges, tailoring solutions, and garnering support for implementation.

Keywords: AI technology, Port, Shipping industry, Implementing, Survey

Introduction

Nowadays, port and shipping industries struggle with challenges for which existing methods and approaches cannot guarantee effective solutions. For instance, the amount of data generated in these industries far outpaces current methods' ability to interpret. In light of this, AI technologies have been developed to boost current systems' capabilities. AI enables human capabilities to be undertaken by software increasingly effectively, efficiently, and at low cost. More specifically, human operators can perform better by cutting errors and making operations faster (Atak et al. 2021). Furthermore, transporting

manufactured goods and container shipping is one of the most complex industries in the world. For example, there are millions of combinations in which one can ship containers from A to B, and every decision needs to consider multiple factors. For example, to change the ETA of a port, it is required to be aware of berth availability, transshipments, impact on bunker usage, weather conditions, etc. Therefore, the port and shipping industry would be one of the industries that will benefit most from applying AI technology to its operations (Chui et al. 2018).

Ports form an essential economic activity in offshore areas as they take up the role of gateways to the world for transportation in the international trade process. They also act as a crucial connection between sea and land transport. The higher the throughput of goods, the more infrastructure, provisions, and associated services are required. These will bring varying degrees of benefit or advantage to the local and regional economy and the environment. Two distinguished approaches can manage this higher throughput. The first approach is to increase infrastructure and resources to cope with extra throughput (Jeevan et al. 2015). Since it is sometimes impossible to expand infrastructure and resources, reinvestments should be considered to deal with high throughput. The second approach is to handle higher throughput with new technologies such as AI, whose capabilities can avoid adding additional infrastructure and resources like the first approach (Advanced Polymer Coatings 2019).

Agrawal et al. (2018) stated that AI technology possesses two primary added value elements for industry: optimization and prediction. According to the literature, port stakeholders most often have prediction and optimization objectives while implementing AI technology (see Fig. 1). Additionally, AI technology can address numerous applications in the port and shipping industries under those two objectives. The present section also exhibits those applications developed in ports worldwide.

Prediction applications are primarily about finding out issues beforehand to assist stakeholders in monitoring and considering every aspect of planning. It can cause them to become ready for disruption earlier. The advantages of employing AI and Machine Learning (ML)-based demand-predicting approaches are diverse. Predicting demand

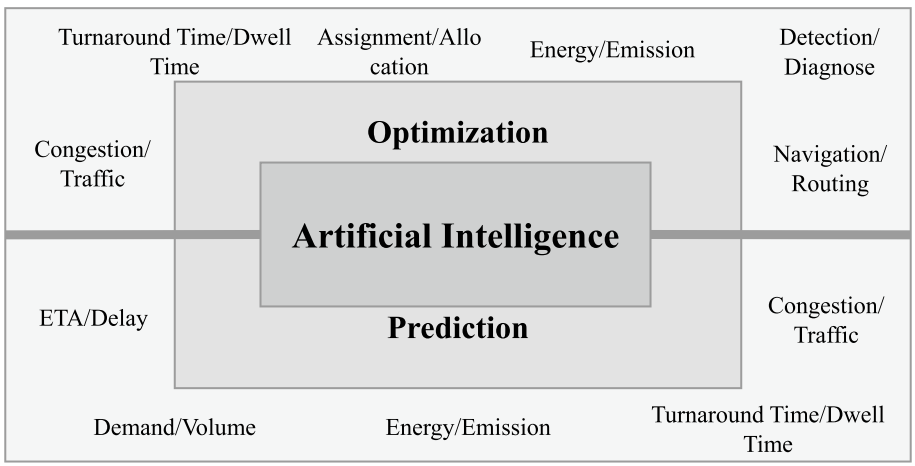

Fig. 1 AI technologies' applications in port and shipping industries. source own composition based on literature review

or volume of cargo through AI technology methods can increase accuracy in supply chain networks. Implementing these innovative forecasting approaches could assist port stakeholders in decreasing errors at all levels (Darendeli et al. 2021; Garrido et al. 2020; Kunnapapdeelert and Thepmongkorn 2020; Moscoso-López et al. 2021; Xie et al. 2017). Precise vessel ETA's give vital information to guarantee stakeholders can enhance port operations efficiency. Throughout maritime supply chain and port operations, predicting arrival times is a crucial task. Hence, bias in predicting vessels' ETA affects port operations and disturbs the port chain. Exploiting AI solutions to predict vessels' ETA can accelerate replanning processes in case of deviation (Flapper 2020; Parolas 2016). Assets' uptime can be increased through the prediction goal of AI technology. In this regard, stakeholders can receive forecasts for berth occupancy earlier and extend developed solutions to predict vessel turnaround time (TT). Those solutions can also foresee container dwell time (DT) in the port area (Štepec et al. 2020).

Optimization applications of AI can address complicated challenges associated with costs and emissions reduction in port operations. Moreover, since the investment level in port assets is massive, the importance of optimization is already high. Therefore, port stakeholders can optimize the utilization of their assets as efficiently as possible through AI optimization applications. One of the complicated problems for terminals is berth planning, which incorporates addressing several challenges like optimizing quay crane assignment, decreasing vessel waiting time, optimizing ship stowage planning, and optimizing vessel queuing (Shahpanah et al. 2014; Shen et al. 2017). In addition, every well-known terminal faces congestion and traffic at the gate, causing a bottleneck within the maritime supply chain. This problem can be addressed through an AI solution that assists stakeholders in optimizing truck flow at the gate by leveraging congestion level monitoring (Luo and Huang 2020; Martins et al. 2020).

Hinterland transport has a critical role and influences other parts (landside, waterside) of port operation. Moreover, trucks are broadly used to transport containers within terminals' sites. Since optimized truck routing can noticeably enhance port throughput and efficiency, trucking companies must anticipate a suitable truck routing approach. Optimization of inter-terminal truck routing considerably increases port efficiency. Port of Busan developed a deep learning method to boost existing inter-terminal truck route optimization methods considering multiple important factors like origin, destination, time window, and promise date (Adi et al. 2020).

With AI technologies, stakeholders can add all aspects to design meaningfully more efficient plans to decrease emissions. Port and shipping industries are critical actors in air pollution, predominantly in coastal areas. Optimization of energy consumption within those industries is a measure towards contributing to emissions reduction. This problem has been initiated to address by availing AI in some ports worldwide (Cammin et al. 2020; El Mekkaoui et al. 2020). AI technologies can also be used within solutions whose feature is to detect failures. This detection includes asset positioning and recognition. Compared to conventional methods, AI solutions can ensure more precise outcomes. Consequently, Taicang and Hong Kong ports employed AI technologies for vessel selection and containers trucks recognition (Mi et al. 2019; Yan et al. 2021).

Consequently, port stakeholders can benefit from implementing AI technologies across their operations. This way, solution providers always tend to stimulate port

stakeholders to start an AI project and address port challenges by implementing AI solutions. However, they don't know whether port stakeholders are conscious of AI technologies' capabilities. They also need to know about status of AI implementation at stakeholders' site. Therefore, once port stakeholders should be encouraged to avail of AI, information should exist about the current stage of their operation in terms of AI implementation. Evidently, there is no overview of port stakeholders' insight into AI implementation in practice. There is no appropriate method also to tackle this problem in the literature. Hence, the current study fills in this gap in science and provides new perceptions regarding AI implementation by designing a framework to collect insight about AI implementation at port stakeholders. This way, this research puts forward two research questions as follows:

RQ1. What is a framework by which AI developers can collect port stakeholders' insight regarding AI implementation?

RQ2. What is the status quo regarding AI implementation at target group of port stakeholder?

This paper is structured as follows. The second section explains the research methodology and how the study was conducted. "Survey's framework: results of the literature review" Section shows the desk research results regarding the AI implementation for building the survey framework. As a follow-up, in "Port stakeholders' insight regarding AI Port stakeholders' insight regarding AI" Section, this study exhibits the survey results regarding the type of port stakeholders that participated in the research and presents the result of survey. In addition, "Consistency validation" Section presents an analysis of whether the survey participants were consistent in answering the questions. Finally, "Conclusion" Section presents general conclusions, conclusions based on the survey results, and future opportunities.

Methodology

In the context of collecting port stakeholders' insights regarding AI implementation, "insight" refers to the valuable information, perspectives, opinions, and experiences shared by stakeholders. It involves gathering their knowledge, observations, and thoughts on various aspects related to AI implementation in the port industry. Generally, "insight" refers to needs, expectations, concerns, experiences, and recommendations. These insights contribute to a comprehensive understanding of the stakeholders' viewpoints, and facilitate the successful implementation of AI in the port industry by aligning them with AI solution developers.

This section puts forward how this research is conducted. Figure 2 explains the research methodology. The adequate methodology to collect stakeholders' insight regarding AI technologies' implementation is considered launching a structured survey. Surveys facilitate availing the standardized questions and response options, guaranteeing consistency in data collection. This assists in analyzing the collected data in a structured manner.

The methodology for preparation of this survey framework contains four steps in this study. The step 1 in the methodology discusses the objective, audience, broadcasting method of survey. Designing the structured survey is conducted by desk and empirical research. Therefore, the second step performs a literature review regarding

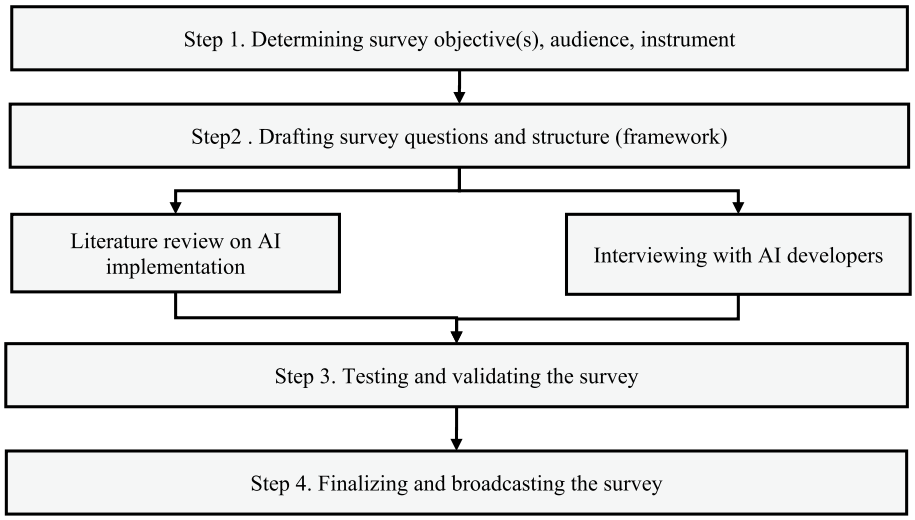

Fig. 2 Research methodology

AI implementation in port and shipping industries. Besides, the empirical part of the second step is performed by interviewing AI developers in the port ecosystem. These AI developers possess experience in providing innovative solutions to particular industry actors. The third step of methodology is to validate and test the framework of survey while the fourth step finalizes the survey and disseminates it across the target group.

Step 1 According to the research questions and objective of the study, this research designs a survey framework to collect the insights regarding AI implementation. Input from port stakeholders should be gathered to obtain this insight. Port stakeholders refers to the various individuals, organizations, and entities that have a vested interest or involvement in the functioning and activities of a port. These stakeholders can vary depending on the specific port and its context, but common examples of port stakeholders include: shipper or sea-carrier, transport operator (road, inland navigation, rail) or logistics service provider, terminal/warehouse/depot operator or, IT/software provider, financial institution (bank, investor), regulatory body, customs authority.

The appropriate broadcasting method for a survey must be taken based on the target audience and research objectives. Common survey releasing methods include online surveys, paper-based surveys, online interviews, or face-to-face interviews. Considering the practicality, convenience, and reach of each method, this study opts for an online survey.

Step 2 This step incorporates two parts. The first parts investigates literature associated with port challenges that can be solved by AI and the barriers to implementing AI.

Figure 3 illustrates the literature review procedure in detail. The second part is to interview AI developers who are fully active in the port and shipping industries. Those developers belong to two research groups named IDLab Antwerp and IDLab Ghent. Developers affiliated with these groups perform fundamental and applied research on AI technology, the internet of things (IoT), ML, data mining, semantic intelligence, and big data.

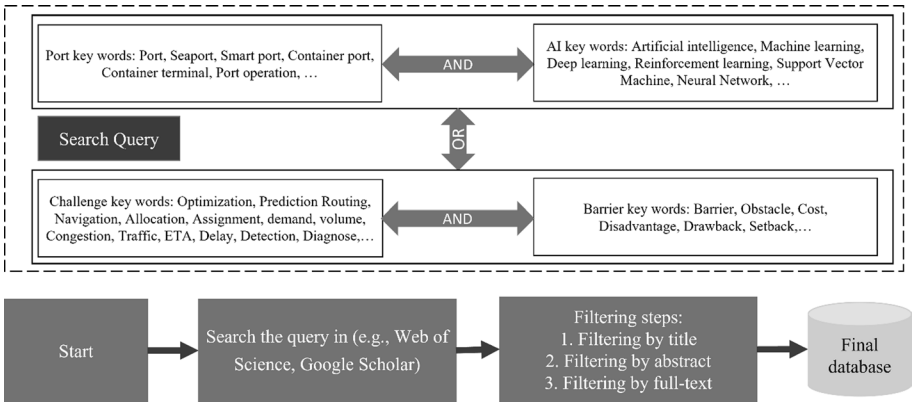

Fig. 3 Literature review procedure

In this step, an initial interview was conducted to discuss the overall structure and sections of the survey. Considering the varying level of AI implementation in the port and shipping industries, the survey was designed to address specific questions pertaining to each level: micro, macro, and sustainable. Additionally, a separate section was included to gather data concerning participants' companies and their AI implementation efforts.

The survey questions for each section were initially drafted through a comprehensive literature review. In the subsequent round of interviews, the draft survey questions and their corresponding response options were thoroughly discussed. If necessary, the questions were reformulated to ensure avoiding any potential bias during data collection. In this round of interviews, the answer options were primarily reformulated based on insights provided by the developers' expertise and knowledge.

Step 3 The survey framework was validated through a pilot test conducted by distributing the survey to a small group. During this process, several important considerations emerged, including ethical considerations, completion time, and consistency issues, which warrant further attention and evaluation.

Survey questions should be clear, concise, and easily understood by the participants. Using ambiguous statements can lead to confusion or misinterpretation of the question, affecting the reliability and validity of the responses. An ethical concern arose regarding a specific question in the survey, potentially leading participants to skip it. The question pertaining to participants' willingness to share data was found to be unclear. Consequently, following the pilot test, the statement "anonymized and in compliance with EU and national law" was added to the question: "Is your company willing to share data and information to implement AI solutions at the port/sustainable level?" This clarification aims to address the ethical issue and provide participants with a clearer understanding of the question.

Lengthy surveys that take a significant amount of time to complete can impose a burden on participants. Asking for an excessive amount of their time may lead to decreased participation rates or survey fatigue, where participants may rush through the survey or abandon it altogether. When participants feel rushed or fatigued due to a long completion time, it can affect the quality of their responses. They may provide incomplete or inaccurate answers, leading to data that may not accurately represent their views or experiences. The initial version of the survey framework consisted of twenty questions,

with some questions having poorly drafted response options. As a result, the average completion time exceeded expectations. To address this, certain low-priority questions were removed, and the response options for questions involving different types of stakeholders were reorganized for better categorization. These efforts resulted in a significant reduction of completion time, up to twenty percent.

Following the pilot test, it became evident that participants' responses were prone to consistency issues, which were attributed to interruptions experienced during the survey completion process. Consistency of participants in answering the survey questions can be assessed by examining the patterns of responses provided by participants. Inconsistencies may be identified if participants frequently change their answers or provide contradictory responses to similar questions.

This survey framework is considered to evaluates the internal consistency of the survey items by using statistical measures such as inter-item correlations. These measures assess the extent to which items within a scale or construct are measuring the same underlying concept. Higher internal consistency indicates greater consistency in participants' responses. More detail about this part is presented later in Sect. 5.

Step 4 This step is dedicated to finalize the survey based on the outcomes of the previous steps and broadcasts it across the target group in the port and shipping industry. After all these steps, the survey results can be extracted, and the study concludes based on them.

Survey's framework: results of the literature review

This study stems from many AI applications worldwide that claim to solve challenges in various parts of the port and shipping industries. On the other hand, this study's results serve port stakeholders who don't have a suitable solution to overcome their challenges. To align these two sides, the status of AI implementation on the port stakeholders' site should be investigated. This study aims at designing a framework that can be an effective tool for gathering and analyzing information about the current state of AI in port and shipping industries. The insights gained from the survey based on the framework can align stakeholders and AI developers in this important and rapidly evolving field (Advanced Polymer Coatings 2019). Therefore, as a first step in implementing AI at the port stakeholders' fields, the below framework's results would be helpful to align stakeholders and AI developers.

This framework consists of seven various parts by which developers can collect insight regarding their potential AI technologies' implementation. The framework's parts are as follows:

- The first part addresses AI technologies' capabilities to increase port efficiency and barriers to implementing AI technologies (Babica et al. 2019; Chui et al. 2018; Gurumurthy and Bharthur 2019; World Bank 2021).
- The second one, refers to AI domains at the port ecosystem and which current system at the port stakeholders' site can benefit from AI (Nunez Castellar 2021; Russo and Musolino 2021; Sinay 2021; Tutorialspoint 2022).
- Third, stakeholders' maturity in the AI implementation and their role when starting an AI project are queried (Jaaksi 2018; Nunez Castellar 2021).

- Fourth, information about stakeholders' preconditions to invest in AI for overcoming their challenges is pointed out (IDC 2021; Mckinsey 2019; Sinay 2021; Tpp Technology 2019).
- Fifth, suitable strategies to start an AI project considering the level of the project are checked (Eckart 2020; Reutter 2020).
- The sixth part refers to the most important stakeholders to collaborate in AI projects (Advanced Polymer Coatings, 2019; Sinay 2021)
- Finally, their willingness to share data and collaborate on AI projects is addressed in part seven (Gupta 2022; Rivas et al. 2021; Ruel 2020) (see Additional file 1: annex 1).

The survey's framework offers helpful contributions to the first step of AI adoption. Firstly, It can provide a comprehensive understanding of the current state of AI in port and shipping industries. If this framework is applied for building a survey, the result will be used to identify gaps, challenges, and opportunities in the field. Secondly, the developed framework can help identify the potential applications for AI in the port and shipping industries. This can assist AI developers in staying up-to-date with the current systems needs in stakeholders' fields. Besides, the framework can help establish benchmarks and standards for the use of AI in port and shipping industries. This can be useful for evaluating the effectiveness of different approaches and for setting goals and targets for future development (Advanced Polymer Coatings, 2019; Tutorialspoint 2022). Finally, it can also provide valuable insights for policy and decision-making related to the use of AI in port and shipping industries. This can help stakeholders make informed decisions about investments and strategies. Following sub-sections present the framework in detail.

AI capabilities to increase port efficiency and barriers to implementing it

This research concludes regarding AI capabilities based on the insight of port stakeholders about the impact of AI in enhancing port efficiency. This insight can arise from the results of previous AI developments, having references from other stakeholders, perceiving it through developing AI solutions, etc.

As mentioned in the introduction, AI and new technologies have significantly impacted on various industries, creating multiple benefits and increased productivity and efficiency in those industries. However, it is worth pondering that whatever has an advantage, flaws must be recognized and considered.

For instance, once new technologies such as AI emerge in ports and the shipping industry, it is expected to find highly specialized human resources to adapt to the new conditions (Gurumurthy and Bharthur 2019). AI is about algorithms and data, so it can be found that data quality is an essential principle in adding AI to port operations. Various studies show that poor data quality may lead to inefficient use of AI (Chui et al. 2018). There can be various reasons for the lack of cooperation, but one of the reasons is a lack of trust in implementing such projects among stakeholders. Successful adoption of new technologies, such as AI in port operations, always requires the confidence of the port's stakeholders to carry out the project (World Bank 2021). Another reason for that could be the mindset of the stakeholders, who are often faithful to the traditions (Babica et al. 2019).

Consequently, one of the significant steps in developing the maritime transport industry and port operations through AI innovation is to identify barriers toward implementing these innovations and thus try to provide a solution to wipe out these barriers.

AI domains at the port ecosystem and relevant systems to benefit from them

After comprehending whether AI can increase port efficiency, the appropriate step would be to know what domain of AI is the most pertinent to port operation. Besides, this section tries to find the most prone systems to be improved by adding AI technologies among existing systems in port operation. In other words, a system that can benefit port stakeholders most by availing AI technologies.

The domain of AI technologies is categorized into mundane (ordinary) tasks, formal tasks, and expert tasks. Since mundane tasks are easiest to learn, people always are learning mundane (ordinary) tasks. They learn through speaking, understanding, and using language. They will learn formal tasks and expert tasks later, respectively. At the beginning of AI emergence, all developments of AI were focused on the domain of mundane tasks. It was gradually discovered that the machine necessitates more knowledge, intricate representation, and complex algorithms to fulfill mundane tasks (Tutorialspoint 2022).

The above categories contain several subcategories by which AI domains can be taxonomized into identified terms within the literature on port and shipping industries. Those sub-categories are virtual reality, vision system, data handling and recognition, cobots, gamification and dynamic planning (Nunez Castellar 2021).

Digitalization in port and shipping industries availing AI technologies can allow handling excess traffic and cargo, decrease human error, optimize employee working hours, and enhance supply chain efficiency. Additionally, AI and automation solutions are counted as retrofitting for ports and shipping industries. Once port stakeholders utilize AI technologies in a conventional system within the port ecosystem, the supply chain will be safer and more organized. Besides, developers can boost software-based platforms and modules through AI technologies domains, and maritime actors will benefit by improving business practices (Sinay 2021). Hence, it should be considered that adding AI to the current port systems can influence port actors and the whole supply chain process. This way, this study will identify the system that can benefit the most from adding AI among current systems like port community system, traffic management, predictive maintenance, and warehouse management (Russo and Musolino 2021).

Stakeholder maturity

The list of relevant AI domains to port and shipping industries and current port systems that could benefit from adopting those AI domains are identified now. However, the essential question remains whether stakeholders are ready to accept this transformation. This section investigates the answers to this question related to the maturity of stakeholders regarding AI in ports.

Various approaches to defining the maturity level of stakeholders often concentrate on the process or technological architecture and the necessities of AI transformation. These approaches aim to illustrate stakeholders' current maturity level quantitatively. Maturity is the "state of being complete, perfect, or ready." To determine the level of maturity, an

understandable direction from the first level to an aim level should be delineated and proceeded. This way, those approaches for estimating the maturity level can take over as a guide to reveal the maturity level of stakeholders (Jaaksi 2018).

This study designs a maturity interval to define the maturity level of stakeholders in terms of AI adoption. This interval contains four maturity levels by which stakeholders can easily designate their maturity level associated with implementing AI technologies. Those four levels are taxonomized as follows: High (currently implementing or using AI), Medium (taking first steps to define AI specifications), Low (waiting to see what comes on the market), and Not at all (Nunez Castellar 2021).

Precondition to implement AI

AI technologies are almost novel innovations, and AI projects are naturally experimental. There is not much information regarding those projects thus far. Therefore, this increases AI projects' uncertainty regarding their outcomes. This way, it is expected that stakeholders might demand a guarantee for these innovative projects. This guarantee can be every measure by which they can decide whether to start an AI project.

Nowadays, AI adoption is growing in most industries more and more. Around 60% of companies (all industries) enhanced their revenues, and almost 40% decreased their costs by implementing AI technologies (Mckinsey 2019). However, according to the claim of 2000 IT project leaders, around 30% of AI projects failed in all industries because of unknown actual costs and benefits brought by AI technologies (IDC 2021). Furthermore, the lack of a source regarding the costs and benefits of AI technologies might make the situation even more complicated. Therefore, there should be a third-party effort to accomplish cost–benefit analyses for AI projects and provide economic feasibility to the problem owner.

Most of the time, stakeholders would like to identify whether the existing AI solutions can deliver before executing it entirely. The response to this question could be a free pilot if stakeholders determine to receive an out-of-the-box solution or minimum valuable product (MVP) development. Although a complete-scale AI solution would consume much cost and time to implement, an MVP project doesn't have that long development time and brings results quickly. MVP also lets stakeholders receive an explicit approximation of the added value of AI solutions before pledging to the long-term development of it (Tpp Technology, 2019).

Alongside the above preconditions, port stakeholders worldwide participate in AI solutions adoption in their operations and assets. The Port of New York and New Jersey designed a comprehensive plan to execute AI technologies. The Port of Hamburg has employed the application of ML, and the ports of Shanghai and the Port of Singapore have both used AI technologies to be called by the United Nations the best-connected ports in the world. AI technologies will continually enhance ports' efficiency. AI developers build modules for forecasting more accurate ETA, which will modify all characteristics of port operations. A precise and reliable vessel arrival prediction influences benefits for the scheduling and assigning of port call organization. These advantages will enhance efficiency in port infrastructure, human resources (like boatmen), administrative tasks, berth allocation, equipment (like cranes), port assets, and maintenance planning (Sinay 2021).

Therefore, it should be noted that there would be another way to approve the outcome of an AI project. Once stakeholders would like to implement an AI solution developed in other stakeholders' sites or on another scale, it can be proven whether the solution will work based on references from previous projects.

Strategy to implement AI

Once stakeholders are convinced regarding implementing AI solutions across their process through meeting required preconditions, it is time for a specific strategy to conduct the project implementation. This decision regarding the suitable strategy depends on each level of AI projects (micro, macro, sustainable). Therefore, participants are asked about the appropriate strategy for executing AI solutions according to each project level.

There are two general ways to acquire a solution when confronting a problem or challenge. 1- Processing all aspects of the problem by matching it with existing information and data. 2- Letting the problem give out its variables without exposing any background. The former expresses a top-down approach employed by stakeholders who would like to exploit preceding knowledge to train their apprehension. The latter approach, bottom-up, relies on the opinion that development should be apart from motivation. To put it another way, what steers humans' perception is what they feel (Alanturing.net 2000).

In the context of AI technologies, it is perhaps modest to conceive 'Top-down AI' relying on a decision tree. For instance, a call center system developed by AI technologies is based on a specified set of alternatives. According to the answers, the system leads the caller via a tree of possibilities. In contrast, what developers commonly allude to as AI nowadays are applications like autonomous cars or diagnostic systems in medicine. They are distinguished as 'Bottom-up AI' based on ML or deep learning. These are solutions of AI that purvey systems with the potency to learn and amend from experiments without being programmed automatically (Reutter 2020).

Both approaches usually can end up with acceptable results. The critical matter would be how project leaders can decide to go for top-down or bottom-up. They should always consider aspects of the problem they are trying to address and associated data availability while selecting the strategy or methodology. Additionally, considering the features and abilities of both top-down and bottom-up approaches to implementing AI solutions, it may not be astonishing that numerous experts refer to the massive potential of mixed strategies. Those approaches possess key business logic components of top-down with efficiencies of the bottom-up approach to assist decision-making (Eckart 2020).

Important stakeholders and sectors in implementing AI

This research considers three demonstrators for AI development, each translating different broader AI solutions applied to the port context. In particular, this involves micro-level intelligence (optimization of own operation, tackling challenges at a company level, addressing one issue in one organization), macro-level intelligence (optimization of process in which more than one port stakeholder is involved), and sustainable-level (intelligent trade-offs with external constraints).

Therefore, against the micro-level projects, macro and sustainable-level projects must include more than one stakeholder. Subsequently, collaboration and sharing of valuable data within those AI projects would be essential for the implementation phase. Hence,

AI project leaders must identify the most critical stakeholders whose data and collaboration would bring the most benefit to the implementation of AI technologies throughout the port and shipping industries.

Moreover, this topic illustrates sectors where those stakeholders are active and whether existing data within those sectors could be valuable in AI project implementations within port and shipping industries. Consequently, understanding the most critical sectors whose data would help address challenges through AI technologies could assist developers in facilitating the process of AI adoption within port and shipping industries.

The stakeholders in the port and shipping industries, such as shippers or sea carriers, terminal operators or warehouse depots, financial institutions (bank investors), regulatory bodies, customs authorities, port authorities, transport operators (road, rail, and inland waterway transport operators or logistics service providers), pilot organizations are the direct users of the results that would have developed and would benefit from more efficient operation across the ports.

Furthermore, it's important then to know the main types of sectors in which those stakeholders are active and the most crucial sector in terms of data and collaboration among the existing five primary sector types such as container, dry bulk, liquid bulk, break bulk and rolling material.

Stakeholders' willingness to share data toward implementing AI

The previous section released the most critical stakeholders and sectors within port and shipping industries whose data could help more than others in addressing existing challenges through utilizing AI technologies. However, the critical question here would be whether those stakeholders agree with sharing their data with others or within a particular AI project. Besides, lack of precise data and collaboration exists among the top three barriers to implementing AI technologies, according to "Survey's framework: results of the literature review" Section.

Data could be represented through any unprocessed statistic, text, value, sound, or image not being elucidated and understood. It is the most crucial phase in developing all ML and AI algorithms and data analytics methods. Having no data, no one can develop any algorithm, and all novel research regarding AI solutions will not have added value. Therefore, enthusiastic companies executing AI technologies have many expenses to collect as much confident data as possible. For instance, Facebook purchased WhatsApp at a massive cost of $19 billion. The reason for this deal is very understandable and reasonable—they invested in WhatsApp to obtain the users' information that may not exist on Facebook, but WhatsApp possesses it. This information of users is of supreme momentousness to Facebook as it will smooth the enhancement task in their services (Gupta 2022).

Sharing data in most industries is not a definitive solution or at least a straight one. Some feel like risking business confidentiality, and others are scared of losing their competitive advantage. However, there are many cases where stakeholders prevail in their fears. To name but a few, the pharmaceutical industry, where producing new medicines usually involves an exceedingly costly remarkable testing phase. Utilizing AI technologies to analyze the resulting data has decreased research time and costs, but AI algorithms cannot be successfully developed when they aren't fed with high-quality data. The

more shared data for algorithm training, the faster and more accurate those algorithms can produce new drugs (Rivas et al. 2021).

Nevertheless, in many fields, sharing data is more challenging than it should be. This primarily generates because stakeholders work in silos from others on similar solutions and don't want to be involved in the same project with their competitors. Stakeholders might claim that it is also primarily concerned with compliance with data protection laws. Despite all the above facts, data integration is still substantial to take advantage of AI. Therefore, effective mode shift should break down silos operation, and data need to be integrated (Ruel 2020).

Port stakeholders' insight regarding AI implementation (result of the survey)

The survey was launched in the second half of 2021 and lasted until early 2022. It was broadcasted among specialists involved in different sectors of port and shipping operational activities of companies located in the Flanders area of Belgium. The survey was shared several times through two approach (sending via email, asking to fill it in in person by scanning the QR code of the survey) across the target group. Approximately 150 Company delegates have received the online survey.

This survey starts with addressing general questions regarding AI technologies. It then comprises three sections to capture results about AI solution implementation to solve challenges at micro/company, macro/port, and sustainable levels in port and shipping industries.

Out of all potential delegates, 86 started to fill in the survey. Of those attempts, 34 fully covered the survey, and their answers are recorded for preparing the conclusion of this research. This filtering step was crucial and was accomplished by storing only the responses of participants who were consistent in answering all questions. This selection also presents the wider Flanders port and shipping industry community. It also incorporates the main actors who can be pioneers in AI technology. The type of port stakeholders represented by these companies is illustrated in Fig. 4.

According to the figure, the survey benefits from stakeholders' responses covering the whole port and shipping industry chain, including IT/software providers. From Fig. 4,

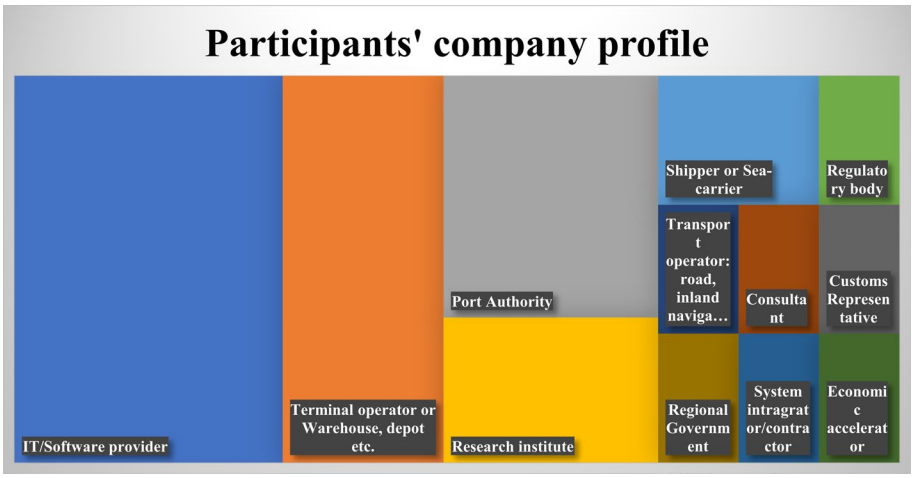

Fig. 4 Share of each type of port stakeholders attending in the survey

IT/software provider, terminal, and the port authority are the top three stakeholders in terms of share of participants. These stakeholders also represent more than half of the participants (64%). Since this survey addressed questions regarding AI solutions, IT/software providers active in port operations could gain a more significant share of participants than other stakeholders. This might empower the research conclusion due to the substantial experience of those IT/software providers in developing AI solutions at the port operation. Moreover, the survey has received answers from participants active in various port sectors such as container (65% of participants), break bulk (40% of participants), liquid bulk (20% of participants), dry bulk (35% of participants), rolling material (45% of participants). Participants can be active in multiple sectors.

AI can increase port efficiency but there are barriers to implement it

According to Fig. 5, 94% of participants know AI capability in the port operation. 85% of participants believe AI can increase port efficiency, and 9% don't believe in AI capability. Only 6% of participants are not familiar with AI capability. As presented in the previous section, many stakeholders participated in this survey. Although the survey is about implementing AI solutions within the port stakeholders' site, IT/software providers have been invited to fill it in. The reason for sending the survey to IT/software providers is that they have sufficient knowledge about innovative solutions like AI and valuable information about developed AI solutions or solutions that are being developed now across the port area. Although IT providers have participated more than other stakeholders, the result of this section won't change that much after extracting IT providers' answers. Despite ignoring IT providers' responses, 83% of participants still think that AI can increase efficiency.

Furthermore, Fig. 6 exhibits that those participants, who agree with the high ability of AI to boost efficiency, believe lack of skill, data, and collaboration are the top three barriers to implementing AI solutions in the port ecosystem. Moreover, other participants, who have doubts about AI technologies' abilities, might change their minds once its barriers are gone by taking suitable measures.

Most relevant AI domains and systems that can benefit the most from AI

Figure 7 shows that more than 80% of participants voted for the Vision system, virtual reality, data/text recognition, and data handling and processing as the most relevant AI

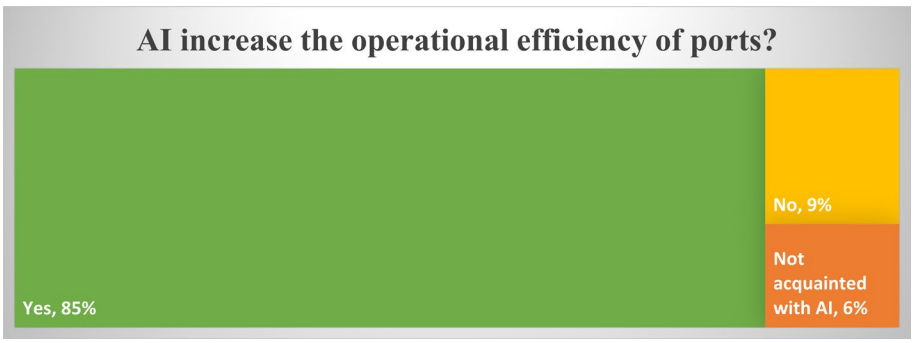

Fig. 5 Share of participants who agree that AI can increase port efficiency

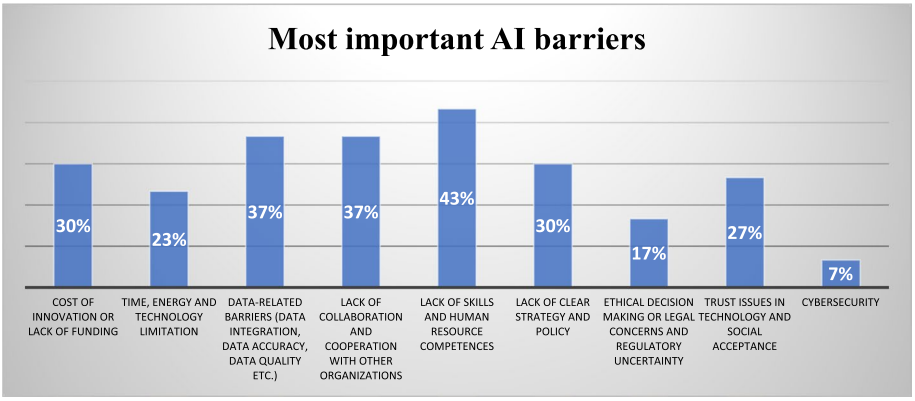

Fig. 6 Share of participants who voted for each AI barrier

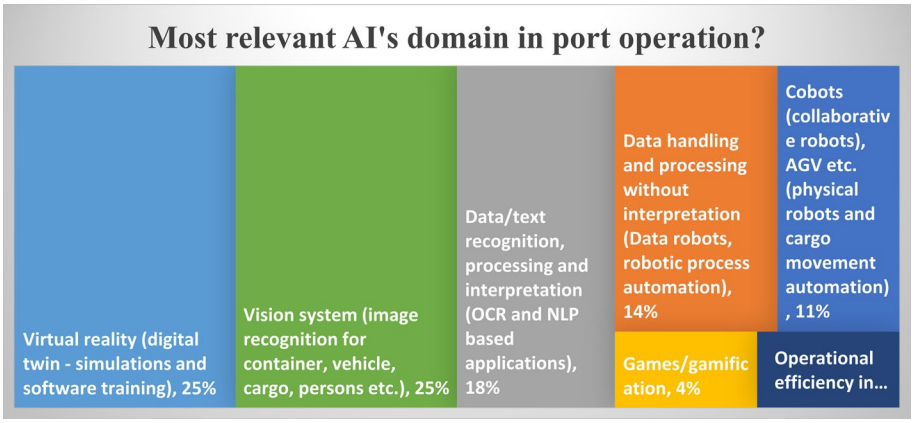

Fig. 7 Share of participants voted to each AI domains

domains to the port ecosystem. Most port stakeholders that voted for those relevant domains are terminal and transport operators. They are also active stakeholders in the container sector in the port and shipping industries in the Flanders area. Furthermore, most participants (60%), verified that the above domains are most relevant to the port operation.

From Fig. 8, Port community, Traffic management, and predictive breakdown and maintenance systems gain almost 90% of the participants' votes. Therefore, they would be the top three systems that can benefit the most from compounding with AI technologies. Moreover, most stakeholders, who voted for the above systems, are port authorities, terminals, and transport operators. They also are primarily active in the container, break bulk and rolling material sectors.

Stakeholders' maturity and role regarding AI projects

Figure 9 illustrates that most participants have started an AI project or are planning to start one. These participants are mostly IT/software providers who implement AI for other stakeholders. It should be noted that each IT/software provider gives insight regarding the maturity based on interaction with stakeholders. Therefore, the response of each IT/software provider can reflect the maturity of stakeholder interacting with the

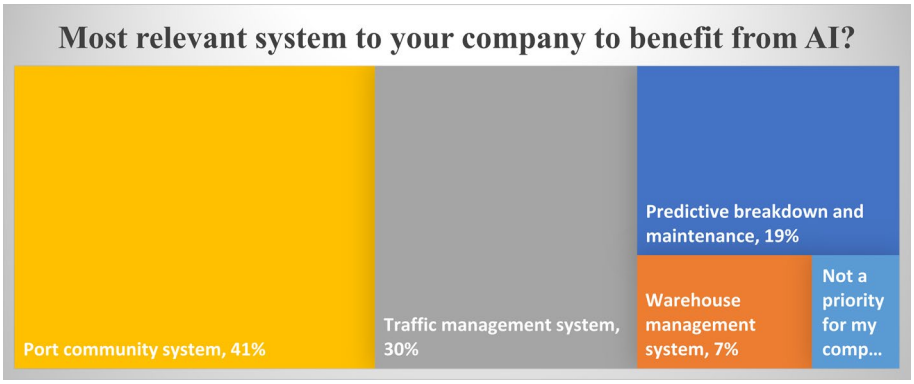

Fig. 8 Share of participants voted to each relevant system to benefit from AI

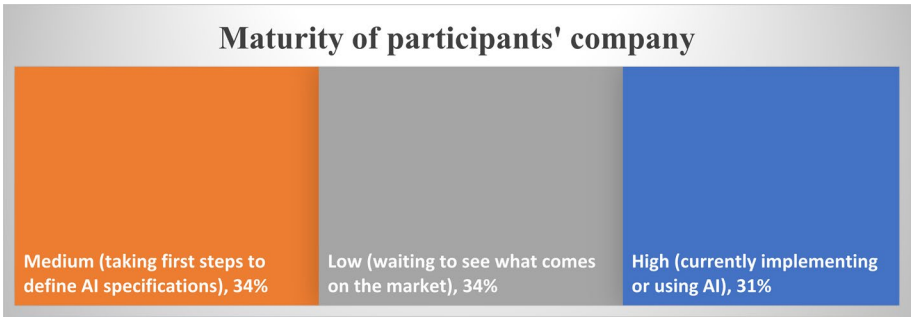

Fig. 9 Maturity of stakeholders regarding AI developments

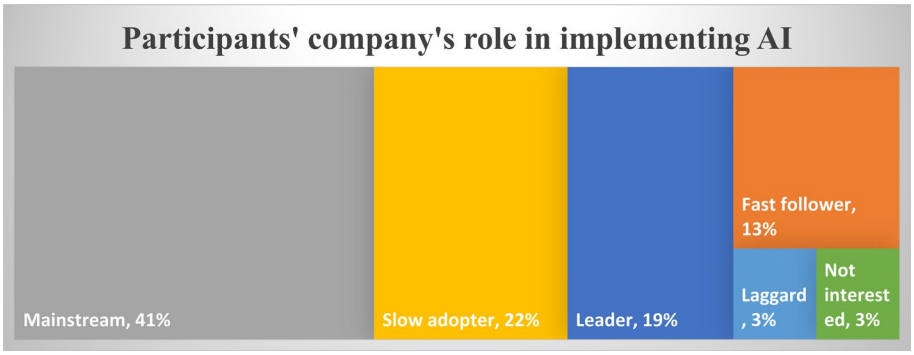

Fig. 10 Role of stakeholders regarding AI projects

particular IT/software providers. Alongside, there are other stakeholders, sea carriers, terminals, and transport operators among those with high and medium maturity levels. These participants mostly run AI projects or tend to run an AI project within the container and rolling material sectors.

Participants also were asked about their role when they kicked off an AI project. The result of this question distinguishes among participants' role in implementing AI. Over 70% expect to play in an acceptable situation, such as Leader, Fast follower, and Mainstream as shown in Fig. 10. Therefore, it should be considered that according to the

result of this section, most participants would like to start an AI project. On the other hand, those who haven't started an AI project might have a reason regarding the lack of preconditions they need to start.

Suitable preconditions to start an AI project

Figure 11 demonstrates that proving economic feasibility is the most acceptable precondition among participants. This precondition is also popular among participants, who represent the slow adaptor role while implementing AI technologies. However, proving by demo/MVP or receiving approval by the group's board of directors are the second most sufficient preconditions based on participants' responses. Leveraging these two preconditions might take less effort than proving the solution's economic feasibility. Furthermore, the precondition of having references from other solutions users, which a few participants have voted for, is the most effortless. Finally, those participants, who are cautious about implementing AI solutions (slow adaptors and low maturity stakeholders), almost need all preconditions to start an AI project.

It is also worth mentioning that AI expenses should be constantly balanced with the cost saving or the extra revenues they generate. Therefore, two questions in the survey inquire about stakeholders' concerns about costs. Those questions are related to barriers and preconditions to implementing AI. Thus, survey participants indicate the expenses size as a suitable precondition if they wish to implement AI. In case of a lack of knowledge about the rate of expenses, they would vote for "Prove of economic feasibility" as a precondition to start. On the other hand, if they know the expenses exceed their expectations, they would indicate for "high cost of innovation" as the most critical barrier to implementing AI in their fields. Besides, if they don't have enough capital to invest in AI, they still can vote for "Lack of funding" as a barrier. This way framework can capture the view of respondents regarding the expense size.

Suitable strategy to start an AI project

As shown in Fig. 12, incremental step (taking mix bottom-up and top-down strategy) is the most popular strategy among participants to adopt AI. The small step or bottom-up approach gains almost the same share of participants in each type of project (micro, macro, sustainable). The percentage of participants, who are unsure about the strategy of implementing AI technologies, is more significant at the macro and tolerable than at the

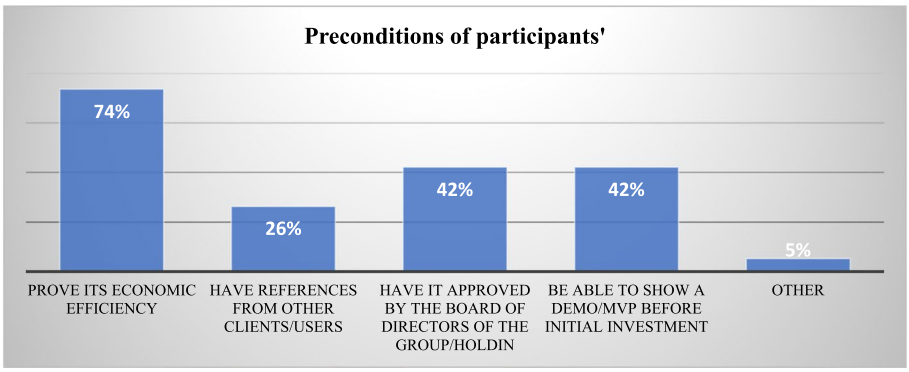

Fig. 11 Stakeholders' preconditions to accept an AI solution

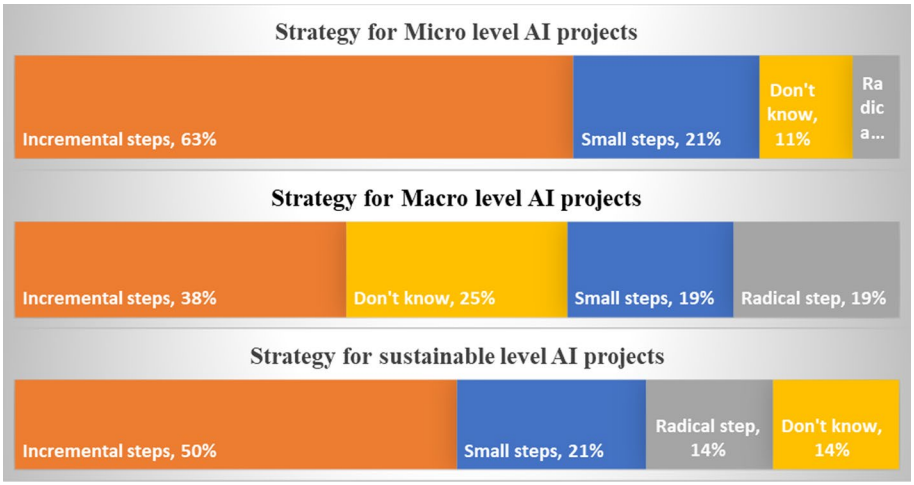

Fig. 12 Participants' opinions regarding suitable strategies

micro level. This might mean figuring out the strategy becomes more complicated when the project becomes more extensive. Furthermore, the share of participants, who voted for the radical step or top-down approach, is also more significant at the macro and sustainable than the micro level. This is because the strategy might be more hieratical from top to down when the project becomes more extensive.

Most important stakeholders and sectors

According to the participants, the top three stakeholders whose data and collaboration could help a lot toward implementing AI projects are terminal and transport operators and sea carriers (see Fig. 13). This might result from the share of the process in which those stakeholders are involved. These three stakeholders cover almost a significant percentage of port operations. They also have close interaction with the most important entity of the process, which is cargo. Therefore, their data could be essential while implementing AI solutions.

There are three ports within the Flanders area: Antwerp-Bruges, Ghent (North Sea Port), and Oostende. The Port of Antwerp-Bruges (PoAB) is the largest one. PoAB (2022) stated that its cargo share contains a large percentage of the container and rolling material. Those two also are the most significant sectors whose data could influence AI projects at the macro level based on participants' responses (see Fig. 14). Furthermore, Fig. 14 demonstrates that the container is the most critical sector whose data could be essential within sustainable AI projects.

Stakeholders willingness to share data

Figure 15 exhibits that most participants would like to share their data to start micro and sustainable level AI projects within the port operation. Answers of IT/Software providers to the question of this section have been deducted from the result. The share of participants, who would like to share data for starting sustainable-level projects, increases compared to macro-level projects. This might stem from participants'

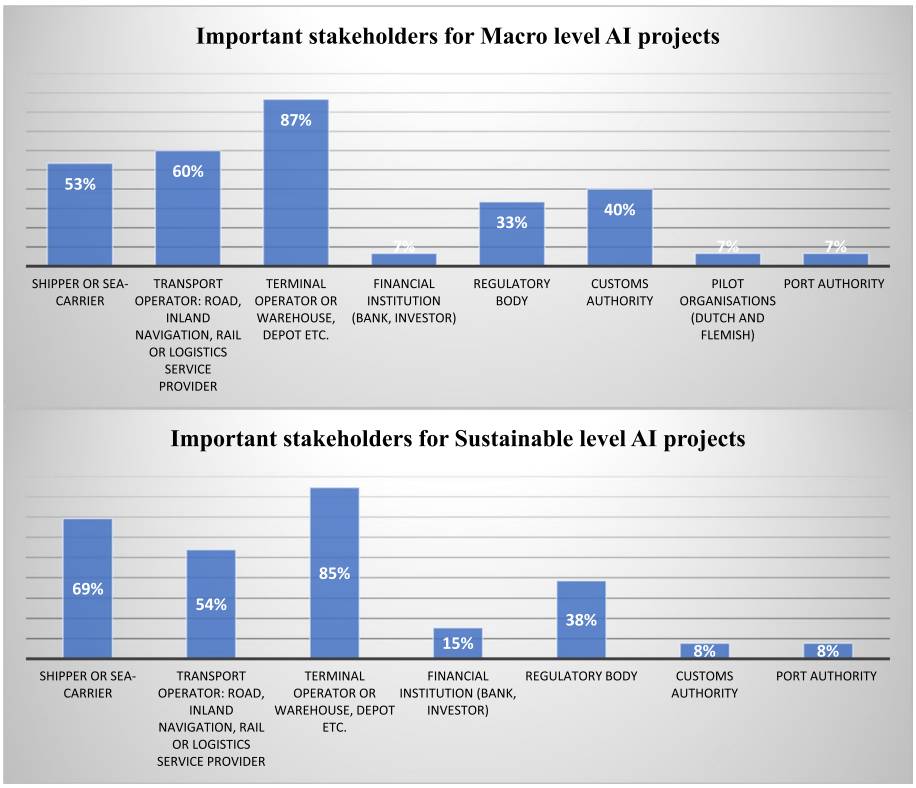

Fig. 13 Stakeholders whose data and collaboration can help the most in AI projects

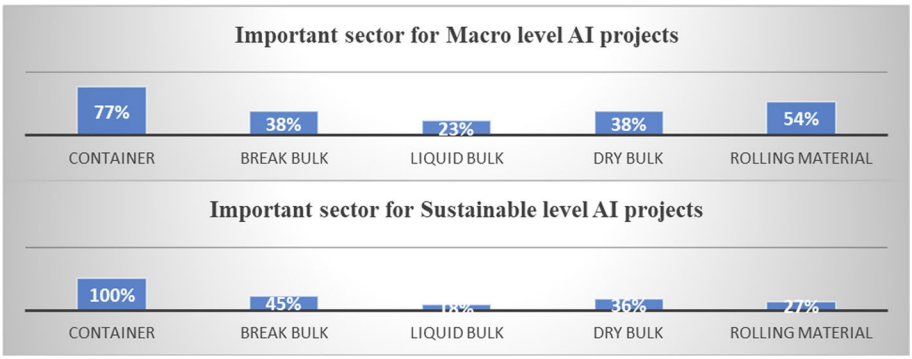

Fig. 14 Sectors whose data and collaboration can help the most in AI projects

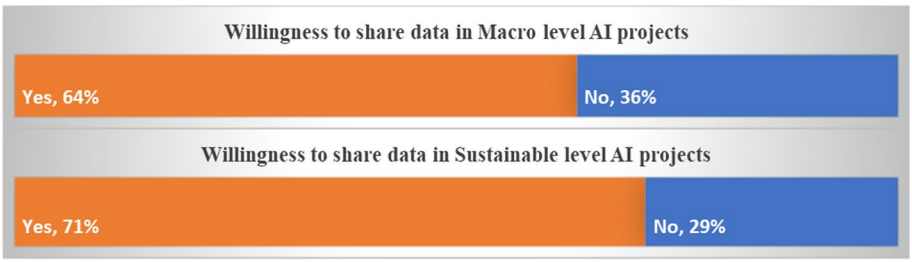

Fig. 15 Stakeholders' willingness to share data in AI projects

social responsibility. Those participants, who won't share data, declared that their reasons mainly concerned their customer and IT provider's contract.

Consistency validation

This section analyses the consistency of the results collected through the just developed framework. This survey collects answers from a group of stakeholders who actively operate in the port and shipping industry in the Port of Antwerp-Bruges and its vicinity. 34 respondents out of 150 potential participants were considered a reasonable rate of response (22%) for a relatively long survey (16 questions). Besides, the survey benefits from answers from CEOs/Founders/Co-Founders (6), General Managers (6), CFOs (2), Business Development Managers (3), AI innovation Consultants (4), Digital Transformation Advisors (4) and Project (innovation) managers (4). The entities in this sample are significant players within the Antwerp-Bruges port community and are large enough to lead the way in innovation, particularly in AI. As such, this sample serves as a representative cross-section of the wider community. Nevertheless, the survey is built based on the structured framework its purpose is extract consistent results. Inconsistent survey answering leads to invalid results and reduces the reliability and validity of research outcomes. To avoid this phenomenon, two questions are considered in the framework by which the consistency of the survey's results can be checked. Those two questions are associated with the "maturity level of stakeholders in AI implementation" and "stakeholders' role once they start the AI project." Since these two questions somehow correlate to each other's, the answer of participant to these two questions should be in same direction. Therefore, the correlation analysis between responses to the above questions is used to check whether the participants were consistent while completing the survey. To do so, the options for answering those two questions are entered into the statistics software through hierarchical indicators (see Table 1). Thus, correlation analysis between the "stakeholders' maturity level" and the "stakeholders' role" will demonstrate consistency in participants' responses (see Fig. 16).

As depicted in Fig. 16, the "Pearson coefficient" shows the correlation between the answers of participants in relation to their "maturity level" and the "role". The calculated value of 0.796, shows that the hypothesis that there is consistency in participants' responses to these two questions is proven with 99% confidence level (p value = 0.01). This study extrapolates this consistency to the other questions and

Table 1 Stakeholders' Maturity level and role indicators

Stakeholders' role level	indicator	Stakeholders' maturity level	indicator
Leader	6	High (currently implementing or using AI)	4
Fast follower	5	Medium (taking first steps to define AI specifications)	3
Mainstream	4	Low (waiting to see what comes on the market)	2
Slow adopter	3	Not at all	1
Laggard	2		
Not interested	1		

Correlations

Correlations

		Maturity_level	Role_indicator
Maturity_level	Pearson Correlation	1	.796**
	Sig. (2-tailed)		<.001
	N	32	32
Role_indicator	Pearson Correlation	.796**	1
	Sig. (2-tailed)	<.001	
	N	32	32

**. Correlation is significant at the 0.01 level (2-tailed).

Fig. 16 Results of consistency check

considers the answers as reliable and representative for the type of respondents participating in the survey. General conclusion, lessons learned from the analysis and indication for future research are presented in the next section.

Conclusion

Over the last few years, the port and shipping industries have not only intended, but also succeeded to invest in automation and digitalization to enhance productivity and operational efficiency. Various technologies are being developed to address the current challenges of the shipping industry and port operations. Yet, a new set of challenges is arising. The physical capacity of ports and their hinterlands is reaching its limits, so innovation is needed. Among all these innovations, AI technologies are new solutions that can overcome some of the existing and incoming challenges.

The adoption of new technologies is conditioned by the lack of trust in technologies delivering the expected results, but can also be stimulated by external factors like labor force or scattered supplies. It is expected that a high degree of AI implementations in the port contribute to port efficiency and resilience. The shipping sector is highly interested in following this trend and chose services accordingly. However, the lack of aligning AI solution providers and port stakeholders in implementing AI solutions remains a topic to address. To do so, information needs to be gathered regarding the status of AI implementation within the target group of port stakeholders. Therefore, this study designed a framework to collect the status of AI implementation at port stakeholders. In addition, a survey is designed based on the framework and broadcast to a group of port stakeholders to collect their insight regarding AI on their fields. Hence, the response of participants help particular solution providers who would like to introduce AI to this target group. This way, those particular solution providers get aligned with the stakeholders in the target group, which helps to initiate an AI project.

Nonetheless, this survey is the first step in this journey, and some other steps should be taken toward convincing port stakeholders to utilize suitable AI solutions to overcome their challenges. Then, it is crucial to acknowledge that placing exclusive reliance only on an online survey might entail certain restrictions when attempting to grasp an encompassing comprehension of stakeholders' viewpoints on AI implementation. Although surveys can yield valuable quantitative information, they may fail to encompass the

intricacies of stakeholder opinions. Therefore, some other methods are needed to investigate the survey results further. For instance, according to the participant's responses, the most acceptable precondition for implementing AI technologies is to prove the economic feasibility of the solution. However, it is still necessary to investigate the return on investment (ROI) of implementing a particular AI solution to overcome a challenge for those stakeholders who voted for the economic feasibility precondition. They only shared their preference about the type of precondition. It might not convince them to exploit AI technology once they find out about the ROI of a particular AI technology.

To sum up, the contributions of this research are manifold. First, the structure framework of the survey can be utilized through modification for collecting data regarding other innovations. Therefore, this study recommends that researchers use this structured survey to gather information regarding the status of other technologies such as IoT, Big data, Digital Twin, etc. Second, the current survey can be sent to different target groups, either specific or more extensive. This way, the survey can be broadcast among all stakeholders in the particular area and obtain a more vast range of stakeholders' status in terms of AI implementation. As a third contribution, this study not only aligns port stakeholders with AI developers but also increases the maturity level of AI in port stakeholders' fields by leveling up their awareness regarding AI technologies. This can be done by sharing the survey results with the target group later.

Finally, this study broadcasted the survey among a target group, collected the responses, and analyzed them. This paper has considered a number of port stakeholders as a target group and collected their responses to draw following conclusion.

According to the result of the survey, although participants believe that AI can boost operational efficiency within port operations, they refer to barriers that come up before implementing these sorts of innovations. One might think that the cost of development and funding issues could be the most significant barrier. However, lack of human skill, data, and collaboration are the top three barriers to implementing AI technologies in the port and shipping industries. By identifying these barriers and taking appropriate actions, stakeholders can overcome challenges, enhance efficiency, and improve decision-making. The action point would involve collecting and organizing the necessary data, improving data quality, promoting collaboration and knowledge sharing, establishing frameworks for information exchange, investing in training and skill development.

Furthermore, the survey shows that most participants spot themself at an acceptable maturity level regarding AI development and are already interested in implementing AI solutions. Accordingly, this helps align stakeholders and developers by establishing much more common goals, better planning and taking the right strategy for stakeholders engagement towards resistance mitigation and collaboration facilitation.

Participants voted for virtual reality (digital twin and simulation and software training) and vision systems (image recognition) as the most critical relevant AI domains to the port industry. Consequently, challenges like cargo recognition or other image recognition application (vehicles, equipment, etc.) and challenges in which simulation of process optimization is required, like cargo flow optimization would be most significant for port stakeholders.

Concerning the required preconditions, participants would like to decide based on the economic feasibility of the potential project rather than receiving recommendations

from other clients/users/boards of directors to start an AI project. However, gathering information on successful past implementations and categorizing them to create a benchmarking database would provide valuable insights for stakeholders in assessing the likelihood of success when considering the implementation of a pre-existing AI solution.

Moreover, participants desire to kick off AI projects in incremental steps by pinpointing and solving system issues one by one (taking a mixed bottom-up and top-down approach). AI project leaders can take advantage of the contribution between companies and data sharing by a diverse range of stakeholders within macro and sustainable level projects. To do so, participants assume that the most critical data is generated by transport and terminal operator and sea carrier companies, which can bring the most benefit for implementing AI. Therefore, collecting, organizing, and analyzing data from the above stakeholders maximizes the effectiveness and relevance of the collected data. By knowing that the most beneficial data comes from above stakeholders, developers can tailor AI solutions to address specific challenges and requirements. This customization increases the relevance and effectiveness of the AI solutions, leading to improved operational efficiency, decision-making, and customer satisfaction.

In addition, emphasizing the significance of data from specific stakeholders allows developers to communicate the value proposition to those stakeholders, highlighting how leveraging this critical data can lead to operational improvements, cost savings, enhanced decision-making, and competitive advantages. This fosters buy-in and support from key stakeholders.

Since this paper investigates AI implementation from a general point of view, future research can consider focusing intensely on particular technique of AI technologies and modify the survey questions based on the chosen technique. This way, the survey results would focus on a specific technique, and those researchers and stakeholders, who would like to concentrate on that technique in detail, can benefit from those results.

Abbreviations

AI	Artificial intelligence
ML	Machine learning
IoT	Internet of thing
ETA	Estimated time of arrival
TT	Turnaround time
DT	Dwell time
MVP	Minimum valuable product
PoAB	Port of Antwerp–Bruges
ROI	Return on Investment

Supplementary Information

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Additional file1. Survey's questions.

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Author contributions

MF was responsible with coordinating the research, design the survey, collect data and interpret the data to describe the results. VC and TV were responsible with supervising the research and manuscript coherency.

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Availability of data and materials
The datasets generated and analysed during the current study are not publicly available due to protect survey participant privacy, but are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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