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Improving pilot boarding arrangements to prevent transfer accidents

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IMPROVING PILOT BOARDING ARRANGEMENTS TO PREVENT TRANSFER ACCIDENTS

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A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of Master of Science in Maritime Affairs

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Declaration

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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Abstract

Title of Dissertation: **Improving Pilot Boarding Arrangements to Prevent Transfer Accidents**

Degree: **Master of Science**

The purpose of this paper is to improve the pilot transfer arrangements (PTA) by designing a pilot boarding lift (PBL) so as to promote the safety of the pilot transfer operation. The PTA include pilot ladder, accommodation ladder and combination arrangement (the dissertation does not discuss the means of helicopter pilot transfer). The pilot ladder as the primary means by which pilots embark or disembark the vessel, however, the pilot transfer accidents have occurred frequently due to its limitations including components of the structure, use in bad weather conditions, and human factors. The intrinsic safety of the PTA is questionable.

Although, the International Maritime Organization ([IMO], 2011) explicitly states that there is no "mechanical pilot lift", the newly designed boarding lift is different from the concept of directly heaving the pilot on-board. This dissertation will explain the design process including sketch design, material selection, test standards and operation procedures, and the advantage compared with the traditional pilot ladder. Considering the feasibility of the design, four different questionnaires were distributed to pilots, shipmasters/deck crew, shipowners/ship management companies, and Maritime Safety Authority/port state inspectors. According to their feedback, the current PTA are indeed to be improved and the PBL is good innovation if it can be adopted by IMO.

Keywords: Pilot, Pilot ladder, Transfer accident, PBL, PTA.

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LIST OF ABBREVIATIONS

ABS	American Bureau of Shipping
CCS	China Classification Society
DNV	DET NORSKE VERITAS
IACS	International Association of Classification Societies
ICS	International chamber of shipping
IMCA	International Marine Contractors Association
IMCO	Inter-governmental Maritime Consultative Organization
IMO	International Maritime Organization
IMPA	International Maritime Pilot Association
IRS	Indian Register Shipping
ISO	International Organization for Standardization
MAIB	Marine Accident Investigation Branch
MEPC	Maritime Environment Protection Committee
MSA	Maritime Safety Administration
MSC	Maritime Safety Committee
NSRI	National Sea Rescue Institute
NZMPA	New Zealand Maritime Pilots Association
PBL	Pilot boarding lift
PPE	Personal Protective Equipment
PTA	Pilot transfer arrangement
SOLAS	International Convention for Safety of Life at Sea, 1974
STCW	International Convention on Standards of Training Certification and Watchkeeping for Seafarers 1978 as amended 1995
UNCTAD	United Nation Conference on Trade and Development

Chapter 1 Introduction

1.1 Research background

Pilot transfer arrangements include pilot ladder, accommodation ladder, and combination arrangement, while the pilot ladder is prime means for pilots embarking and disembarking the vessels. Sachi (2021) said that the pilot operations using pilot ladder are high risk activities. International Maritime Pilot Association ([IMPA], 2022) estimates that pilots under its umbrella perform more than 2 million acts of pilotage each year, contributing to the safe movement of 8 billion tons of cargo. Unfortunately, the profession loses an average of 2 maritime pilots each year.

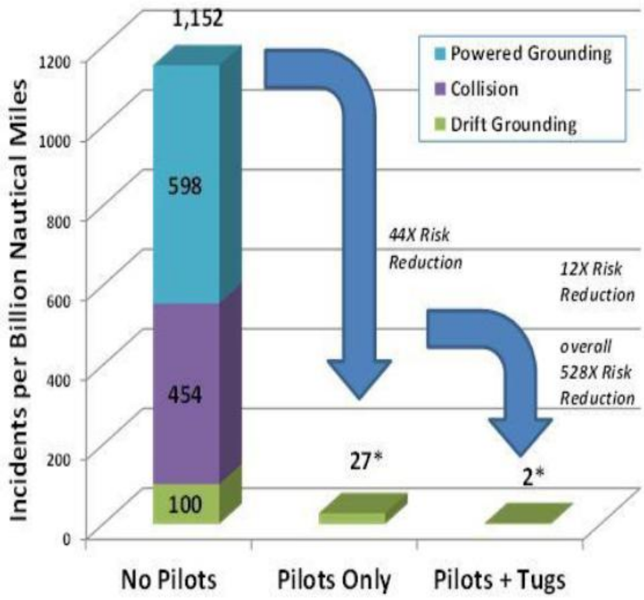
Pilotage plays an important role in maritime shipping. Maritime shipping is important for industrial activity, commodity trade, globalized production processes and economic growth, with ships carrying more than 80% of global commodity trade and more than two-thirds of its value (United Nation Conference on Trade and Development [UNCTAD], 2017). For ships on international routes, both inbound and outbound operations usually require pilot assistance. Qualified maritime pilots are the professional mariners and experienced experts with knowledge of the geography, hydrology, and navigation of the particular waters they navigate, who are usually employed by shipowners to maneuver ships through dangerous or congested waters, such as ports, harbors, rivers and locks. Although the captain usually has rich navigation experience and is familiar with the ship itself and the crew, the captain cannot be expected to be fully aware of the special channel and management requirements of a certain area, when it comes to specific waters, ports, berths, and waterways, the pilotage seems to be the best choice. In 2021, the number of port calls are 4,286,204 times (UNCTAD, 2021), which requires the same number of pilot services, which also means the same number of pilot transfer operations.

The requirements for pilot embarkation and disembarkation arrangements under the SOLAS Convention came into force on 1 January 1994. The IMO, IMPA, International Association of Classification Societies (IACS), navigation circles and national pilotage agencies all attach great importance to the safety of pilots' embarkation and disembarkation. However, the pilot transfer accidents happen again and again, prompting IMO, IMPA and other organizations to constantly modify and improve the pilot embarkation and disembarkation arrangements and their arrangements on the ship in view of various defects provide, and make it compulsory for ships to implement. On December 3, 2010, IMO maritime safety committee meeting, 88 adopted A resolution to amendment of SOLAS convention No. 308, namely the IMO a. resolution 1045 (27), requirements take effect on July 1, 2012. The amendment to the pilot the ship equipment put forward new requirements. Cancel the original allow mechanical pilot hoist, and updated the poster of PTA.

Inter-governmental Maritime Consultative Organization ([IMCO],1963) recommended that the governments should organize pilotage services in those areas where such services would contribute to the safety of navigation in a more effectively way than other possible measures and should, where applicable, define the ships or classes of ships for which the employment of a pilot would be mandatory. Pilotage plays an important role in ship safety, port security and pollution prevention. IMPA (2022) found that pilots can largely reduce ship accidents (**Figure 1)**.

Figure 1

The relationship between pilots and ship accidents



Note. From *IMPA Seminar on Maritime Pilots and Pilotage* (p.21) by IMPA, 2022, (https://www.impahq.org/sites/default/files/content-files/20220916-IMPA%20IMO%20Seminar%202022-FINAL.pdf). Copyright 2022 by IMPA.

However, because the current PTA is highly susceptible to structural limitations, weather and human factors, pilots are prone to frequent fall accidents during transfer operations, resulting in injuries and fatalities. The New Zealand Maritime Pilots Association ([NZMPA], 2018) states that it takes many years to become a pilot, but only minutes to lose one. Pilot transfer accidents do not appear to be preventable, so there is a need to improve PTA.

1.2 Research significance

This dissertation is significant as it provides an analysis of the current pilot boarding arrangements and the potential risks associated with them. It provides an in-depth examination of the structural components of the pilot ladder, accommodation lad-der, and combination arrangements. It also provides a case study of maritime pilot transfer accidents and the limitations of the current structures. Finally, it presents a PBL design that addresses the limitations of the current structures and provides a safer and more efficient boarding method. The standards for pilot ladder have been improved over 50 years since they were developed (**Table 1**), but the pilot ladder has no substantial improvement.

Table 1

Evaluation of the pilot ladder standard

Standard	Date
ISO/R 799:1968 Shipbuilding — Pilot ladders	1968-07
ISO 799:1980 Shipbuilding — Pilot ladders	1980-07
ISO 799:1986 Shipbuilding — Pilot ladders	1986-09
ISO 799:2004 Ships and marine technology — Pilot ladders	2004-02
ISO 799-1:2019 Ships and marine technology — Pilot ladders — Part 1: Design and specification	2019-02
ISO 799-2:2021 Ships and marine technology — Pilot ladders — Part 2: Maintenance, use, survey, and inspection	2021-05

In view of the fact that the current PTA are still subject to pilot fall accidents under certain situations such as bad weather condition, poor maintenance of pilot ladder, wrong rigging operations, failure of components of pilot ladder, the author considers it necessary to improve pilot transfer safety by designing PBL to improve pilot boarding conditions.

1.3 Research objective

Based on IMO, IMPA regulations and ISO 14798:2009 on PTA, the purpose of this paper is to present the design concept including analysis of the structure, mechanics and feasibility of a PBL. This design has been used to overcome the limitations of traditional pilot boarding arrangements such as steps, side ropes, man ropes, spreaders, life jackets, heaving line, rubber steps, lighting and safety belt, as well as human factors such as pilot maintenance, rigging requirements and weather factors that increase the difficulty of climbing, in order to improve the safety of pilots at sea when transferring between pilot vessels and ships.

1.4 Research Methodology

The research employed literature review, case study, questionnaire, and comparative method.

1.4.1 Literature review method

Literature review will provide an overview of the current pilot boarding arrangements and the potential risks associated with them. The analysis of existing pilot boarding arrangements will provide an in-depth examination of the structural components of the pilot ladder, accommodation ladder, and combination pilot boarding arrangements. The IMO and ISO requirements for PTA are used as design criteria to improve pilot transfer safety.

1.4.2 Case Study Method

Case study analysis focuses on pilot transfer accidents and accidents involving crew members operating pilot ladders. Data will be collected by analyzing the problems with current pilot transfer arrangements in practice and the risks they pose to pilot transfer safety, which will be used to validate the material and design limitations.

1.4.3 Questionnaire method

In order to identify the limitations of the PTA and to verify the feasibility of the design of the PBL, the questionnaire survey will be carried out in this study. The questionnaire will be distributed to frontline workers and stakeholders who have a direct im-pact on pilot transfer safety, including seafarers, ship owners, classification society surveyors, port state control (PSC) officers, and pilots. By analyzing and collating this feedback, the design will be improved and prepared for future marketing and practical use.

1.4.4 Comparative research method

A comparative study was conducted to compare the current pilot boarding arrangement with the newly designed pilot boarding lift in the same usage scenario to identify the advantages and disadvantages of each, including safety, operational performance and structural cost. Based on this, a questionnaire survey was conducted to verify the rationality and feasibility of the pilot boarding lift design concept.

1.5 Structure of dissertation

The dissertation consists of six chapters. Chapter 1 provides an introduction to the dissertation and outlines the research background, significance, objective, methodology, and structure of the dissertation.

Chapter 2 analyzes the limitations of the current PTA including the structural components of the pilot ladder, accommodation ladder, and combination arrangements, and the causes of the pilot transfer accidents.

Chapter 3 explains and elaborates the PBL design process including design principles, material selection, layout, installation, operation, maintenance, and makes a risk assessment on PBL.

Chapter 4 summarizes and analyzes the data from questionnaire respondents and makes comparison between PTA and PBL.

Chapter 5 discusses the research findings of PTA and the significance, advantages, and
limitations of PBL design.

Chapter 6 concludes the research.

Chapter 2 Literature review

The current PTA has limitations, which are the causes of pilot transfer accidents. This chapter will analyze the limitation from three aspects, i.e., the construction of the PTA, the use of the PTA in severe weather, and the human factors. Identifying the limitations of the PTA is the first step in developing a strategy against transfer accidents.

2.1 Limitations of PTA'S structure

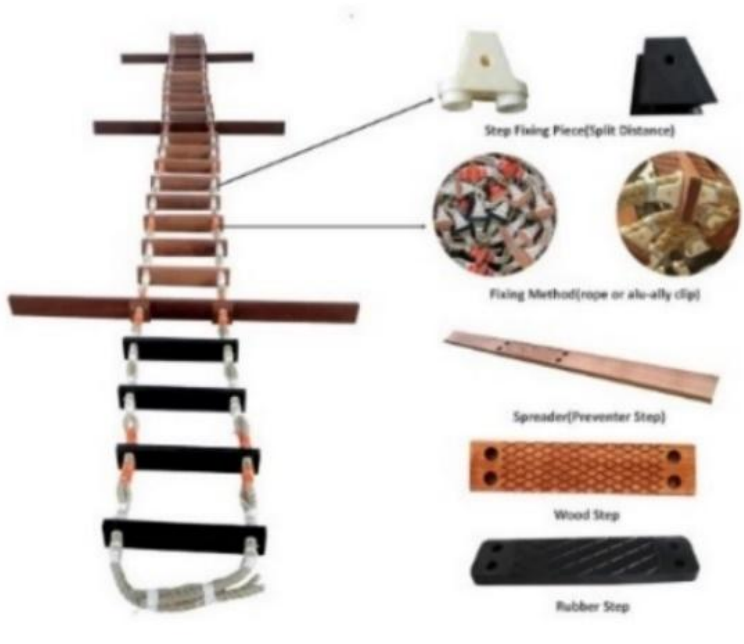
Currently, there are three types of pilot transfer arrangements, i.e., pilot ladder, accommodation ladder, and combination arrangement (pilot ladder combined with accommodation ladder). Normally, the accommodation ladder is used only at the terminal, while the pilot ladder and combination arrangement are used at sea. When the ship's freeboard is 9 meters or less than 9 meters, only the preparation of the pilot ladder can meet the requirement, when the ship's freeboard is more than 9 meters, the combination arrangement is mandatory.

2.1.1 Pilot ladder and combination arrangement

The pilot ladder is a structure made up of several components (**Figure 2**) include side ropes, step fixing pieces, steps, spreader steps. These components are made of wood, fiber, rubber, and plastic. For the materials of the components, ISO (2019) already provides standards, e.g., for the type and strength of wood, the breaking load of fiber ropes, the test requirements for plastics. However, the pilot transfer incident showed that the materials were inherently flawed. Li et.al (2019) stated that although the ISO standard for plastic steps separately requires them to pass a one-year natural weathering test, there are no clear verification requirements for plastic steps after aging. Analysis and summary of the structural and operational limitations of PTA through the case of pilot transfer accidents

Figure 2

Pilot ladder and its components



Note. From *What is Pilot Ladder*, Pros marine, (n.d.). (https://www.prosmarine.com/pilot-ladder/). Copyright 2017~2023 by Pros Marine for Marine Safety Equipment.

2.1.1.1 Side ropes

A pilot fell approximately two meters to the deck of pilot boat and caused injuries to ankle due to both ropes on the pilot ladder broken simultaneously when disembarking a dry cargo ship (Rob, 2013). Xie (2016) reported that he was injured because the side rope of the pilot ladder was wet and unevenly sized. In 2016, a pilot fell from the water surface from a height of 5~6m and fell into the narrow water between the pilot boat and the ship because of both side ropes of the pilot ladder broke, resulting in the pilot suffering multiple soft tissue injuries, Pilot transfer accident creates psychological shadow of boarding and disembarking for first-line pilot (Lu, 2017). The side ropes are made of fiber ropes and are easily wet, dirty, and broken, which puts the pilot in a dangerous situation. Liu (2018) said that a pilot from Guangzhou port fell from 8 meters due to a broken pilot ladder, and a pilot from Lianyuangang port fell overboard for the same reason. The steps of the ladder are made of wood, the crew can only check the exterior when inspecting, the internal architecture is very unseen to be able to be inspected. On the other side. A 40-year veteran pilot fell from the pilot ladder due to a broken pilot ladder and died after two hours of recovery from the water, and this was his second fall from the ladder (Rob, 2019). Marine pilot Capt. Agha Umar Habib (Port of Sohar, Oman) fell overboard due to a broken pilot ladder while disembarking (Marine-pilots, 2019). And he said “Something I had to bear for someone else’s negligence” (Habib, 2019). A pilot fell from the pilot ladder while disembarking from a crude oil tanker due to the failure of the pilot ladder (National Sea Rescue Institute [NSRI], 2020). In 2021, when a pilot was boarding the ship side rope of pilot ladder suddenly broken, fortunately, the pilot did not fall (The Nautical Institute, 2021)

Breakage of the pilot ladder side ropes is fatal to pilot safety.

2.1.1.2 Step fixing pieces

If the step fixing pieces are damaged or incorrectly positioned, such as at different levels, the steps will tilt, making it impossible for the pilot to stand on them.

2.1.1.3 Step and Spreader step

The function of the spreader steps is to prevent the twisting of the pilot ladder, but Kinzo et.al (1998) concluded that the 1.8-meter length of the spreader steps is too short to prevent the twisting of the pilot ladder, especially under the condition that the ship's speed is 4~7 knots, when the wave touches the lower end of the pilot ladder, the pilot ladder will easily twist if no countermeasure is taken based on the results of their experiments. The step and spreader step are made of wood and scar knots can affect their strength **(Figure 3).**

Figure 3

Knots in the steps

Note. *From IMCA, Pilot ladder requirements, (https://www.imca-int.com/safety-events/pilot-ladder-requirements/).* Copyright 2023 by IMCA

IMO (2011) required that if the step is made of hardwood, they should be made in one piece, free of knots.

2.1.1.4 Combination arrangement

In 2006, a sailor fell overboard because the ladder's suspension wire failed, causing the ladder to swing while he was rigging combination arrangements. Although he was recovered from the water, he died in the hospital (MAIB, 2015).

2.2 Limitations on the use of PTA in severe weather

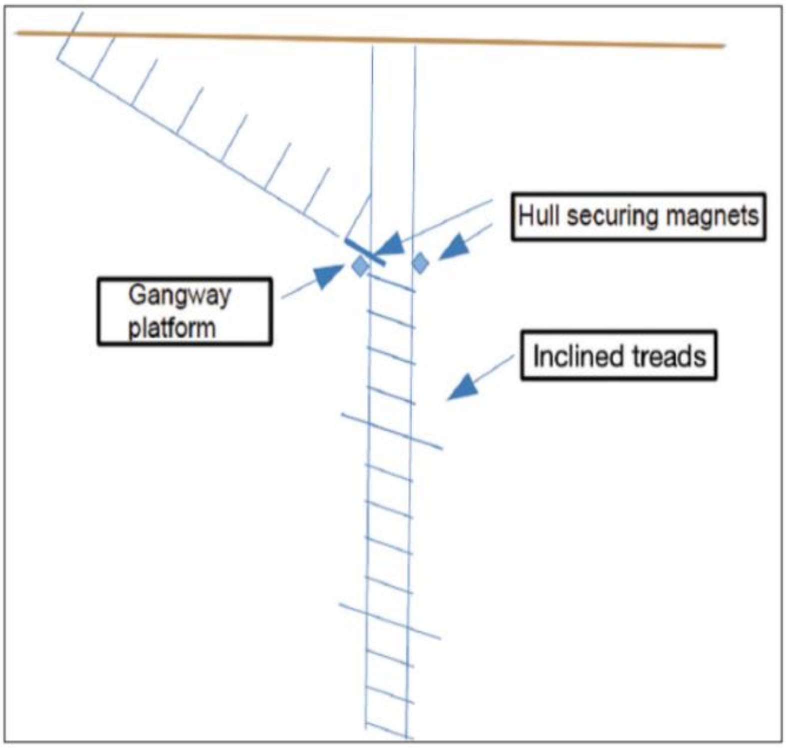
In 2011, a pilot fell down the pilot boat deck and then overboard while the motorboat was alongside the ship, a wave lifted it up and washed it under the ladder (The Nautical Institute, 2011). A veteran Sandy Hook maritime pilot died after falling during a boarding a container ship at the Port of New York and New Jersey (Mike, 2019). As he climbed the pilot ladder, he experienced significant wave heights in excess of 4 to 5 feet, with wind gusts up to 30 knots.

2.3 Limitations of human factors

In 2012, an on-signing crew fell from the combination ladder and drowned because he did not use personal protection equipment and a fall arrester (South Africa Maritime Safety Authority) [ASMSA], 2012). In 2008, a pilot was boarding a ship with two luggage in Landguard pontoon, Felixstowe when his lower leg got stuck between the Pontoon and the hull and was injured (MAIB, 2015). Carrying luggage can put a burden on climbing pilot ladder. The Nautical Institute (2019) reported that pilot slipped down three time because of incorrect installation of pilot ladder **(Figure 4)**

Figure 4

Incorrect installation of pilot ladder



*Note***.** From *201965 Dangerous pilot ladder arrangement,* The Nautical Institute, 2019, https://www.nautinst.org/resources-page/201965-dangerous-pilot-ladder-arrangement.html. Copyright 2019 by The Nautical Institute.

Correct installation of the pilot ladder is a guarantee for pilot transfer, any deficiency may cause pilot fall accident. For example, the different lengths of the side ropes made the steps uneven level, the pilot ladder did not touch the ship's hull well, the platform of the accommodation ladder was at an unreasonable angle, and the steps are arched instead of flat. In 2007, a seafarer fell from the pilot ladder on deck and injured when climbing the pilot ladder (The Nautical Institute, 2007). A marine pilot from the Port of London Authority was killed in an accident while boarding a ship on the River Thames Mike (2016).

2.4 Comprehensive Factors

In 2002, a pilot fell approximately two meters vertically to the deck and was injured while disembarking from a ro-ro ship because two side ropes had already rotted. The subsequent investigation showed that:

- The side ropes of the pilot ladder are uneasy to inspect when it served.
- When the pilot disembarked the vessel by climbing the ladder, there were no handrails or stanchions, he could only use the edge of the door to steady himself.
- The ladder was hanging in the air and could not cling to the ship's hull.
- Only one polypropylene man-rope available.
- Heavy rain during the transfer
- Pilot ladder was not well maintained.
- Deck officer was not familiar with the test and inspection procedures for pilot ladder (The Nautical Institute, 2002)

In 2016, a Port of London Authority marine pilot tried to board a general cargo vessel from a pilot boat, when he fell and was crushed between two vessels. Despite receiving immediate medical attention, he died instantly. The causes were:

- Due to bad weather, the general cargo vessel made a lee for the pilot boat, causing the freeboard to vary.
- The pilot did not use the vessel's designated pilot boarding arrangements.
- The pilot's blood alcohol level was more than twice the legal limit (MAIB, 2017).

A UK maritime pilot died during pilot transfer in northern England's Humber estuary. And UK Maritime Pilot's Association (UK MPA) urged that:

Maritime industry and regulatory authorities, once again, to prioritize safety and training with regard to the transfer of Pilots and crew, and to invest in safe and reliable technologies and procedures to ensure that our Maritime Pilots and seafarers return home safe after every voyage. (Mike, 2023).

The International Safety Management Code ([ISM Code],2018) requires:

The company should establish procedures to ensure that the ship maintained in conformity with provisions of the relevant rules and regulations and with additional requirements which may be established by the company. (ISM Code 10.1)

The company should identify equipment and technical systems the sudden operational failure of which may result in hazardous situations. The safety management system should provide for specific measures aimed at promoting the reliability of such equipment or systems. These measures should include the regular testing of stand-by arrangements and equipment or technical systems that are not in continuous use. (ISM Code, 10.3)

The shipping companies must implement the regulations in accordance with the requirements of the ISM Code to ensure the PTA are in good order. These regulations include but are not limited to:

- SOLAS Chapter V/Safety of Navigation, Regulation 23: PTA.
- Resolution 1045 A. (27): PTA adopted by IMO in 2021.
- ISO 1118: Fibre ropes — Manila and sisal —3-, 4- and 8-strand ropes.
- ISO 799-1:2019 Ships and marine technology — Pilot ladders — Part 1: Design and specification.

- ISO 799-2: 2021 Ships and marine technology — Pilot ladders — Part 2: Maintenance, use, survey, and inspection
- ISO 799-3:2022 Ships and marine technology — Pilot ladders — Part 3: Attachments and associated equipment
- IMPA requirements for PTA.
- IMO Resolution MSC/Circ. 1482.
- International chamber of shipping (ICS)：Shipping Industry Guidance on PTA.

The regulations have made, but the deficiencies of PTA are still existing. According to the IMPA safety campaign between 2016 and 2020, the non-compliance and deficiencies in PTA are still keeping in high level. **Figure 5** shows the non-compliance and deficiencies in PTA.

Figure 5

Non-Compliance and Deficiencies in Pilot Transfer Agreements

No.1 Percentage of Non-Compliance by ship type

Percentage of Non-Compliance by ship type					
Ship Type	2016	2017	2018	2019	2020
General Cargo	22%	17%	16%	12%	14%
Oil Tanker	14%	17%	12%	14%	9%
Roro	18%	16%	9%	13%	13%
Passenger	12%	11%	11%	6%	21%
Container	17%	14%	12%	10%	12%
Gas Tanker	11%	13%	7%	11%	13%
Reefer	17%	21%	18%	14%	19%
Fishing	33%	40%	38%	37%	15%
Bulkcarrier	23%	17%	17%	16%	12%
Chem Tanker	10%	21%	13%	11%	16%
Car carrier	8%	5%	10%	11%	7%
Rig Supply Vessel	23%	22%	16%	17%	8%
Other eg navy	28%	22%	12%	18%	15%

No.4 Percentage of Non-Compliance by transfer type

Percentage of Non-Compliance by Transfer Type					
Tranfer type	2016	2017	2018	2019	2020
Pilot Ladder	18%	16%	12%	13%	12%
Combination	23%	21%	16%	15%	14%
Side door and Pilot ladder	12%	12%	13%	12%	11%
Gangway	14%	0%	7%	0%	6%
Helicopter	24%	23%	7%	1%	3%
Deck to Deck	16%	13%	17%	12%	12%

No.5 Non compliance by type of defect

Non Compliance by type of defect					
Type of Defect	2016	2017	2018	2019	2020
Pilot Ladder %	43%	53%	49%	51%	51%
Bulwark/deck %	20%	19%	20%	24%	23%
Combination %	9%	12%	12%	11%	14%
Safety Equipment %	31%	16%	18%	14%	12%
Total	102%	100%	100%	100%	100%

No.2 Pilot ladder defect by type

Pilot Ladder Defect by Type					
Type of Defect	2016	2017	2018	2019	2020
Not against ship's hull	15%	13%	12%	11%	10%
Steps not of suitable material	3%	3%	2%	1%	1%
Poorly rigged retrieval line	11%	16%	11%	14%	21%
Steps broken	6%	2%	3%	2%	3%
Steps not equally spaced	3%	5%	5%	5%	4%
Pilot Ladder more than 9 metres	2%	2%	2%	2%	1%
Steps dirty/slippery	4%	4%	4%	3%	4%
Sideropes not of suitable material	3%	2%	4%	3%	1%
Pilot Ladder too far forward/Aft	8%	3%	3%	3%	3%
Steps painted	1%	1%	2%	1%	3%
Incorrect step fittings	7%	5%	6%	4%	5%
No bulwark ladder	3%	2%	2%	1%	1%
Steps not horizontal	18%	17%	18%	17%	18%
Other	16%	27%	27%	32%	24%
Total	100%	100%	100%	100%	100%

No.6 Defects of bulwark/deck

Defects of Bulwark / Deck					
Type of Defect	2016	2017	2018	2019	2020
No / Faulty Handhold Stanchions	37%	42%	34%	15%	17%
Ladder not Secured Properly	53%	49%	56%	74%	72%
Other	11%	9%	10%	11%	10%
Total	100%	100%	100%	100%	100%

No.7 Pilot ladder not properly secured

Pilot Ladder not Properly Secured					
Type of Defect	2016	2017	2018	2019	2020
Total observations	2709	2919	4339	4225	6394
Number of observations"pilot ladder not properly secured"	72	57	87	130	183
Percentage of NC observations	2,7%	2,0%	2,0%	3,1%	2,9%

No.3 Combination detects by defects type

Combination defects by Defect Type					
Type of Defect	2016	2017	2018	2019	2020
Accomodation Ladder not Leading aft	0%	2%	2%	1%	
Lower platform stanchions/rail incorrectly rigged	9%	7%	5%	10%	
Accommodation ladder too steep (>45 degrees)	5%	4%	3%	6%	
Pilot ladder not attached 1.5m above accomodation ladder	20%	27%	15%	23%	
Lower platform not horizontal	12%	10%	9%	12%	
Ladder(s) not secured to ship's side	33%	28%	32%	25%	
Lower platform less than 5 metres above the sea level	13%	17%	16%	14%	
Other	9%	5%	16%	11%	
Total	100%	100%	100%	100%	1

No.8 Safety equipment defects by defects type

Safety Equipment defects by Defect Type					
Type of Defect	2016	2017	2018	2019	2020
Inadequate lighting at night	10%	14%	9%	11%	21%
No Lifebuoy with self-igniting light	33%	32%	37%	31%	29%
No VHF communication with the bridge	12%	13%	9%	14%	6%
No heaving Line	22%	15%	20%	22%	21%
No responsible officer in attendance	23%	24%	19%	18%	18%
Other	1%	1%	6%	3%	4%
Total	100%	100%	100%	100%	100%

Note. From *IMPA safety campaign comparison 2016-2020, IMPA (p.4-9), 2020.*(https://pilotladdersafety.com/wp-content/uploads/2020/12/impa-safety-campaign-analysis-2016-2020.pdf)*. Copyright2020 by IMPA*

In Figure 5:

- No.1 Percentage of Non-Compliance by ship type shows that the PTA non-compliance keeps between 7 percent and 21 percent, it is clear that whatever type of ship the regulations are not well conducted.
- No.2 Pilot ladder defect by type shows the various defects of pilot ladder:
  - Pilot not well against ship's hull

- Side ropes broken
- Broken steps
- Incorrect rigging
- Unsuitable materials
- Lack of maintenance
- Uneven distance between steps
- Step not in horizontal plane
- The steps of the accommodation ladder are curved instead of flat.
- Steps are dirty or slippery
- The accommodation ladder is not well secured, causing twisting
- Accommodation ladder not well secured causing swing
- No pilot lifeline provided, causing pilot to fall overboard or onto pilot boat deck
- Inadequate lighting
- Poor communication between ship and pilot
- Transfer operation conducted in bad weather
- Failure to follow test procedures
- Human factors including seafarers and pilots

- No.3 Combination detects by defects type show the defects of combination arrangements:
  - Wrong leading direction
  - Wrong installation
  - Excessive angel
  - Platform not in horizontal position
  - Pilot ladder not secured to the ship's hull
- No.4 Percentage of by transfer type shows the percentage of non-compliance of pilot transfer arrangement from 2016 to 2020 decrease, but in the author's

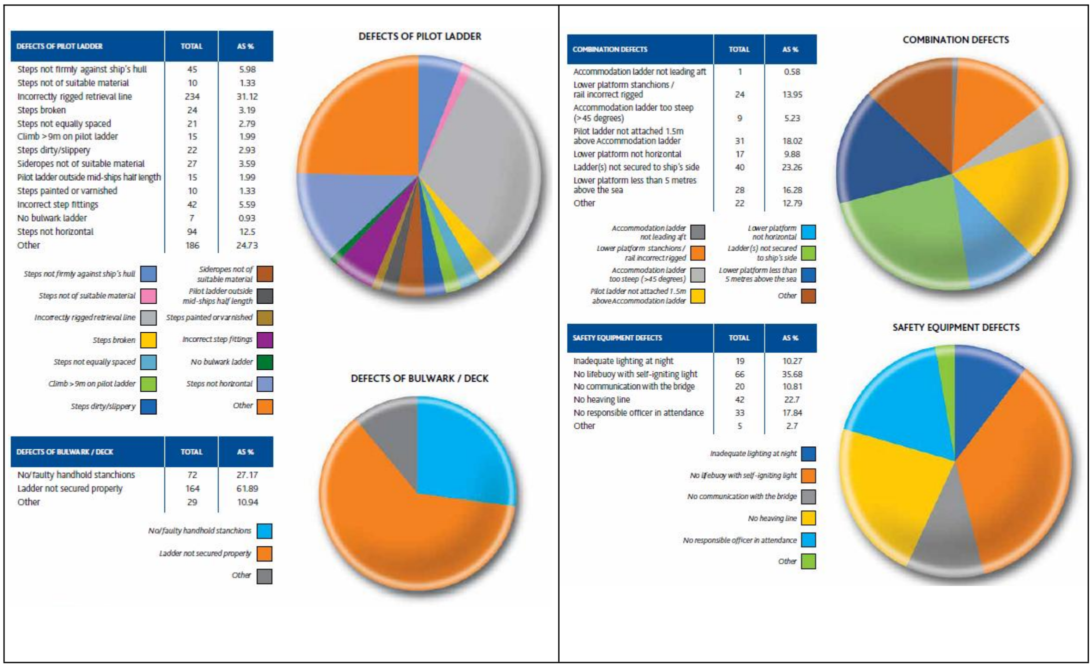
opinion, they are still unacceptable, because any non-compliance or defect may cause pilot die.

- No.5 Non-Compliance by type of defect show the pilot ladder, bulwark/deck, combination arrangements, and safety equipment are in unacceptable level.
- No.6 Defects of bulwark/deck and No.7 Pilot ladder not properly secured show the accessories of pilot ladder are not ready and pilot ladder not well secured in high percentage of non-compliance.
- No.8 Safety equipment defects by defects type shows the defects of safety equipment may exist in:
    - Insufficient illumination at night
    - Life-saving appliance not available
    - Poor communication
    - No heaving lines
    - No officer in attendance

A review of the IMPA Safety Survey 2022 shows that PTA have not improved significantly (**Figure 6**). Whether it is pilot ladder, bulwark, combination, or safety equipment, the deficiencies in PTA remain at a high level.

Figure 6

Defects of PTA



Note. From *Safety campaign 2022* (p.7-9) , by IMPA, 2022, (https://www.impahq.org/sites/default/files/content-files/IMPA%202022%20Safety%20Campaign%20Results.pdf). Copyright 2022 by IMPA.

Wei (2022) calculated the number of crew casualties and found that the number of crew casualties far exceeded the number of pilot accidents, being more than three times the number of pilot accidents. Pilot ladder safety accidents mainly occur when crew members are rigging and retrieving the ladder, embarking and disembarking and using the ladder to check the draft, with the most accidents occurring when seafarers are operating the ladder.

2.5 Summary of pilot ladder's limitations

The pilot ladder is not a labor-saving and bulky equipment, it requires manual handling for both installation and retrieve. Climbing the pilot ladder is not only an arduous process for the pilot, but also involves various potential risks.

The construction of the pilot ladder involves a wide range of materials and standards. Although the IMO has established requirements for pilot transfer safety, these appear to be poorly enforced or difficult to enforce on board, resulting in a high number of pilot transfer accidents. For example, the side ropes are made of fibre and although the breaking strength meets the requirements, the internal condition is not easy to inspect, the pilot ladder is not against the ship's hull, the surface of the steps is slippery and dirty, the pilot ladder is poorly maintained. Why can these requirements not be fully implemented and why does the current situation not change? In this context, the author has reason to question the safety of the current structure of the PTA. It is dangerous to place the safety of the pilot's transfer on these vulnerable links

Chapter 3 Methodology

3.1 Theoretical and application background of designing of pilot boarding lift

Elevators or lifts are widely used for vertical transportation of people and materials. In industrial and civil buildings, large bridges and shafts are indispensable and good transportation devices, as permanent or semi-permanent ones can also be used in various occasions such as warehouses and towers. However, today, with the rapid development of maritime technology and shipbuilding technology, the pilot does not have a labor-saving or power-assisting device embark and disembark the ship. Today, pilots still use traditional pilot ladders as transfer devices, which are not only cumbersome in structure and susceptible to external environmental factors, but also place high demands on the pilot's physical strength and health. Even healthy and experienced pilots fall from the ladder and are injured or killed every year. Despite the fact that international organizations have established many requirements for the safety of pilot transfer devices, the fact is that pilot injuries and fatalities are frequent. The transfer accidents are the authors have been thinking about, namely the need for a new boarding arrangement to fundamentally improve boarding safety. The product is simple with lifting mechanism, stability, safe and reliable, it does not take up additional space to facilitate disassembly and flexibility, fundamentally solve the pilot's climbing labor intensity, to prevent the risk of not holding the side rope, stepping in the air, etc., in improving the transfer efficiency has a significant impact.

The PBL as a new concept of PTA, it has the reasonable design, novel structure, stable operation, complete and reliable safety device, easy installation and maintenance. It mainly has the following features:

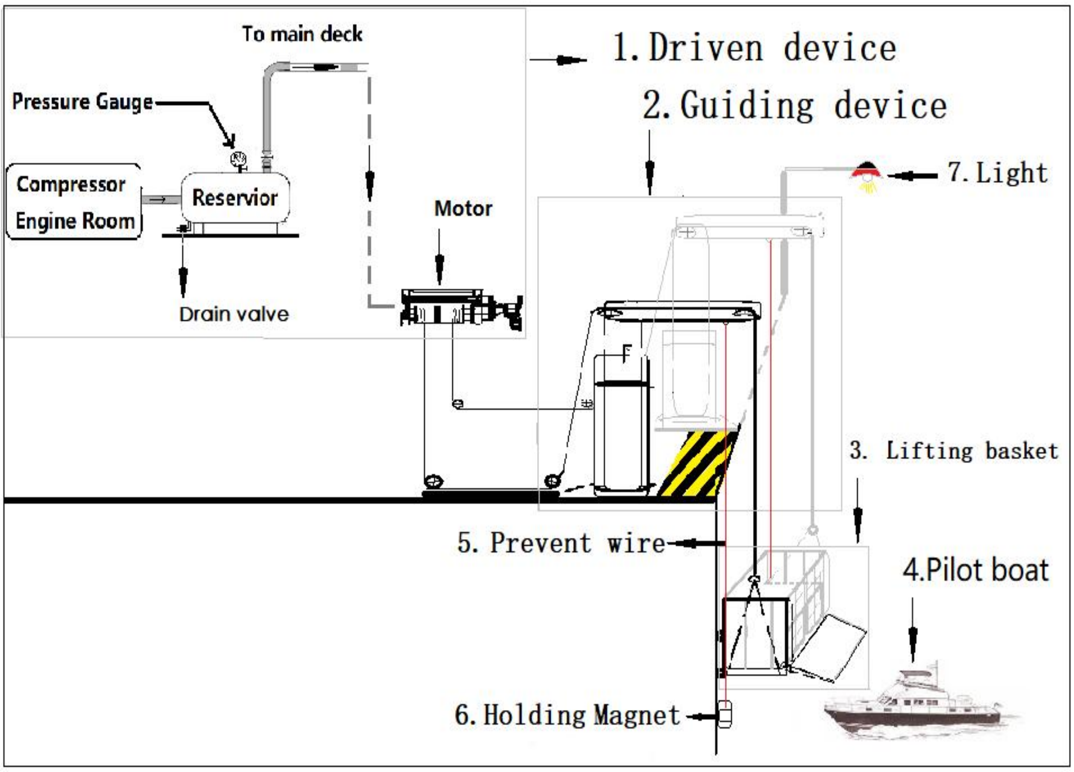
- The transmission mechanism adopts pneumatic motor, make the machine to receive strength evenly in the gear and rack, safety smoothly.
- The basket equipped with anti-fall device, can effectively prevent the basket from falling, to ensure the safe and reliable operation of the PBL.
- The PBL is equipped with a safety limit switch, it can stop immediately and automatically to prevent accidents.
- The PBL can be stopped at any position during ascending.
- The structure of the PBL has been designed through scientific and strict computation, with reasonable structure, reliable solidity and lightness.

3.2 PBL layout

The PBL is a simple lifting system consisting of three parts, namely the drive unit, the guide unit and the lift basket (**Figure 7**). It is installed on each side of the midship, as the parallel body of the ship is advantageous for it to rest well against the hull and there is no any obstruction in pilot access area. The pneumatic winch is powered by compressed air from the engine room. The guide device mainly transmits the power from the winch to the basket. As the winch rotates, the wire is hoisted in/out and the PBL is simultaneously raised and lowered. The lift basket is used to transfer the pilot between the pilot boat and the vessel.

Figure 7

The PBL layout

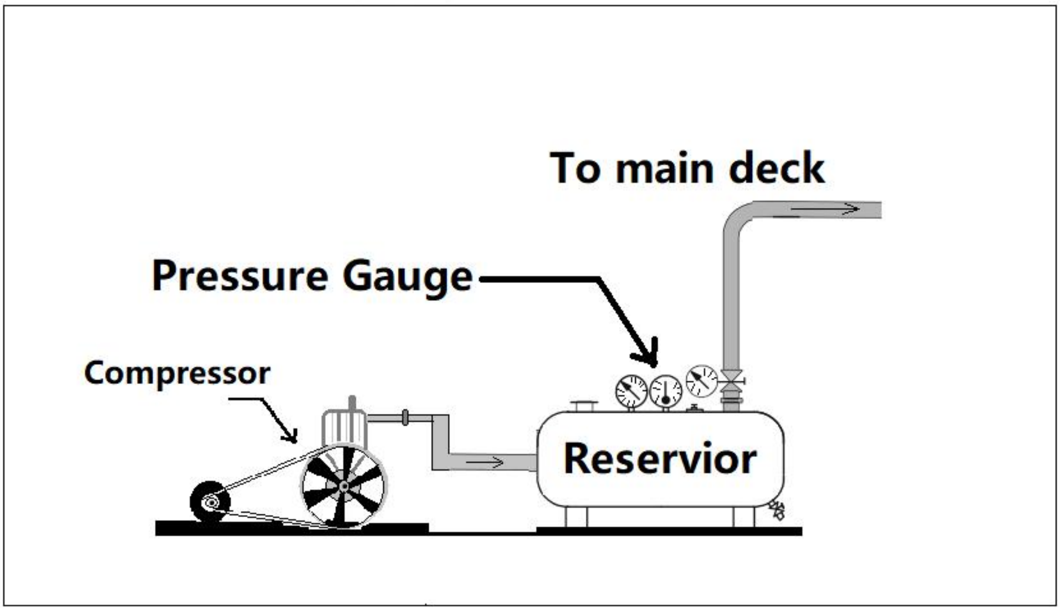


3.2.1 Driven device

The driven unit consists of two parts, the compressed air system **(Figure 8**) and the pneumatic motor. The compressed air is generated by the compressor and stored in the reservoir tank. The compressed air in the reservoir tank is normally kept between 0.6 and 1.0 MPa, which can drive the pneumatic motor, while the pressure is lower than 0.6 MPa, the compressor can start automatically and fill the reservoir tank. There is a pipe system that can supply compressed air to the air motors (both sides) on the main deck.

Figure 8

Compressed air system arrangement



3.2.1.1 Definition of pneumatic motor

A pneumatic motor is a power device that uses compressed air as a power source and converts pressure energy into mechanical energy by using its expansion effect.

Although it has the disadvantage of small output power, high air consumption, low efficiency, high noise, easy to produce vibration, it is widely used in ship's gangway and accommodation ladder because of its advantage:

- Availability. Air is available practically everywhere in unlimited quantities.
- Transport. Air can be easily transported in pipelines, even over large distances.
- Storage. Compressed air can be stored in a reservoir and removed as required. In addition, the reservoir can be transportable.

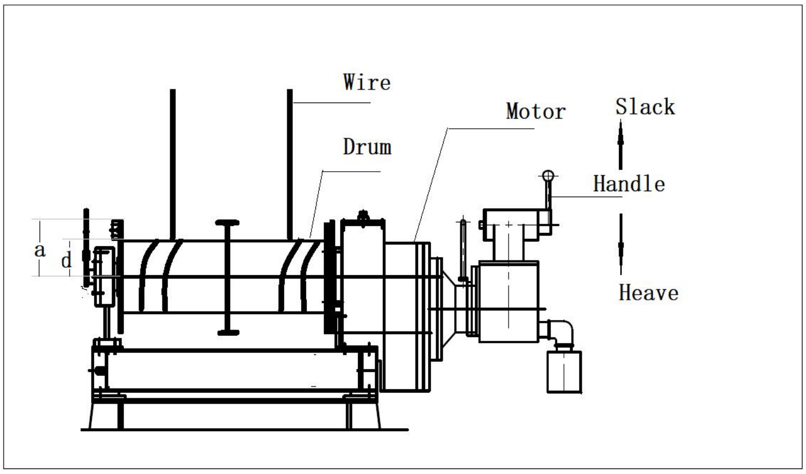
- Temperature. Compressed air is relatively insensitive to temperature fluctuations. This ensures reliable operation, even under extreme conditions.
- Explosion proof. Compressed air offers no risk of explosion or fire.
- Cleanliness. Unlubricated exhaust air is clean. Any unlubricated air which escapes through leaking pipes or components does not cause contamination.
- Components The operating components are of simple construction and therefore relatively inexpensive.
- Speed Compressed air is a very fast working medium. This enables high working speeds to be attained.
- Overload safe Pneumatic tools and operating components can be loaded to the point of stopping and are therefore overload safe. (Croser et.al, 2002, p.15-16)

3.2.1.2 The structure of pneumatic winch

The pneumatic winch consists of motor, gear, reel, brake system and handle (**Figure 9**). The air winch is a power unit that uses compressed air as a working medium. The pneumatic motor and gear are the main power components. It is a power device that converts pressure energy into mechanical energy by utilizing the expansion effect of compressed air. The working principle of the air motor is basically similar to that of the internal combustion engine. The expansion of the air drives the piston in a reciprocating motion, which is then converted into a circular motion by a crank mechanism. The gear box is connected to the air motor and contains two sets of gears that transmit the circular kinetic energy from the air motor to the drum to make it rotate and work. The pneumatic motor is now universally used in ship's accommodation ladder.

Figure 9

Pneumatic winch arrangement



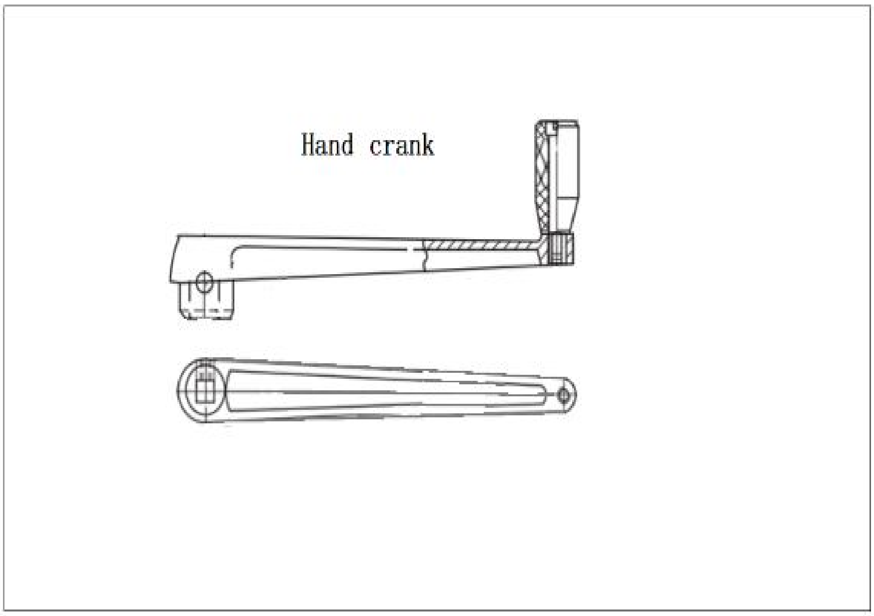
The drum is a split drum for two wire ropes, and the length is sufficient for the wires to be fully wound in effective working length. When deciding the length of the drum, the rope size (diameter), vessel size (moulded depth) and installation position should be taken into consideration.

- The design standard of the roller diameter should be not less than 14 times of the diameter of the wire rope.
- The height of the edge of the roller is at least 1.5 times of the outermost diameter of the wire rope, that is, $a = 1.5d$ (International Organization for Standardization [ISO],2016)
- The pneumatic winch is provided with a safety protection device that can hold the drum at 1.5 times the holding load. When the compressed air supply fails, the winch can automatically stop to prevent the basket from falling. And the

winch is equipped with a manual hand crank (**Figure 10**). The PBL can be hoisted or lowered manually. Meanwhile, an emergency stop button is also available.

Figure 10

Hand crank



- For pneumatic winches, such device shall automatically operate when the drive is being shut off or if the compressed air cuts off.
- The wire rope is using of 6 × 37 galvanized steel wire rope with fiber core of 1 770 N/mm² tensile grade (ISO, 2017). And the safety factor of the wire ropes is at least five in relation to the holding load (ISO, 2015).

The specific winch dimension should be designed according to the ship's particular, such as length overall, moulded depth, molded breadth. The technical specification of the winch is shown in **Table 2**.

Table 2

Winch technical specification

Items	Data
Motor type	WMU-2023
Drum load	10KN
Supporting loading	30KN
Hoisting speed (Maximum)	30m/min
Winding wire layers on drum	3
Wire capacity	30m
Wire rope size	6 × 37 galvanized steel wire
Working pressure	0.6-0.8MPa
Pneumatic transmission ration	70
Manual transmission ratio	30
Total efficiency	0.85
Air consumption	7 m^3/min

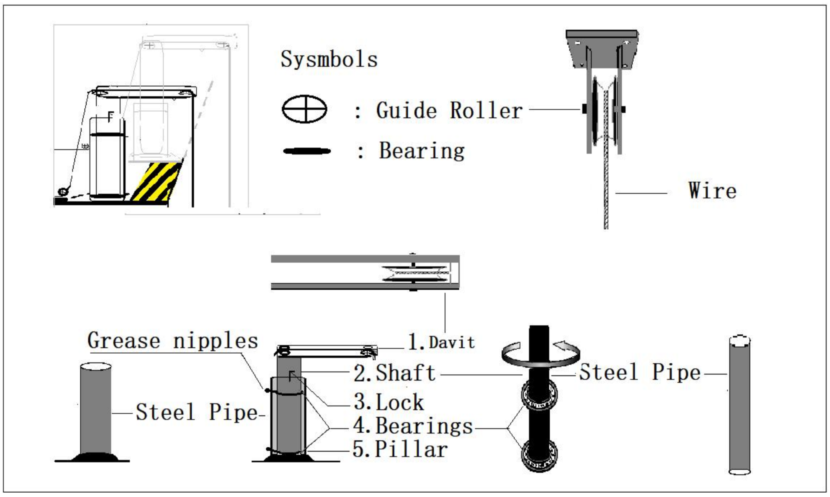
In this design, the parameters are related to the ship's pneumatic winch, namely ISO7364: Ships and marine technology-Deck Machinery-Accommodation ladder winches. Thus, the parameters comply with the design standard**.**

3.2.2 The structure of guide device

The guide device is used not only to change the direction of the force, but also to support the force from the winch and the weight of lift basket (pilot inside). It consists of four parts, that is, the wire ropes, the pillar, guide roller and the bearing (**Figure 11**).

Figure 11

Guide device arrangement



The guide device's constructure and functions as:

a) The pillar consists of steel pipe and bearings. The pillar is used to support wire ropes. The bearings are mounted inside the pillar and outside the shaft, so that the shaft can be rotated. When the PBL be retrieved on deck, the direction of the davits can be adjusted to the bow and stern of the ship by the rotating of the shaft.

b) The davits reach the overboard which can keep the wire ropes in vertical condition guided by the end of the mounted guide roller. When they are retrieved, the davits can turn inward to align with the ship's fore and aft direction.

c) The locks are used to lock the arm in a stationary position when the davits are reached overboard.

d) There is a grease nipple set for greasing the bearing.

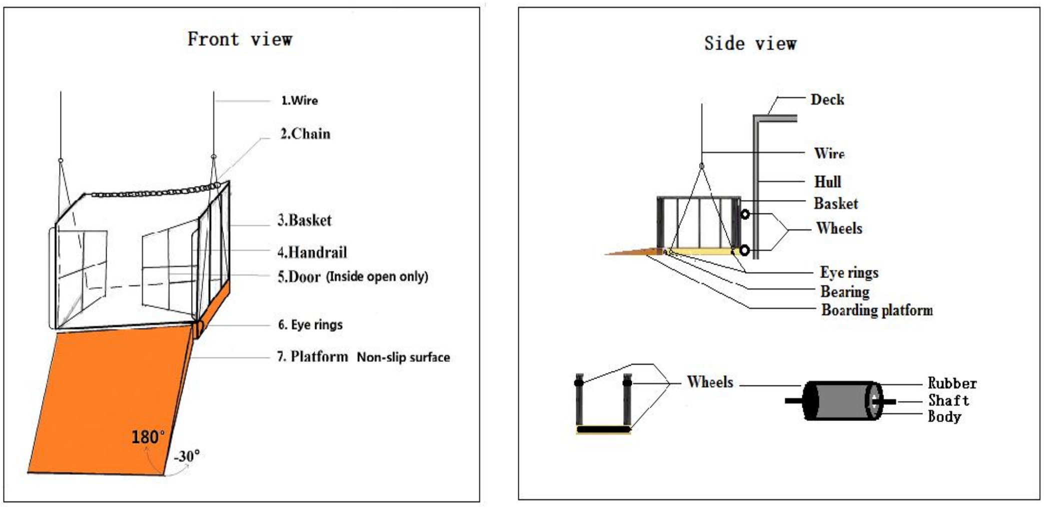
e) The base of the pillar is reinforced by means of welded steel plates

3.2.3 The structure of lift basket

The lift basket is made up of wire, chain, basket, handrail, doors, eye rings and platform (**Figure 12**).

Figure 12

Lift basket



Using the lift basket as a transfer device not only reduces the burden of climbing the pilot ladder, but also eliminates the risk of the pilot's luggage falling overboard for improper use of the heaving line. The wheel is installed on the contact surface of the basket and the hull, and the outer edge of the wheel is made of rubber, which can reduce the friction of the hull and increase the smoothness of vertical movement and increase the horizontal friction and reduce the tendency of the basket to move forward and afterward. A removable chain is set on the side of the basket against the ship's hull, which provides safety for the pilot.

Two handrails are located on the outside of the basket to provide a support point for the pilot when entering the platform. Pilots can hold onto the handrails to stabilize their bodies to prevent falling down or falling overboard.

The basket is equipped with inward opening doors. The doors should be opened before the basket is lowered. Close the doors after the pilot has entered the basket.

When encountering bad weather in the pilot station, the eye rings (in Front view numbered 6) provide a securing point for one end of the rope while the other end is secured to the deck. This can reduce the swinging intensity of the basket.

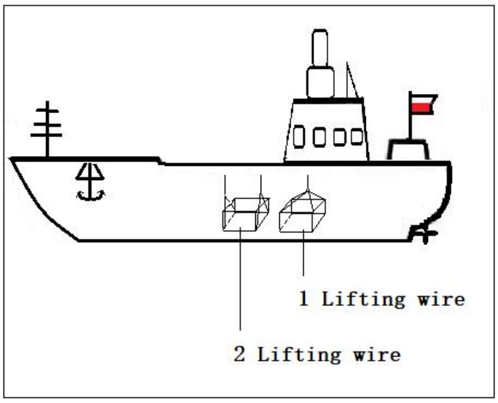
Ships and marine technology-Aluminium shore gangways for seagoing vessels

The boarding platform is designed to support a uniform loading of 4 000 N/m² (ISO, 2015). It is an up-and-down movable element, and the working angle is between minus 30 degrees and 180 degrees. The purpose of this design is that when the boarding platform touches the deck of the pilot boat, it will float up and down with the pilot boat to maintain a better fit between the platform and the deck. The platform is made of rubber with non-slip surface treatment, compared with the metal platform, it can reduce the damage of the platform to the deck of the pilot boat to a greater extent, more importantly, to prevent bruising the pilot, but also to prevent slipping.

In this design, two wire ropes are used as lift wires instead of one, which can reduce the tendency to twist. Meanwhile, each wire rope is connected to both sides of the basket bottom, which can reduce swinging **(Figure 13).**

Figure 13

Comparison of single and dual wire baskets



The use of two wires means that there are two points of force which, together with the contact point between the wheel and the hull, form three points of force, making the movement of the lift basket more stable, whereas a single wire does not have this effect.

3.2.4 Preventer wire and holding magnet

In this design, two preventer wire ropes and holding magnets are used to stabilize the basket when the ship encounters bad weather. The top ends of the preventer wire ropes are secured on the davits and the other ends to the holding magnets. Before arriving at the pilot station, the master should assess the weather and sea conditions. Prepare the preventer wire ropes and holding magnets when the basket is launched at the designated position. The holding magnet can provide 450kgs breakaway strength **(Figure 14**). Two magnets provide 900kgs breakaway strength, which can effectively prevent the basket from rolling and twisting.

Figure 14

Pilot ladder magnet

Note. Adapted from International Network and Community*, 2021, New Pilot Ladder Magnet Is Switchable* (https://www.marine-pilots.com/articles/270684-new-pilot-ladder-magnet-is-switchable). *Copyright 2021 by Serpent & Dove - Applied Magnetics Pty Ltd*

3.2.5 Material standard

The materials and engineering standards used in this design are showed in **Table 3**.

Table 3

Material standard of PBL

Name	**Standard**
Winch	ISO 7346 Ships and marine technology — Deck machinery — Accommodation ladder winches
Steel pipe	ISO 10763-1994
Wire rope	ISO 2408, Steel wire ropes for general purposes — Minimum requirements
Bearing	ISO/AWI 19457 Rolling bearings--Linear roller bearings--Boundary dimensions and tolerances
Guide roller	CBT 3861-2011
Grease nipples	ISO 7824:1986 Shipbuilding and marine structures — Lubrication nipples — Cone and flat types

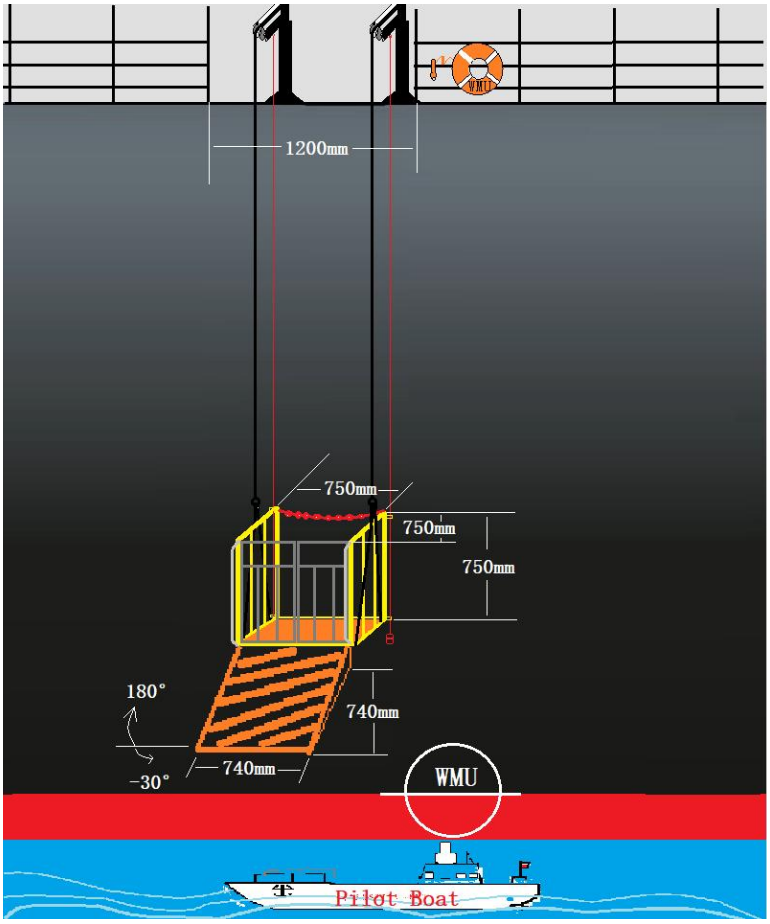
Chain	ISO 487:1998
	Steel roller chains, types S and C, attachments and sprockets
Handrail	500 N/m without permanent deformation
Platform	Rubber, ISO 877-2: 2009. Uniform loading of 4 000 N/m2
Eye ring	Stainless Steel
Magnet	450kgs breakaway strength

3.2.6 The PBL dimension

The PBL is a new designed boarding device, there is no dimension standard for it. The dimension PBL has been designed according to “Required boarding arrangements for pilot” (**Appendix A**) the far as possible.

Figure 15

PBL dimension



3.2.7 Installation, Test, Operation, and Maintenance

3.2.7.1 Installation

For the installation of PBL, reference is made to MSC.1/Circ.1331: Guidelines for the construction, installation, maintenance and inspection/survey of means of embarkation and disembarkation, as far as possible to meet IMO requirements. The PBL is installed on the main deck on either side of the midship and do not interfere with cargo handling and keep pilot access clear at all times. The area around the winch should be marked as a warning zone with a warning color, such as yellow and black stripes, to prevent trespassing. The wire between the winch and the post should be covered with steel plates or equivalent material to prevent people tripping over it. Adequate lighting is provided in the pilot boarding area, and a lifebuoy with lifeline and self-igniting light is installed near the pilot access for emergency use. The maximum safe working load, load test date, wire renew date information marked on PBL.

3.2.7.2 Test Program

As there are no relevant design standards for the new design of PBL, this test program refers as far as possible to ISO 7364 Ships and marine technology-Deck machinery- Accommodation ladder winches (second edition 2016-04-01) (**Table 4**).

Table 4

Performance data

Normal size (mm)	Drum load (KN)	Holding load (KN)	Winch load test procedure		Steel wire rope diameter actually selected (mm)	
			Minimum rope strength (5*holding load) (KN)	Steel wire rope diameter (mm)	Single drum	Split drum or double drum
5	5	15	75	12	11	-
6	6.3	18	90	13	11	-
8	8	25	125	16	13	-
10	30	150	18	13	13	-

12	12.5	37.5	188	20	13	13
16	16	48	240	22	14(15)	14(15)
20	20	60	300	24	16(15)	16(15)
25	25	60	300	24	-	16(15)
30	30	90	450	28	-	16
NOTE Choose the actual steel wire rope diameter of winches according to the following case that the breaking load of steel wire rope shall be not less than five times the actual holding load of accommodation ladder winches. a. For winches working with two ropes, the listed values are the sum of the forces on each rope. b. In column 4, based on a holding load safety factor of five, all values shall be selected in winch load test. c. The rope diameter given in column 4 is used only for static load test of winches with one rope according to 6.4. d. The rope diameter in brackets means that these values are included in national standard specifications.						

Note. Adapted from *Ships and marine technology — Deck machinery — Accommodation ladder winches (p.4)*. by ISO, 2016, (https://www.iso.org/standard/61449.html) Copyright by 2016 ISO

The winch shall be tested as a complete unit, i.e., prime mover, drum, gearing and controls and the results of tests shall be recorded in the certificate. The test program includes the purpose of the test, the test procedure, and the items to be tested.

a) The test purposes:
   - Check that the design of the PBL meets the relevant requirements of the accommodation ladder winch.
   - Check that the dimensions of the upper platform, the davit1 and the installation of each part meet the design requirements.

- Check that the positioning dimensions of each part can meet the requirements of the actual vessel layout/installation and use.

b) Test procedure:

- Test the winch run without load for ten min continuously, five minutes up and down. The temperature of bearings shall be checked.
- The winch shall be subjected to two lowering and lift cycles under drum load, including hauling, using a rope length of not less than one third of the drum capacity. In the case of power winches, the rated speed for lift the accommodation ladder shall be not less than 0.05 meter per second.
- The winch drive shall be capable of continuously overloading the drum load by 1.5 times for two minutes without failure.
- The static test should be under 1,5 holding load with the wire rope wound in a single layer on the drum.

3.2.7.3 Operation

The PBL operation instruction for pick up the pilot are:

a. The PBL is powered by a pneumatic motor, check the compressed air hose and pressure before operating.
b. Fix the basket handrails, lock the chain, open the doors (inward only) and unfold the boarding platform.
c. Start the winch and swing the davit outwards, and lock the davit to prevent movement.
d. Lower the basket to the intended height.

e. The crew descends with the basket to a pre-determined height and then uses magnets to secure the preventer wire ropes, which effectively dampens and prevents the basket from rolling due to wind and/or waves.
f. Adjust the lift basket heigh as per pilot's instruction anytime.
g. Operate the motor lever to hoist the basket, when the bottom of the basket is level with the deck, the limiter will start to work and then the winch will stop automatically.
h. The deck officer unlocks the chain and directs the pilot to the bridge.
i. Swing davits inwards at the master's command if they obstruct the berthing.
j. After use, secure the moving parts for sailing.

3.2.7.4 Maintenance

a. Designate someone to carry out maintenance and inspections to ensure the equipment is in good working order.
b. Apply lubricating oil through nipples to all moving parts, including lubricating the wires.
c. Arrange for an annual survey of the PBL by the manufacturer or service provider and a five-year survey by the shipyard (IMO,2022), including load test and replacement of the wire rope.

3.3 Pilot boarding lift-Risk assessment and reduction methodology

The author believes that a new design or product should be subjected to a risk assessment before it is put into use. Risk assessment is a tool for identifying the risk of harm from various hazards, hazardous situations and events. Identifying the risks of PBL prior to risk assessment

Table 5

Identification of PBL hazards

Type of hazard	Details
Mechanical	Failure of motor, winch, wire, bearing, roller, handrail, magnet
Compressed air	Low pressure
Pollution	Grease oil leakage
Lighting	Insufficient lighting
Fire	Material on fire

ISO (2019) states that the risk assessment method is a tool for identifying hazards, hazardous situations and risk of harm from harmful events. The risk assessment and reduction methodology were made as shown in **Table 5**.

Table 6

Pilot boarding lift-Risk assessment and reduction methodology

Subject: Pilot boarding lift **Moderator: Author** **Date: 2023**

Case number	**Scenario**			**Estimation of risk elements**		**Protective measure (risk reduction measure)**	**After protective measures**		**Residue risk**
	Hazardous situation	**Harmful event**		$\boldsymbol{s^b}$	$\boldsymbol{p^c}$		$\boldsymbol{s^b}$	$\boldsymbol{p^c}$	
		Cause	**Effect**						
1	Mechanical	Failure of motor	Injury/Death	1	E	a) Annual survey b) Manufacturer inspection every five years c) Test before using d) Develop maintenance plan	3	E	Personnel may be affected by emergency stop
		Failure of winch	Injury/Death	1	B		2	E	Personnel may be affected by emergency stop
		Breaking of wire	Injury/Death	3	B		3	F	Tilting of the basket
		Poor handrail	Injury/death	2	B		3	E	Incorrect installation
		Failure of magnet	Unstable lift	3	B		3	F	Incorrect installation
		Failure of step	Falling	2	B		3	E	Incorrect installation

Case number	Scenario			Estimation of risk elements		Protective measure (risk reduction measure)	After protective measures		Residue risk
	Hazardous situation	Harmful event		s^b	p^c		s^b	p^c	
		Cause	Effect						
	Comments: Training is required before operation								
2	Compressed air	Interruption, low pressure	Unexpected stop, low speed	2	B	Develop a maintenance plan for compressor and piping system.	3	F	Unexpected air supply
	Comments: Engine department								
4	Pollution	Grease oil leakage	Pollution, Slippery	3	E	Setting the drip tray	4	F	No
	Comments: The drip tray can prevent pollution from grease oil								
5	Lighting	Insufficient lighting	Inaccessible	2	B	Prepare portable search light	4	F	No
	Comments: Pilot light and search light can provide sufficient illumination								

<table>
<tr><th rowspan="3">Case number</th><th colspan="3">Scenario</th><th colspan="2">Estimation of risk elements</th><th rowspan="3">Protective measure (risk reduction measure)</th><th colspan="2">After protective measures</th><th rowspan="3">Residue risk</th></tr>
<tr><th rowspan="2">Hazardous situation</th><th colspan="2">Harmful event</th><th rowspan="2">S^b</th><th rowspan="2">P^c</th><th rowspan="2">S^b</th><th rowspan="2">P^c</th></tr>
<tr><th>Cause</th><th>Effect</th></tr>
<tr><td rowspan="2">6</td><td>Fire</td><td>Material on fire</td><td>Case fire</td><td>4</td><td>F</td><td>Flame retardant material</td><td>4</td><td>F</td><td>No</td></tr>
<tr><td colspan="9">Comments: There is no inflammable material</td></tr>
<tr><td colspan="10">a Purpose, team moderator and member may be recorded in a separate document.
b S- Levels of severity of the harm
1- High, 2- Medium, 3-Low, 4-Negigible.
c P-Level of probability of occurrence of harm
A- Highly probable, B-Probable, C-Occasional, D-Remote, E-Improbable, F-Highly improbable</td></tr>
</table>

Note: Adapted from *Lifts (elevators), escalators and moving walks-Risk assessment and reduction methodology.* ISO, 2009, (https://www.iso.org/standard/46048.html). Copyright 2009 by ISO

Chapter 4 Survey Results

For this study, five sets of questionnaires on the safety of PTA were distributed via Email and WeChat to seafarers, shipowners, Classification Society surveyors, Port State Control (PSC) officers and pilots. In order to obtain detailed statistics on the perceptions of experts from different sectors regarding the safety of water diversions, different questionnaires were developed according to their professional background, including common and individual questions. The questionnaires were carried out between February and May 2023.

4.1 Common question part

In order to collect the universal feedback on all aspects of pilot transfer safety, this part has four questions that apply to all participants:

01 What is your rank and/or profession?

a) Seafarer
b) Shipowner
c) Classification society surveyor
d) Port state control (PSC) officer
e) Pilot

02 How many years have you been in your profession

a) 1-5years

b) 5-10 years

c) 10-15 years

d) More than 15 years

03 The PBL in **Figure 16** was designed by the author to be used as a boarding device, would you choose it or the pilot ladder to embark or disembark the vessel? Why or why not?

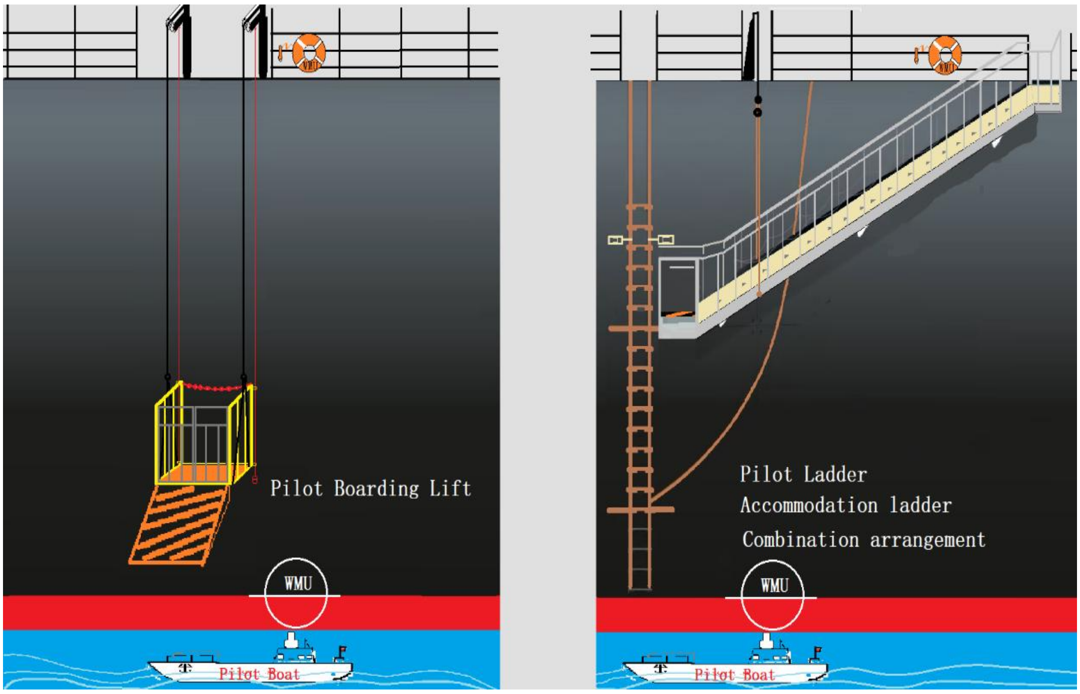
a) Acceptable

b) Unacceptable

c) Unsure

Figure 16

Comparison of boarding means between PBL and PTA



The common questionnaires are aimed at people in occupations directly or indirectly related to pilot transfer safety. Their professional background and work experience are shown in **Figures 17 and 18**.

Figure 17

Profession of respondents

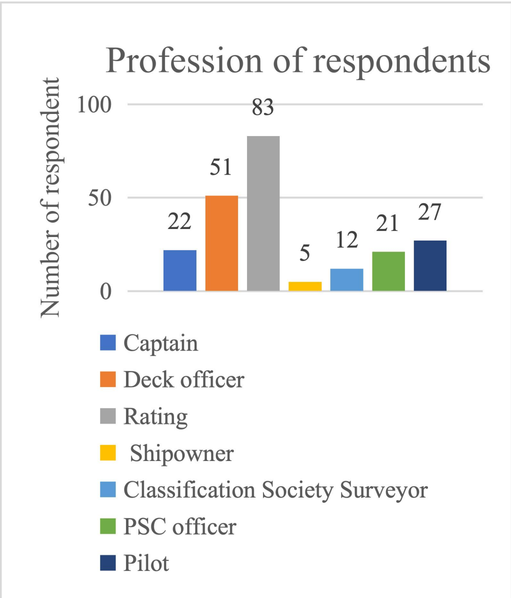


Figure 18

Work experience

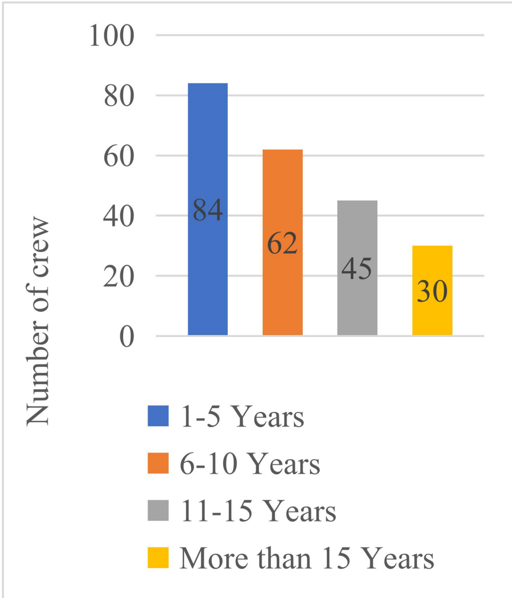


Figure 17 shows that the respondents included 156 seafarers (of whom 22 were masters, 51 were deck officers and 83 were deck ratings), 5 shipowners, 21 PSC officers, 12 classification society surveyors and 27 pilots. Seafarers are responsible for installing pilot transfer arrangements, shipowners are responsible for providing pilot boarding facilities and training in the operation of PTA, PSC officers have a supervisory function, classification society surveyors carry out ship surveys including PTA, they work on the first front line of pilot transfer operations, so the author intended to collect first-hand advice from them on how to improve PBL.

Figure 18 shows the work experience of the respondents, of whom eighty-four had between one and five years of experience, sixty-two had between six and ten years of experience, forty-five had between eleven and fifteen years of experience and thirty had more than 15 years of experience. Theory comes from practice and experience, and they are in the best position to understand and familiar the causes of pilot accidents. The authors' aim is to summarize their valuable professional experience to identify the shortcomings of the current PTA and to improve it.

Figure 19

Acceptance of PBL

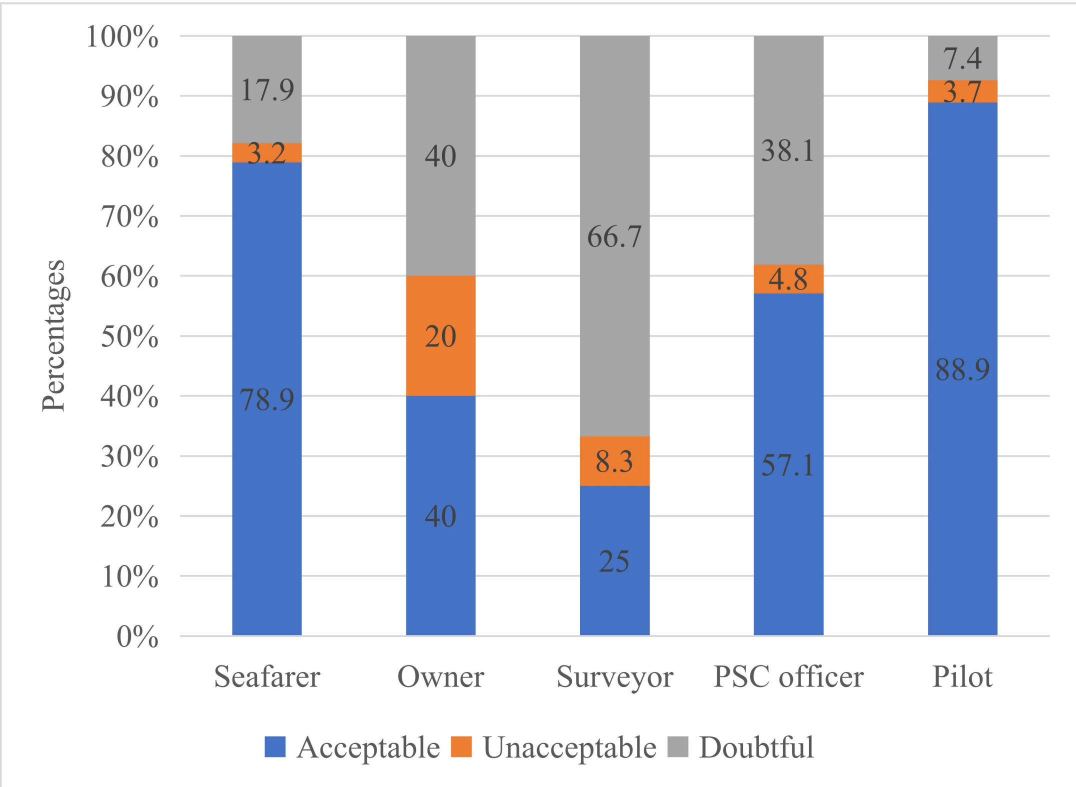


Figure 19 shows 78.9% seafarers think the design is acceptable. Captain A, who is from a chemical tanker said that this PBL may be easy to be launched and the height can be adjusted at any time to meet the pilots' requirements. Pilots used to complain that the height of the pilot ladder did not follow their instructions, so re-rig the pilot ladder was often the case. I did not worry about re-rigging, but I was afraid that in the rush of operation, the recheck would be neglected. Captain B hoped that the facility would be approved and applied on board as soon as possible, so that complex operations such as preparing the accommodation ladder, pilot ladder and combination arrangements with long hours could be avoided. Captain C, who works on the VLOC (Very Large Ore Carrier), says that his vessel has a freeboard height of over 12 meters in ballast and the pilot ladder is so bulky that some crew members have twisted their backs and feet when moving it, and someone have had accidents where the crew have fallen overboard while rigging the ladder. The process of rigging for the combination arrangement usually takes four crew members nearly 40 minutes to complete and assembling the combination ladder is an awful experience. Bosun XXX said that the PBL seemed to be a simple device, not only saving physical energy but also easy to maintain. The pilot ladder is a complicated thing for me, firstly, the internal condition of the side ropes is not easy to check, secondly, to replace any of the steps, to replace any of the side ropes would require dismantle the whole ladder and there would be no guarantee that the step space of the ladder would be correct, I hate repairing pilot ladders. ISO (2019) required that the pilot ladder should not include more than two replacement steps and if the third replacement step is required, the ladder should be rebuilt according to the original manufacturer's standard. In the author's opinion, it is difficult to ensure that the reconstruction of the pilot ladder is carried out exactly to the manufacturer's standards due to the craftsmanship of the seafarers. At the same time, it is a requirement that the person carrying out the ladder load test must be able to issue a certificate, and the crew do not have such a qualification. As a result, the safety of the reconstruction of the pilot ladder by seafarers cannot be guaranteed. 3.2% of seafarers felt that the design was not safe in bad weather. They considered that the PBL could shake when the ship was rolling. In fact, the author has taken this situation into account by providing two preventer ropes, as shown in **Figure 19**, 17.9% of seafarers have no idea. They considered the current pilot transfer arrangements to be acceptable, but are not opposed to the PBL either.

Of the five responses from shipowners, two found the design acceptable, one thought it could not replace a pilot ladder and two thought it needed to be approved. Manager XXX, from XXX shipping company, said that if the device could be approved by the authorities, the company would consider installing it on board as it seemed more practical than a pilot ladder. Mr. XXX, manager of a XXX shipping company, said that the device would facilitate the use of a pneumatic winch as a driving force and was a good idea as the compressed air piping system was already arranged on deck and installing the device would be an easy job.

The design of the ladders was considered by 25% of the classification society surveyors to be an obvious reference to the current construction and operation of gangway and accommodation ladders and that the design was reasonable and acceptable without damaging the deck and hull structure of the ship. 8.3% of surveyors considered that there was a lack of authoritative approval, particularly from IMO and IMCS, and that safety was unpredictable in the absence of verification. Furthermore, the IMO specifically states that "no mechanical pilot lift" is permitted. 66.7% of the surveyors recommended that the authors speed up the design to physical implementation and apply for a patent. Mr. XXX of the Beijing branch of the China Classification Society said that it takes a long time for a new device to go from design to application, involving industry standards and empirical data.

There are 27 PSC officers from China MSA, 12 PSC officers accepted this design concept (57.1%). 1 stated that the PBL is unacceptable because of there was no precedent (4.8%), and it had not been discussed. 8 were unsure whether the design complied with the technical standard (38.1%).

In terms of respondents' opinions, 164 respondents were in favor of the design (74.2%), 9 were against it (4.1%) and 48 were unsure (21.7%). Maritime pilot Li (2021) said that the failure of the pilot's ladder not to be well against the ship's hull is the most significant deficiency, as it not only consumes a lot of energy and time, but also significantly increases the number of pilot falls.

4.2 Individual question part

Targeted questions are developed based on the industry background of the participants in order to improve study efficiency.

4.2.1 Questionnaire for Seafarers

04 Have you ever been complained about by the pilot due to rigging of the pilot ladder rigging, if so, please specify the reason?

a) Yes   Reason: ________________________

b) No

05 Have you ever been involved in the pilot transfer accident or near miss?

a) Yes

b) No

Figure 20

Complaint on Non-compliance of PTA

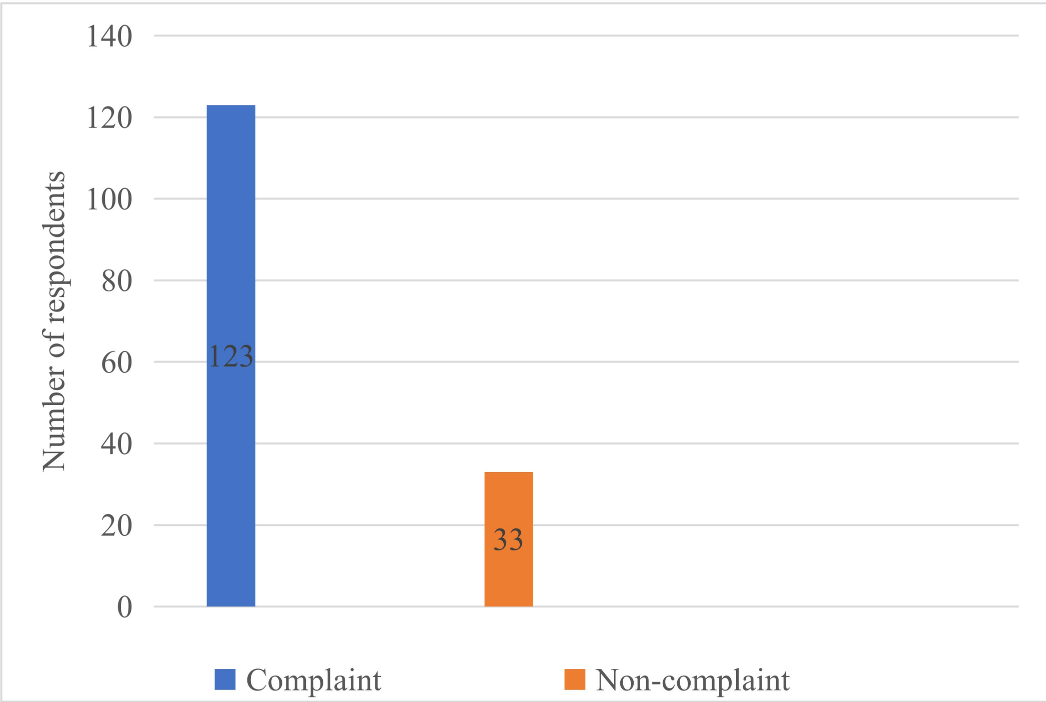


Figure 20 shows that there were one hundred and twenty-three crewmembers who were complained about for non-compliance of pilot rigging (78.8%), thirty-three crewmembers were not complained about. More than seventy-eight percent of the crew were complained (21.2%). Although the figures do not reflect the frequency of complaints (e.g., number of complaints per hundred) as these investigations may cover a long period of time, they do also reflect the fact that crew members are complained about unsafe pilot ladders. In the author's opinion, unsafe pilot ladders not only affect the safety of the pilot, but also cause complaints, which can also

affect the pilot's mood, and this has a negative impact on the safety of the ship's pilotage.

Figure 21

Non-compliance complained by pilots

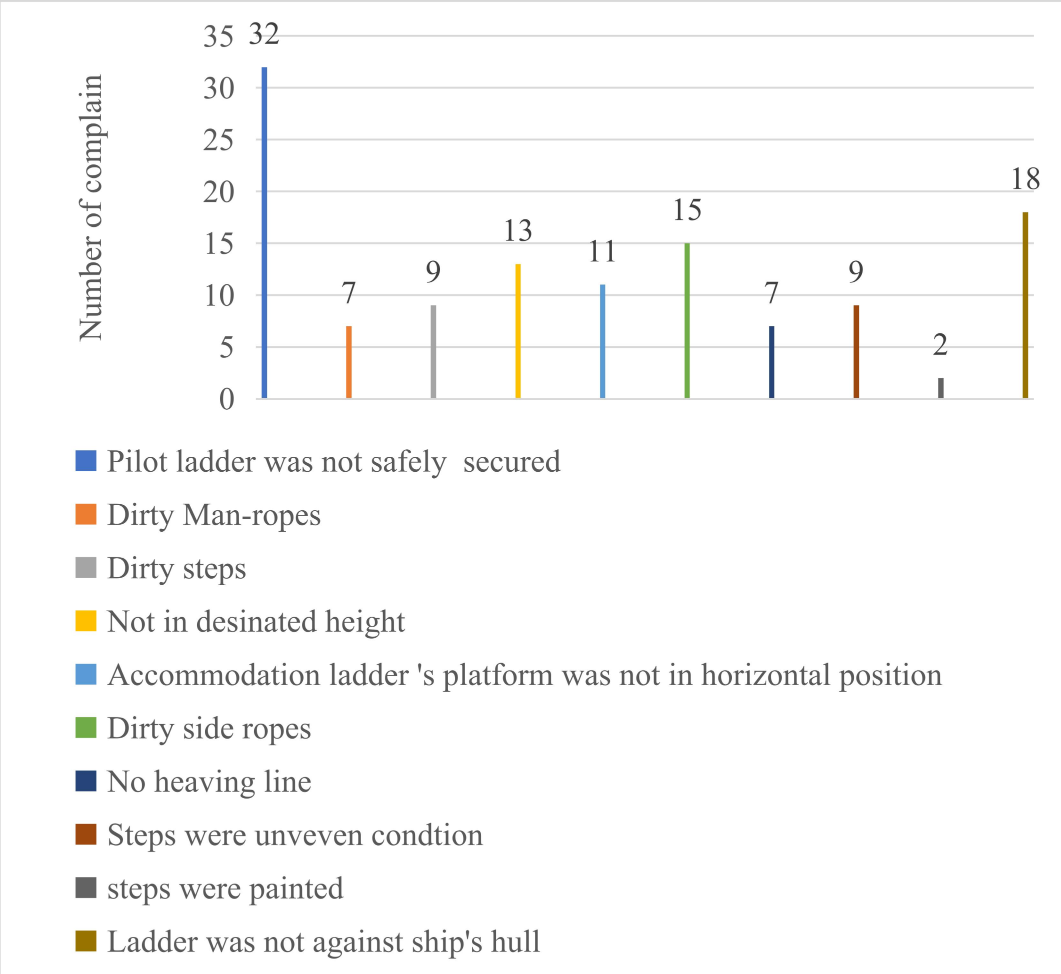


Figure 21 shows the non-compliances of the pilot ladder that were complained about by pilots. According to the feedback from the 123 respondents, the non-compliances items that were complained about are as indicated:

- Pilot ladder not well secured, 32cases, 26%.
- Dirty man-ropes,7 cases, 5.7%.
- Dirty steps, 9 cases, 7.3%.
- Not in designated height, 13 cases, 10.6%.
- Accommodation ladder's platform was not in horizontal position, 11 cases, 8.9%.
- Dirty side ropes, 15 cases, 12.2%.
- No heaving line, 7 cases, 5.7%.
- Steps were uneven condition, 9 cases, 7.3%.
- Steps were painted, 2 cases, 1.6%.
- Ladder was not against the ship's hull,18 cases, 14.6%.

Seafarers are the primary guardians of the pilot safety, because they are the operators and maintainers of the PTA. In fact, these feedbacks reflect the current situation of the PTA. From the moment the pilot boards the ship, his safety depends entirely on whether the ladder is properly installed, properly tested, and well maintained. Enhance ship management and improve the pilot transfer arrangements are the way to ensure pilot transfer safety.

4.2.2 Questionnaire for Shipowners

06 How long time does your company renew the pilot ladder?

a) 1-3years

b) 3-5years

c) Other comments

07 Do you know the requirements for pilot ladder load test?

a) Yes

b) No

Five shipowners responded as follow:

- Five owners stated that the renew of the pilot ladder depends on its condition.
- Two of them did not know how often pilot ladder load test need to be performed.

Pilot ladders over 30 months old must have a certificate of strength testing (ISO, 2019).

4.2.3 Questionnaire for Classification Society surveyors

08 What were the most common deficiencies in the pilot transfer arrangements when you carried out the ship's annual survey?

a) Poor maintenance
b) Non-compliance with the repair of PTA
c) Pilot ladder certificate expired
d) Did not carry out Pilot ladder load test

Table 7

Non-compliance in annual survey

Classification Society	DNV	IRS	CCS	ABS
Number	3	2	5	2
Non-compliance items	a. Poor maintenance b. Non-compliance with the repair of PTA, such as the use of non-required spare parts (ropes, steps, spreader steps), unequal space between the steps			

c. Pilot ladder certificate expired
d. Did not carry out Pilot ladder load test

There were 12 surveyors from classification societies, three from DNV (Guangzhou), two from IRS (Qingdao), five from CCS (Beijing) and two from ABS (Shanghai). The main findings of the pilot ladder which provided by surveyors were poor maintenance, failure to use required materials for repairs, expiration of certificates and failure to comply with the requirement to carry out load test.

4.2.4 Questionnaire for PSC officers

09 Of the inspections you have had done, what are the most common deficiencies in pilot transfer arrangements?
10 Based on your inspection experience, if the pilot transfer agreements are not in compliance, what code is issued to the ship?

Twenty-one officers responded that the PTA is an important item to inspect, because it is very related to the pilot safety, if the deficiencies are found the ship will be ordered to take rectify measures, otherwise the ship will not be allowed to leave the port which means detention. Officer He, who was from Guangxi MSA, said that the broken strands and severe wear on the side ropes, old and dirty steps, poor maintenance of the pilot ladder are the most common deficiencies when he conducts inspection on board.

4.2.5 Questionnaire for pilots

11 What is the prime means for embarking the vessel?

a) Pilot ladder

b) Combination arrangement

c) Helicopter

12 Have you ever been involved in the pilot transfer accident or near miss?

a) Yes

b) No

13 What caused the transfer accident or near miss?

Figure 22

Number of pilot and pilot certificate level

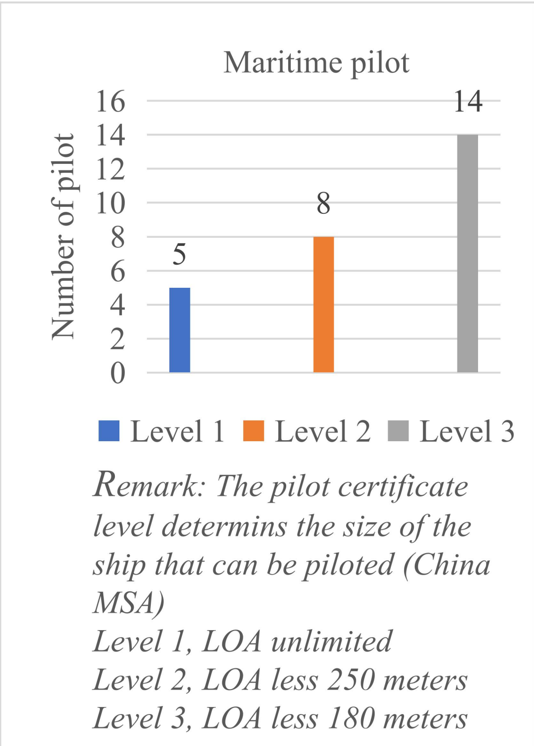
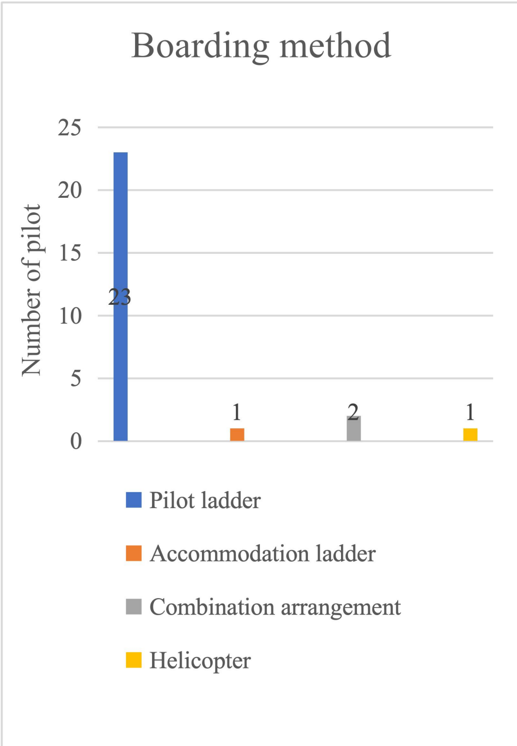


Figure 23

Pilot boarding methods



Regarding the safety of the pilot ladder, as the first users, pilots are best qualified to talk about it. Twenty-seven pilots responded, five held Level 1 certificates, eight held Level 2 certificates, and thirteen held Level 3 certificates. Twenty-three pilots said that the pilot ladder is the primary boarding method, one said the accommodation ladder is his boarding method in the inner river, two said they are responsible for VLCC pilotage the combination arrangement is the primary boarding method, one said he used to land the ship via helicopter.

Figure 24

Transfer accidents and near misses

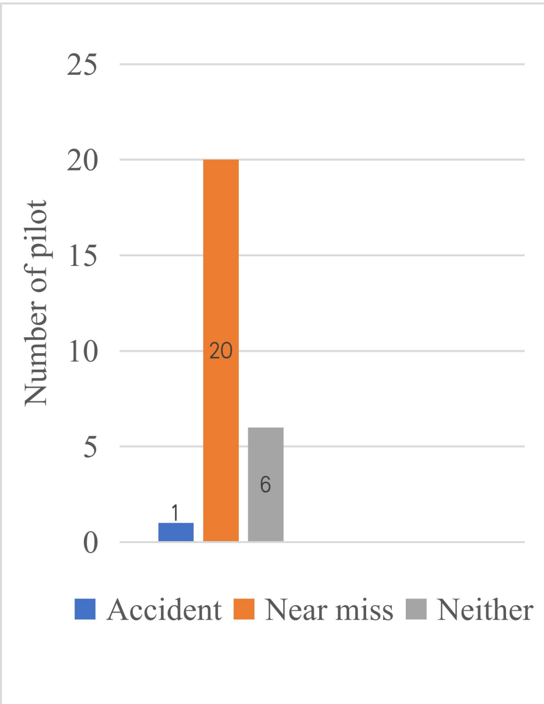


Figure 25

Causes of accidents and near misses

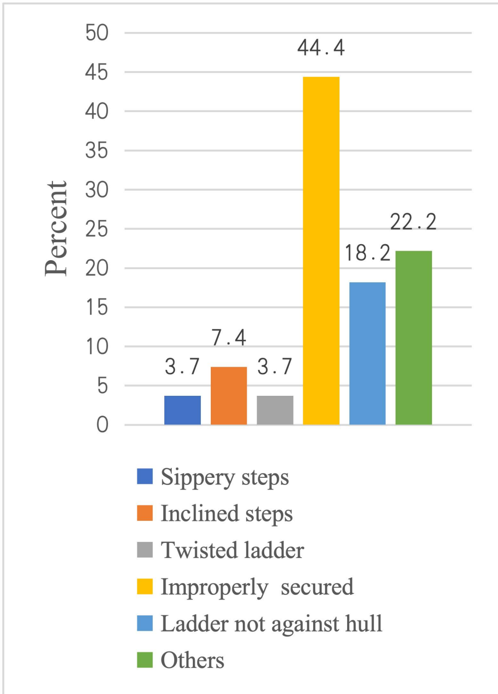


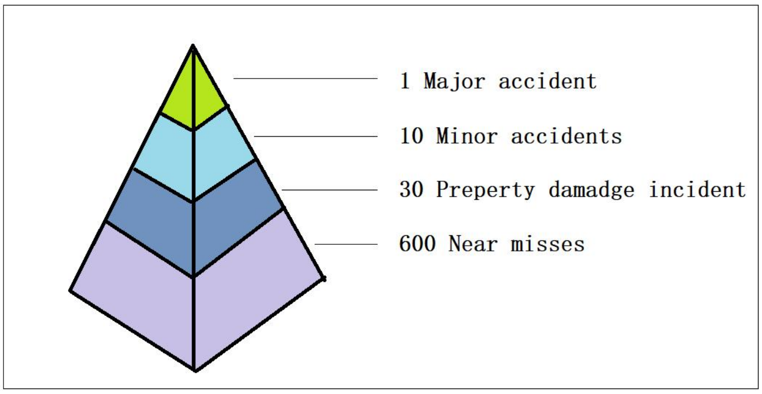
Figure 24 shows one pilot were involved transfer accidents (3.7%), twenty were involved near miss (74.1%), and five were involved neither (22.2%). **Figure 25**

shows the causes of the accidents and near misses, the results well matched the IMPA safety campaign-2022.

According to Heinrich accident triangle theory, the relationship between accidents and near misses is shown in **Figure 26**.

Figure 26

H. W. Heinrich's accident ratio



Note. Adopted from Risk Management and Accident Investigation (p. 21). Schröder-Hinrichs, 2023, (https://academics.wmu.se/course/view.php?id=820). Copyright 2023 by WMU.

Based on the data of the questionnaire:

a) Number of Property damage incident = 20 Near misses $\frac{30\,Near\,misses}{600\,Near\,misses} \times 20\,Near\,misses = 1\,Property\,damage\,incident$

b) Number of Minor accidents $= \frac{10\,Minor\ accidents}{600\,Near\ misses} \times 20\,Near\ misses = \frac{1}{3}\ Minor\ incident$

c) Number of Major accidents $= \frac{1\,Major\ accident}{600\,Near\ misses} \times 20\,Near\ misses = \frac{1}{30} Major\ accidents$

The ration of accident to near miss is $\frac{1Major\ accident+20\,Minor\ accidents}{600\,Near\ miss} = \frac{21}{600} \cong \frac{1}{30}$, while the accident ratio in the questionnaire result is $\frac{1}{20}$. The results show that pilot transfer is a high-risk operation, while pilot transfer accidents are strongly related to PTA.

4.3 Test PBL in scenarios of wind and list

When using PBLs at sea, the effects of the wind received by the ship and the ship's list scenario should be taken into account.

4.3.1 Calculating the effects of wind on the basket

For the calculation of the effect of wind on the basket, the author has used the wind load calculation formula as follows:

F=A×P×Cd

F: Wind force on the basket

A: Area under force (Unit: m^2)

P: Wind pressure (Unit: Newton/ m^2)

Cd: Coefficient of resistance

A=L×B=750mm×750mm=0.5625m^2 (a. The wind direction may be from forward, afterword and beam.

b. The wind could pass through the basket due to its structure.

c. A= 0.5625m² is an estimated figure.)

$P=0.613\times V^2$ (Unit: V-m/s)

Cd= 2.0 (Standard factor of 2.0 or 1.4 for flat surfaces, take the maximum value 2.0 here)

The wind speed refers to the Beaufort wind force scale **Table 8.**

Table 8

Beaufort wind and sea force scale

Beaufort wind scale	Wind speed (Meter/second)	Sea state	Wave height (Meter)
0	<1	0	-
1	1-2	1	0.1
2	2-3	2	0.2-0.3
3	4-5	3	0.6-1.0
4	6-8	3-4	1.0-1.5
5	9-11	4	2.0-2.5
6	11-14	5	3.0-4.0
7	14-17	5-6	4.0-5.5
8	17-21	6	5.5-7.5
9	21-24	6-7	7.0-10.0
10	25-28	7	9.0-12.5
11	29-32	8	11.5-16.0

Beaufort wind scale	Wind speed (Meter/second)	Sea state	Wave height (Meter)
12	33+	9	14.5+

Note. Adapted from *Beaufort wind force scale,* n.d., (https://www.metoffice.gov.uk/weather/guides/coast-and-sea/beaufort-scale). Copyright by Crown

The forces on the lift basket (one pilot inside) at each wind scale (1-12) are shown in **Figure 27**.

Figure 27

Force on lift basket

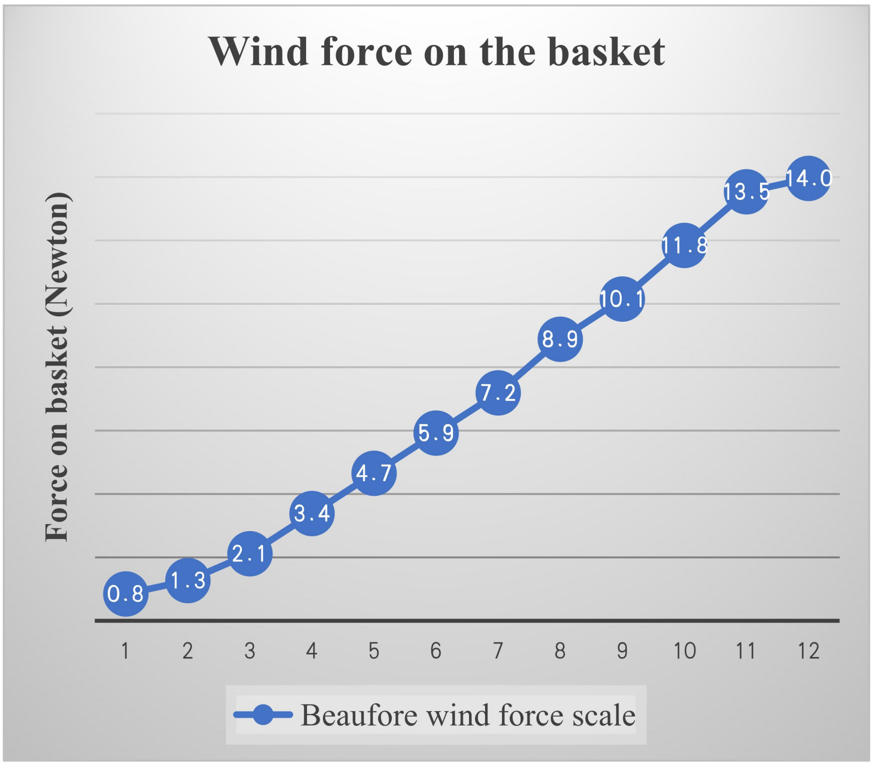
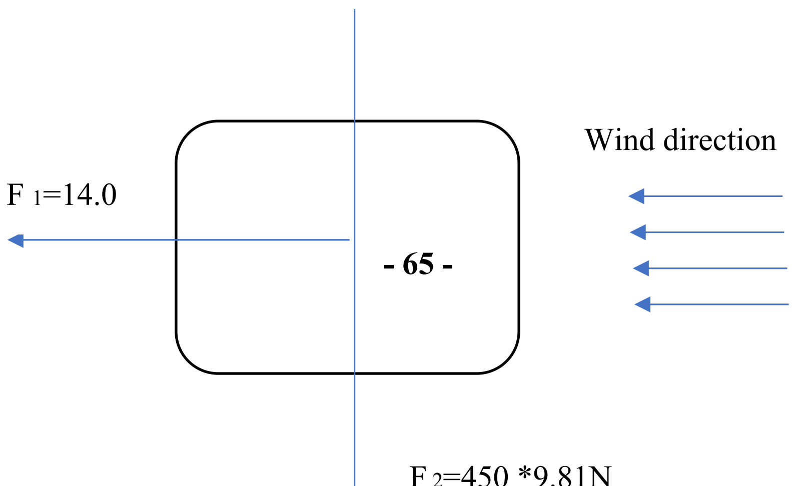


Figure 27 shows the effect of wind (from force one to force twelve) on the basket, ranging from 0.8 Newtons to 14 Newtons. While one magnet provides 4415.5 Newtons (450kg*9.81N/kg) of holding force (**Figure 28**), this is obviously more than 14.0 Newtons. This means that the basket will not roll and twist under this situation.

Figure 28

Mechanical analysis (wind)



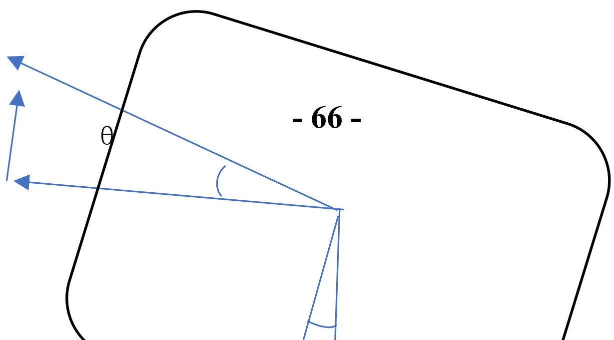
4.3.2 Calculating the effects of ship listing on the basket

To determine whether the lift basket will not be able to be against the ship's hull due to the ship's listing, a force analysis is required (**Figure 29**). For calculation, the angle of heel is assumed as θ and total weight of basket and pilot is 200kgs. Angle θ is the angle of heel in degrees at which the righting lever curve reaches its maximum (IMO,1993).

Regarding the effect of Angle θ on the use of the pilot ladder, IACS (2012) suggested the single length of pilot ladder is capable of reaching the water from the point of access to, or egress from, the ship and due allowance is made for all conditions of loading and trim of the ship, and for an adverse list of 15 degrees. Actually, even Angle θ is greater than 15 degrees, the PBL would not be affected.

Figure 29

Mechanical analysis (List)



$$450 \times \tan\theta > 200 \times \tan\theta$$

The mechanical calculations show that, whatever the angle of inclination θ, the force provided by the magnet is always greater than the lateral force generated by the basket due to the inclination of the ship, and the basket will not move away from the hull, but be well against it. In fact, the captain always tries to keep the ship in no list or even keel condition before arriving at the pilot station.

4.4 Comparison between PTA and PBL

In order to explain the design feasibility of PBL, a comparison (**Table 9)** was made between the PTA and PBL in terms of structure, specification, operation, boarding, requirements and risk. The results show that:

- The PBL is simpler than PTA in structure.
- The PBL dimension standard is not available.

- The design of PBL is using metallic and rubber material, while the PTA is using metallic, wooden, alloy, rubber, fiber, plastic. There are more material standards involved in PTA than in PBL.
- There are fewer seafarers needed for operating PBL than PTA.
- Embarking or disembarking by PTA requires climbing. Climbing requires physical energy and climbing skills, whereas PBL does not require climbing and is not physically demanding.
- The PBL requires an annual inspection to ensure the reliability of the equipment. The accommodation ladder requires inspection every five years and the pilot ladder requires a load test every 30 months. The inspection intervals for the PTA are too long, which is not conducive to confirming the safety of the equipment.
- There is a potential risk of slips and falls when using the PTA, which can be demonstrated by pilot transfer accidents. When using the PBL for embarkation and disembarkation, the risk of slipping and falling overboard is eliminated as soon as the pilot enters the basket, as there is no rope breakage, tread breakage, failure to hold on to the side ropes, unsteady footing, etc.

Table 9

Comparison between PTA and PBL

Items	PTA	PBL	Result

Structure	1. Pilot ladder: Wooden step, rubber step, side ropes, fixing pieces, spreader, fastening hardware, magnet, heaving line; 2. Combination arrangement: Motor, winch, davit, accommodation ladder, safety net	Motor, Winch, Davit, Basket, magnet	The structure of PBL is simpler than that of PTA
Specification	1. Material: Wooden, alloy, rubber, fibric, steel; 2. Size: ISO 5488,7364,799	Material: Rubber, Steel; Size: Specified in 3.2	PTA has more standards than PBL
Operation	Manual, requires more than 3 crew. The height of the ladder above the water is adjusted manually.	Mechanical, requires 2 crew. Height is adjusted mechanically.	PBL is easier to repare than PTA. educe the perational risk of TA
Boarding	Physical climbing	Automatic lift	PBL is more labor-saving
Requirement	Pilot ladder (Freeboard ≤ 9 meters); Combination arrangement ((Freeboard ≤ 9 meters); Ladder is limited to 45 °; 30mths load test; Five-year survey	Annual survey	PBL is no freeboard and angle limitation.
Risk	Slip, fall and overboard accidents due to the limitations summarized in 2.5.	No limitations summarized in 2.5	PBL is safer than PTA

Chapter 5 Discussion

5.1 Findings on the PTA

The pilot transfer accident was caused by the structural limitations of the PTA and human factors. As a multi-component boarding device, the failure of any component is a potential risk of accident. Not only is its use influenced by the marine environment, but its proper installation by the crew is directly related to the safety of the user, and it also requires the physical strength and climbing skills of the boarder.

5.2 Significance of Designing PBL

The technical background for the design of the PBL is based primarily on ISO 799 Ships and marine technology-Pilot ladders, ISO 5488 Ships and marine technology-Accommodation ladders, and ISO 14798 Lifts(elevators), escalators and moving walks-Risk assessment and reduction methodology. Both the mechanical parts, the choice of materials, the layout and installation, the use and operation and the maintenance/inspection comply with these international standards as far as possible.

The PBL is a mechanical and labor-saving device. It transfers personnel up and down without the physical effort of a pilot climbing a ladder to embark on and disembark the vessel. It also eliminates the risk of personnel falling overboard once they are in the basket. While it is an easy device for the seafarer to launch and recover. This

convenient facility will improve the safety of seafarers involved in pilot ladder rigging.
This is because it no longer requires the seafarer to manually pull in and out of the pilot ladder, nor do they have to climb up and down to secure and check the pilot ladder.

A risk assessment has been carried out on the design of the PBL and the risks can be reduced through the use of effective safety measures.

5.3 Advantages of PBL

As a new way of boarding, the pilot boarding lift is relatively simple in construction and the power unit is a reference to the pneumatic motor and winch used in the gangway, with mature technology and good stability.

In this design, metallic material has been used instead of fiber ropes, wooden steps and spreader steps, which have a relatively low safe working load. A railing on the lift basket provides a reliable support point for the pilot's hands to steady his body. The movable boarding platform has a range of 30 degrees below and 180 degrees above the horizontal.

The preventer wire and magnet are used in this design. These two components are used in combination, with the top end of the preventer wire secured to the davit and the bottom end secured to a magnet fixed to the ship's hull.

Based on the force analysis of the lift basket in the wind and the force analysis of the ship in list condition, it was found that the combination of preventer wire and magnet could effectively stabilize the up and down movement of the lift basket. The PBL accessory includes adequate lighting, lifebuoys are located near the pilot access and the pilot access is marked “No obstruction”.

5.4 The limitations of PBL

Although theoretically feasible, it has not been physically proven, particularly when it comes to being used in the complex environment of the sea. It will also require the adoption of regulations and standards for PTA by organizations such as IMO, ISO and others, which will be a lengthy process.

Chapter 6 Conclusion

Despite the fact that the IMO and ISO are constantly updating their ladder regulations and standards, the current boarding arrangements, whether pilot ladders or combination arrangements are complex in design, inefficient in boarding methods and inconvenient to install, these limitations can be seen in the statistical analysis of pilot transfer accidents and seafarer accidents during PTA rigging. The constant updating of pilot transfer requirements and standards by international organizations has not significantly reduced the accidents in terms of accident analysis. Mechanical analysis of using the PBL in wind and ship listing scenarios showed that it had worked properly in this environment. Feedback from respondents indicated that more people accepted PBL as an option for boarding ships than those who were unacceptable and unsure. The risk assessment on PBL has shown that the design is feasible. Compared with PTA, PBL is simpler in structure, easier to operate and safer for personnel transfers, but only in theory, the application onboard has not been verified.

More attention should be paid to the pilot transfers, and if upgrading existing facilities is not effective in improving transfer safety, it is time to change the approach. Herman (2023) said now is the time for a new "PTA as a system" approach rather than an upgrade of existing pilot ladders. Efforts by the maritime industry should aim to use modern design and manufacturing techniques to improve the safety of maritime pilots. Current PTA regulations, guidelines, procedures and standards are an obstacle to innovation in this area.

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Appendix A

Pilot Ladder Poster. Required boarding arrangements for pilot.

https://www.impahq.org/impa-policies-publications/pilot-ladder-poster