The Risk Assessment Safety of a Multipurpose Small Port

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Abstract

Activities at the port can be an environment that is potentially prone to accidents. Various studies have been conducted to reduce risks and discuss safety factors in large ports but little for small ports, especially in determining the analysis method. This paper aims to discuss various risk analysis methods that may be used in analyzing small port areas that are considered dangerous in port areas: (1) Formal Safety Assessment (FSA), (2) Risk-Based Decision-Making Guidelines (RPDM), (3) Frequency, probability, event tree (4) Quantitative risk assessment (QRA), and (5) Risk index and ranking. The literature method used is a literature study on a risk assessment which is then adjusted to the port characteristics. The results concluded that the FSA is a method that can still be used with adjustments in several ways, especially related to accident characteristics. Furthermore, we are developing the use of FSA with As Low As Sufficient and Practical (ALARP) based innovations, especially in small ports.

Keywords
Risk Assessment, Safety, Small Port and Sea Transportation

1. Introduction

The port is one of the infrastructures in the marine transportation mode which plays an important role in supporting the smooth operation of sea and land transportation activities which are organized for the benefit of the public service. There have been many studies that have shown how important the role of port infrastructure is in economic growth and trade, job creation, and attracting investment (Putra et al. 2018). furthermore, To further spur service performance improvements, especially related to safety, the Indonesia government has concerning sea transportation service standards, which emphasize more on the aspects of safety, order, regularity, comfort, convenience, and equality. A port is a vital means of economic development in a region and a source of state revenue, so a port that operates properly is needed so that the economy runs smoothly. In the eastern part of Indonesia, people with their economic activities rely heavily on the marine transportation sector, especially in Papua-Maluku Islands.

1.1. Objektives

The government has encouraged the development of ship infrastructure in Indonesia to be in line with the country's main infrastructure projects. As a result, sea transportation activities have increased, but this has increased incidents and accidents. Accidents issued by Komite Nasional Keselamatan Transportasi (KNKT) in 2019, the number of accidents at sea has increased every year. From 2011 to 2018 there were 125 accidents (Figure 1), with the most accidents occurring around 43. During that time, 673 victims died or disappeared and 418 injured victims. The results of research on the characteristics of ship accidents in Indonesia for the 2007-2014 period stated that 47.44% of ship accidents were 'collisions' that occurred at the port. This opinion is generally due to the actions of ship operators, ship owners, classification bureaus, and representatives from the government for administration and port authorities that have not complied with the applicable regulations. load passengers or goods (Hasugian et al. 2018) .

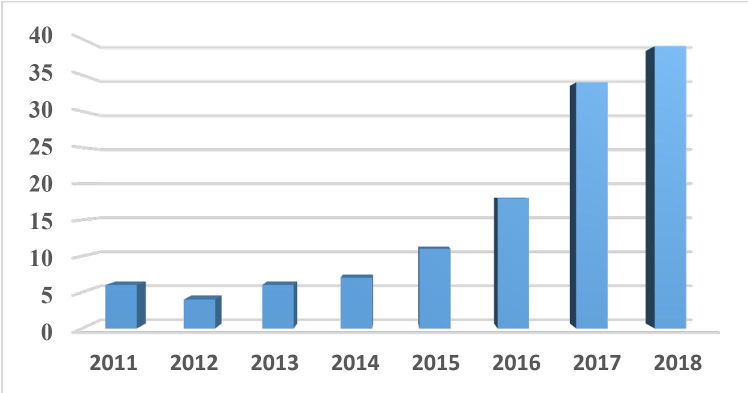

Figure 1 Chart of Ship Accidents by KNKT 2011-2018

Figure 1 Ship Accidents by KNKT 2011-2018, stated that 47.44% of ship accidents were 'collisions' that occurred at the port

2. Literature Review

Research Port safety, Risk analysis is the key to researching Port safety (Trbojevic & Carr 2000). Much debate remains around risk analysis in terms of validity, practicality, methodology and other areas. Research can be broadly divided into qualitative ,and quantitative risk assessments, although some studies use a combination, or use a mix of qualitative-quantitative or semi-quantitative. Regarding quantitative methods, it is used when the phenomenon of interest is relatively rare, so expert judgment and experimental support are essential, even though the results may be subjective. Qualitative methods can be used as an initial method of exploration, and then fully more complex quantitative investigations can be used on a larger scale. Many studies have been conducted to reduce risks and discuss safety factors at ports, especially in determining accident factors and analysis methods. Several risk analysis methods are used in analyzing specific port areas that are considered risky. This paper aims to discuss various risk analysis methods used in analyzing port areas, i.e *(1) Formal Safety Assessment (FSA), (2) Risk-Based Decision-Making Guidelines (RPDM), (3) Frequency, probability, event tree (4) Quantitative risk assessment (QRA), and (5) Risk index and ranking*. Therefore, it is necessary to research to reduce risks and discuss safety factors in eastern Indonesian ports, especially in determining risk assessments. Ports in Eastern Indonesia are multipurpose small ports. Determining the appropriate risk analysis method can mitigate various types of accident risks at ports, so that the role of ports can be more efficient and effective in supporting programs to accelerate economic development in Eastern Indonesia (KTI=Kawasan Timur Indonesia). This research aims to recommend an appropriate risk assessment method for the port system in multipurpose small ports.

3. Methods

Multipurpose small Port is defined as a small area of infrastructure, limited infrastructure area, difficult to develop due to limited area, with wharf length <400 m, equipment to serve various types of ships and cargo flexibly and provide optimum usability. The multipurpose small port is serving the transportation of people and goods in one terminal, accommodate heterogeneous loads from a general cargo of loose cargo which is limited in number to containers. Various loads are combined, not necessarily in large quantities as in special container terminals. The port provides an effective cargo handling facility for a considerable period of time. To be able to handle all types of loads effectively and efficiently, the terminal requires a wider variety of mechanical equipment than conventional break bulk terminals, but lower than the normal requirements for container-specific terminals. This terminal also requires a different layout (layout) and modern management.

The approach used in literature research. Analysis of the suitability of risk assessment technique variables and port characteristics. The port under study is a port with a tendency to carry out loading and unloading activities or multipurpose activities in KTI. Therefore, accident investigation is very important, and currently, several public institutions aim to analyse and record accident information. These can be national or international bodies. in Indonesia, there is Komisi Nasional Keselamatan Transportasi (KNKT).

4. Port Characteristics in Eastern Indonesia

In Rencana Pembangunan Jangka Menengah Nasional (RPJMN) 2015-2019, the areas included in the Eastern Indonesian Region are the islands of Kalimantan, Sulawesi, Maluku, Nusa Tenggara and Papua. Port selection is based on Wilayah Pengembangan Strategis (WPS) which are new growth centres in KTI, namely NTT, North Maluku, Maluku, Central Sulawesi.
In general, the specific characteristics of ports in eastern Indonesia are:

- Deficient of documentation of accidents
- Multipurpose small port is a port whose terminal can serve various kinds of ships and cargo to anticipate various kinds of commodity traffic being unloaded at the port.
- Port of passengers and goods
- Has loading and unloading equipment in the port space which is a limited area, because from the beginning it was a public port that was not designed for a large port.
- Port functions other than loading and unloading activities can also be used for another functions

5. Result and Discussion

The seaports with safe and reliable operations are of great significance for the protection of human life and health, the environment, and the economy, therefor Any inappropriate operation could lead to a profound negative impact on service quality, productivity cost, and lifestyle, (Wang et al. 2017) Furthermore, the effect of accidents and/or disasters that jeopardize terminal operations can be reduced/eliminated if a robust risk forecasting mechanism.(Alyami et al. 2019). The hazardous events related to port operations can be classified as follows : Carrier accidents at sea in the vicinity of ports (Altan 2019), (Debnath & Chin 2016), (S. A.M. Youssef et al. 2014), Accidents during berthing at port, and Accidents during a ship-to-shore transfer of people or goods (Vidmar & Perkovič 2015), Accidents at cargo sheds (Nævestad et al. 2019), Accidents during lifting and transportation of hazardous cargo from port premises to outside area of port (Chen et al. 2018)

5.1. Formal Safety Assessment (FSA).

International Maritime Organization (IMO) defines FSA as a "way of ensuring that action is taken before a disaster occurs, and a systematic process for assessing the risks associated with shipping activity and for evaluating the costs, and benefits for reducing these risks" (IMO, 2002).

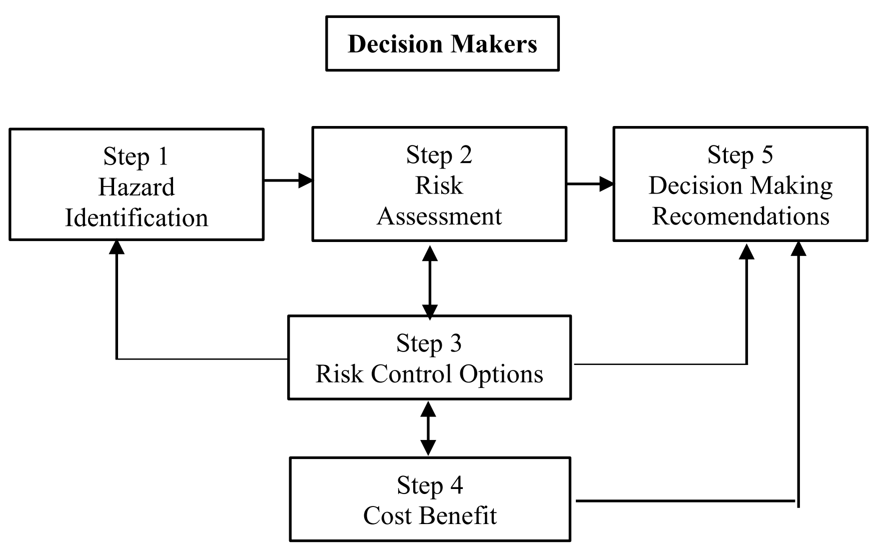

Figure 2. FSA – a risk approach (IMO, 2000)

Figure 2, FSA – a risk approach, International Maritime Organization (IMO) defines FSA as a “way of ensuring that action is taken before a disaster occurs.

FSA can be used as a tool to help evaluate new regulations or to compare proposed changes with existing standards. It enables to draw a balance between various technical and operational issues, including the human element and between safety and costs. FSA consists of five steps (Figure 2) (Marine Safety 2008) :

- Identification of hazards, i.e. preparing a list of all relevant accident scenarios ;
- Assessment of risks, i.e. evaluation of risk factors;
- Risk control options, i.e. devising measures to control and reduce the identified risks;
- Cost-benefit assessment, i.e. determining cost-effectiveness of each risk control option; and
- Recommendations for decision-making, i.e. defining a decision strategy based on the results obtained in the previous steps.

The basic goal of FSA is to facilitate a transparent decision-making process. In addition, FSA provides a means of being proactive, enabling the interested parties to consider potential hazards before a serious accident occurs, approach to one that is proactive, integrated, and above all based on risk evaluation and management in a transparent and justifiable manner, thereby encouraging greater compliance with the maritime regulatory framework (Montewka et al. 2014). The weakness/drawback of the IMO method is that it does not clearly show the criteria of the limits used for each consequence (life, environment, and property), and also does not explain the method in determining the criteria and limits/criteria whether the consequences are biased or not.

This method refers to past accidents to predict the likelihood of future unwanted events. This type of analysis is primarily a qualitative analysis, but it is possible to draw quantitative conclusions if many accident records are available (J. Zhang et al. 2016). In some cases, certain trends can be inferred from the data set, with respect to the many variables and aspects involved in accidents, i.e. Causes of accidents, the parties involved, Number of parties involved, activities carried out at the time of the accident, Type of accident (fire, explosion, gas, etc.), Consequences of accidents (casualties, injuries, refugees, economic losses, environmental damage).

5.2. The Risk-based Decision-making Guidelines (RBDM).

This method was implemented by The United States Coast Guard (USCG) to show great interest in risk analysis and accident risk prevention techniques, and has developed several solutions and tools for risk analysis and marine accident management in general, with an occasional focus on port accidents. This manual consists of 3 volumes (*A Navigating Navigator Onboars or a Monitoring Operator Ashore*, n.d.) i.e. Risk-Based Decision Making Navigator, Introduction to Risk-Based Decision Making, and Procedures for Assessing Risk. RBDM can be specialized by the public and private sectors for navigation safety, traffic efficiency, and environmental protection. If these resources are spent in a limited manner on low-risk issues at the expense of high-risk issues, then the shipping industry will face a higher risk of being unsustainable due to imbalances in resource distribution. Implementing RBDM can improve this situation. Risk-based decision-making provides a powerful tool that can help ensure that limited public and private resources are allocated more effectively to reduce risks, maximize marine safety and environmental protection and increase traffic efficiency

The RBDM Guidelines approach is one that offers Marine Safety Offices (MSOs) a complete, reliable and easy-to-use toolbox so that they can carry out their own projects in the areas of risk assessment, management, and evaluation. As noted above, the definition of risk on which this Guide is based is relatively broad and involves not only dangerous cargo but also unforeseen events that cause harm to people, installations, and the environment (Lounis & McAllister 2016). Some of the techniques presented in the RBDM Guidelines, because of their high logical formalization and intrinsic need to be implemented in well-defined systems (as an industrial process), cannot be adapted to complex (and obscure) environments such as ports to be considered as a whole.

5.3. Frequencies, Probabilities, Event Trees

Probability is a dimensionless number between 0, and 1. Within the framework of both probabilistic risk assessment and quantitative risk assessment is often necessary to establish the likelihood that certain events occur, not others, and the frequency with which certain events occur over time. For example frequency collision ship and port. The frequency is expressed by 1 event/duration unit, usually year. Thus, the frequency of occurrence of collision can be once in ten years). Probabilities is the probability that an event after it has occurred, whereas Frequencies is the expected rate of occurrence of an event produces a certain result. The probability and frequency data are mainly used in the QRA analysis framework, to assign a frequency for each accident scenario identified. The scenario frequency is then multiplied by the consequences (Konovessis & Vassalos 2008).

The above calculation scheme requires a variety of probability data, which often arise from mere expert judgment, but sometimes are estimated based on historical analysis. In addition, it involves a structured form of forecasting how an event is developing, which is called an event trees. This method the need to determine the frequency of the initiating event. with general, this is discovered through one of three methods: historical analysis, expert judgment or fault tree analysis (FTA)(Lestari et al. 2017). The frequency with which this item fails is the most basic element of an FTA (Toz et al. 2018). They are available in specialized databases for a wide variety of items and devices. They are always counted after observing a large number of such devices over a very long working time. Some authors have tried to use fault trees to describe events that are not defined by a rigid set of conditions, such as, Trees and fault trees (Kum & Sahin 2015).

5.4. Quantitative Risk Assessment (QRA).

QRA aims at estimating the risk entailed by a system, in terms of human loss or, economic loss, results are presented forms curves (f) frequency-(N) Number of victims caused by a number of accident scenarios. f-N curves are always decreasing and often used to test the system analysed in terms of acceptable risk against some criteria defined in regulations and guidelines. Acceptability criteria are sometimes represented by way of straight, decreasing lines (Samy Adly Mansour Youssef & Paik 2018). As mentioned before, QRA builds on a number of other methods, including historical analysis as a tool for hazard identification, as well as fault and event trees. Moreover, quantitative risk analysis makes use of accident consequence calculation and vulnerability theory in order to fully define individual risk. The combination of all these tools into a single methodology makes QRA a very comprehensive instrument. The combination of all these tools into a single methodology makes QRA a very comprehensive instrument. For the same reason, QRA is more demanding than other risk assessment techniques, in terms of time to the risk analyst (Steijn et al. 2017) . QRA sometimes poses the problem of finding the number of non-fatal victims. The standard way to solve the problem is to apply vulnerability analysis. Vulnerability equations are empirical relations that link the effects of accidents with the probability that a certain receptor suffers a certain consequence, via a probit function. The receptor can be a human individual or an object, like a structure or some piece of equipment (Collins & Najafi 2017). In the case the receptor is a person, the consequence examined can be either death or some kind of injury.

5.5. Risk indices and ranking

Risk indexing expresses the level of risk associated with a plant or an installation. Nevertheless, the scope of an index can be other than establishments, facilities, buildings, and machinery. For instance, there are indices describing the inherent hazards of substances, reacting systems, etc. This technique had already gained a widespread acceptance as a cost-effective prioritization and screening tool for risk assessment programmes. From a simplistic point of view, it can be said that risk indexing is the same as quantitative risk assessment, in that both approaches are intended to describe the level of risk of a certain object/system. The ranking is generally expressed by way of a dimensionless number, which is normally provided a verbal translation by way of verbal assessments such as “unacceptable”, “tolerable”, “negligible”, etc. Risk indexing is not a substitute for a detailed risk analysis, but it is probably the best assessment tool at the stage of planning, screening and ranking priorities.

A risk index may be more or less complex. Whereas QRA expresses risk in proper units of measurement (e.g. expected number of casualties per year) and is a deterministic methodology, risk index provides only a ranking (that is a value to be compared with those previously calculated for other plants/units) and is essentially based on expert judgment. Generally, the more complex the index, the more aspects related to a plant or installation are taken into account, and the “better” the device. An index demonstrates good performance when it has good sensitivity to the presence of safety systems. While using a risk index may be very cost-effective in comparison with turning to a QRA, a risk indexing algorithm has to be sufficiently well structured and representative of the system for which it has been devised: using a very simplified method could lead to significant errors in the decision making.

Compared with other methods, excess FSA is that it can be used as a tool to increase measures and new regulations in ship design and analysis, operation and control of ships, safety management standards and regulations and can be combined according to the realistic needs (Marine Safety 2008), (Pak et al. 2015), (Montewka et al. 2014), (Görçün & Burak 2015). The use of the FSA has been carried out several times to identify some of the shortcomings of the FSA (Table 1), both due to improper application of the method, and several suggestions for further action, including the need to be careful in formulating risks / hazards, not being transparent, using the FSA not according to the IMO guidelines, there are the same input data but have different results and therefore unusable, determinations, but the FSA provides a proactive way of being, allowing potential hazards to be considered before serious accidents occur (Montewka et al. 2014) .

Table 1. Research on the use of the Formal Safety Assessment (FSA)

Author/ year	**Issue**
Tang et al. (2008)	The port of Wuhan, China ship traffic system (VTS), a new risk control option (RCO) can be identified with the revised Domino mode. Ship traffic in shipping lanes
Kontovas & Psaraftis (2009)	A Critical Review a review of the FSA methodology and critical ways to fix it. Oil spills and ships (LNG, Cruise, Ferry, Container, Oil Ship, etc.)
Harilaos N. Psaraftis (2012)	Disadvantages of FSA (Transparency, Root cause, initial events and curve of F - N curve and ALARP region, etc.), Weakness of FSA according to environmental criteria Ship and oil spill
Zhang et al. (2013)	The navigational risk of the Yangtze River can be determined using the FSA concept and the Bayesian network (BN) technique with possibility and fraud-related. navigation on rivers, waterways
Jakub et al. (2014)	On a systematic perspective on risks for formal safety assessment (FSA) Use of Knowledge and Understanding variables in determining ferry risk
Görçün et al. (2015)	Istanbul Straits risks associated with marine traffic with different factors selected for risk analysis such as vessel specifications, accident location, time of the accident, type of accident Hazard risk Ships in shipping lanes/straits
Pak, J. et al. (2015)	Identification of the factors that affect the safety of navigation in ports and to analyze which of these factors affect port safety. From the perspective of the captain of the ship. Ship navigation activities at the port
Pallis (2017)	Port Risk Management Methodology (PRM), seeks to transfer the Formal Safety Assessment (FSA terminal) of a safety-oriented port container port
Youssef et al (2018)	Crude oil tanker safety assessment FSA assessment for risk to different tanker operations

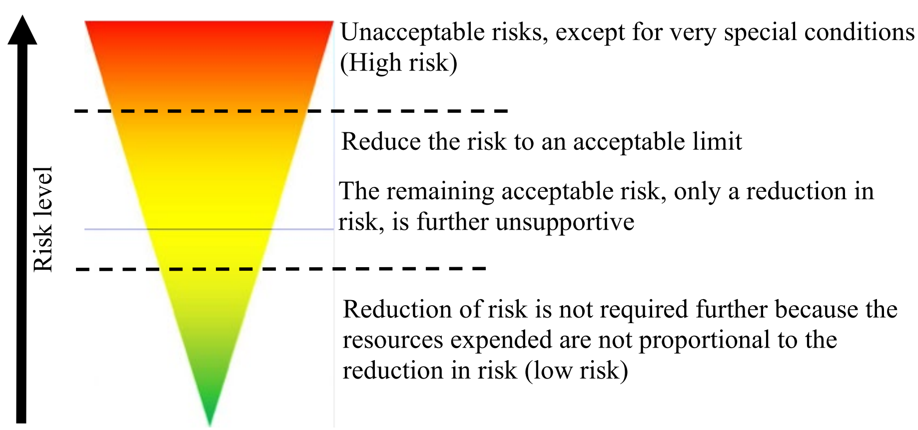

Figure 3. Concept of ALARP (Hurst et al. 2019)

Table 1, Research on the use of the Formal Safety Assessment (FSA), include evaluation of risk factors, as an answer to the question "how severe and how might it happen, it is investigated in detail about the causes and consequences of the scenarios that have been identified and evaluate the factors that influence level of risk. These objectives can be achieved by using a technique in accordance with established risk models and the attention focused on the risk that is rated high.

Figure 3, Concept of ALARP, the term used to describe the extent to which an occupational risk should be reduced by applying various mitigation is required

The value in question is the level (level) risk, which can be divided into risks that cannot be justified or accepted, except in extraordinary circumstances (intolerable), risks that have been made so small that it does not need further precautions (negligible), the risk whose levels were between intolerable and negligible levels so introduced methods (As Low As Reasonably Practicable = ALARP)(Selvik et al. 2020),

"Reasonable" or "can be justified". The opposite is "unreasonable" that is "absurd" or "making it up". Whereas "practicable" is often defined as "practical" or rather "can be applied relatively easily"(Baybutt 2014). Usually the reference is the availability of current technology and available resources. More details, if efforts to lower the risk of a job was difficult because the available technology is not adequate or require effort and funds were too large, then when it is necessary to re-think by finding another more adequate effort(Van Coile et al. 2019).

6. CONCLUSIONS

Risk assessments are nowadays an integral part of any port activity, mainly because of a need for port reliability, which is strongly related to service revenue. Port activity is much more sensitive to safety faults in the transportation of people and goods. An accident is an inability of a port operator and other partners in a process to manage unpredictable events. Risk Assessment and criteria, as presented in the paper, are strongly related to actual safety standards and modern port management. The use of Historical analysis, databases, statistics and frequency, probability, event trees in port risk assessments is not currently usable, due to the lack of accident data documented by the port in the form of accident reports. Analysis of both Refers to past accident data where the probability is only on certain events with frequent occurrences and subsequent impacts. National data collection was done by KNKT, and this was limited to major and reported accidents. Many accidents have been handled directly by the Polisi Air (POLAIR) and the Port Authority.

Format Safety Assessment (FSA), Quantitative risk assessment (QRA), The risk-based decision making (RBDM), and Risk Indices Ratings guidelines provide proven methods for addressing real decision-making needs in the marine safety, security, and environmental protection arenas. Decision-makers throughout the marine industry will find the insights, suggestions, and procedures in the guidelines valuable in the conduct of their operations. The results conclude sequentially that the FSA, GRA, RPDM, and Risk Indices Ratings are deemed appropriate for port risk analysis. The use of the FSA with innovation ALARP needs to be considered in analyzing port safety risks. This is to ensure that safety resources are allocated to maximize the number of lives saved, and implies that the ALARP criteria result in stronger minimum requirements for life safety investments.

The paper presents the methodology applying different approaches, deterministic and qualitative to present deeper understanding and relations governing risks. Operational (technical) risks are analyzed and discussed for further improvement in their management.

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Biographies

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Tri Tjahjono as Associate Professor, Indonesia University, Faculty of Engineering at the Department of Civil Engineering, Indonesia University. Obtained his Bachelor of Civil Engineering degree at FTUI in 1981. Completed his Masters in 1987 and 2003 in the field of Transportation Engineering at the University of Leeds. His teaching career began in 1981. Until now, he is still active. He has produced a lot of research, including in the fields of port planning and management, transportation planning and policy, transportation economics and transportation safety.

Sunaryo as a Professor in engineering Faculty in the department Mechanical Engineering, Indonesia University. Holds a bachelor's degree in Mechanical Engineering at FTUI in 1982. He finished Master and doctoral education fields Ship Production Tech at Strathclyde University Scotland in 1989 and 1993. His teaching career began in 1985. Until now, he is still active teaching in the Department of Mechanical Engineering. many related types of researchin the field of shipping, including the safety of Shipyard System and Shipbuilding Engineering.