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ORIGINAL PAPER

Maintaining and researching port safety: a case study of the port of Kaohsiung

Po-Hsing Tseng [1] · Nick Pilcher [2]

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Abstract
Introduction Maintaining port safety in full conformity with IMO standards is a requisite for every port and country. To do this, understanding the challenges and human factors involved is key. To date, much research has shed valuable light on these factors and considered how to address them. One aspect that is often noted is that both maintaining port safety and researching port safety presents numerous challenges. This paper considers both these aspects in the context of a case study of port safety in Kaohsiung port, Taiwan.
Methods Historical data and data from in-depth interviews with port operators and government officials are presented, analysed, and discussed alongside the literature.
Results and conclusion In the spirit of case study research, discussion and conclusions of the data are used to generate theory for consideration in ways to approach research in the field. Specifically, more holistic large scale research is recommended into how port safety is maintained, to explore the interdependencies of the factors involved to help improve port safety and complement and sit alongside our current understandings of it. Suggestions for how this research can be approached are made.

✉ Po-Hsing Tseng
phtseng@fcu.edu.tw

Nick Pilcher
N.Pilcher@napier.ac.uk

1 Department of Transportation Technology and Management, Feng Chia University, No 100, Wenhwa Road, Seatwen, Taichung 40724, Taiwan

2 The Business School, Edinburgh Napier University, Edinburgh EH10 5DT, UK

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1 Introduction

Kaohsiung Port is largest international port in Taiwan and was ranked 13th among global container ports in 2016. Such a port-city development has significant contribution in Taiwan's economic growth but has also brought negative environmental impacts on port operations and human health. To be a sustainable port-city, and to operate in future as a smart city, it is key for aspects such as port safety to be considered. Russo et al. [1] note that to successfully develop cities for the future, three processes should be noted: city development, city planning theories and city rules [1]. Improving port safety is key to the evolution of technological processes and city development, and in turn, this development should be framed within appropriate theories implemented through appropriate rules, and it is the convergence of these aspects that helps reach any practical implementation of plans [1]. Importantly, port operations entail many risks and related hazards such as oil spills, collisions, grounding, truck accidents, injuries, and personnel going overboard. Reducing such risks diminishes their subsequent adverse (and possibly serious) impacts on the environment, health, and also on company viability through financial loss [2] and increased insurance costs. Concomitantly, effective port safety has many positive impacts of increased health, green port sustainability, and reduced company costs, and is required by international law to be maintained in full conformity with IMO standards and should be measured against an appropriate benchmark such as "Maritime and Port Authority of Singapore" [3].

Human factors [4] are recognised as root factors in 80–90% of incidents [5–7]. Dangerous human factors include fatigue, carelessness, stress, health, situation awareness, mistakes, inadequate training, and safety culture [8–10]. Further, port policies, port facilities, increased vessel traffic and loading/unloading of cargo, international policies, and *force majeure* events such as typhoons, earthquakes, and tidal waves are also key. There are therefore a huge number of factors studied in port safety, and much literature describes and analyses studies of these factors individually.

Further to the challenges involved in *maintaining* port safety, numerous challenges in *researching* port safety exist. By *maintaining* we mean the actual process of keeping the port safe, in reducing risk, in reacting to events, and all the factors that may be involved here. By *researching* port safety we mean the idea of investigating and establishing how such safety is achieved, what are the factors involved, and issues such as the amount and nature of the data involved. The process of actually researching port safety can be highly complex. For example, some accidents may be caused by a combination of factors (e.g. port environment, human risk perception and safety culture, facilities failure, etc.), and ascertaining culpability and cause can be very difficult, or even impossible [11]. Some sensitive cases may be settled out of court, some data may be official, and sensitive data involving business reputation, secrets, or lawsuits may be withheld. For example, accident investigation of port state jurisdiction over vessels is usually limited within the territorial sea, but flag states have greater jurisdiction [12]. Even insurance premiums, the knowledge of which would help ascertain costs and magnitude of risk, are hard to access. There is thus a need to approach what data exists with caution and to contextualize it within whether it is self-generated or historical.

In Taiwan, maritime shipping accounts for 99% of international trade. Kaohsiung port, the largest in Taiwan, accounts for 70% of container throughput, and plays a key shipping hub role in the East Asia region. In 2015, there were 34,456 ship movements in Kaohsiung port,[1] and thus constant vigilance for port operators is essential to help ensure port safety. According to Shanghai Maritime Safety Administration report,[2] collision/contact are the main port accident causes (86.6%) and reports indicate that crews lack safety awareness. In Taiwan, port accidents have continued to occur in Kaohsiung in recent years. Table 1 shows the publically available statistics related to fatalities/injuries and ship damage in the port of Kaohsiung during 2014–2015, and that 8 fatalities occurred, and 114 ships were damaged.

Table 2 shows the publically available data on the distribution of accident types. Collision/contact has accounted for 48.1% of all accidents within Kaohsiung port. As Table 2 shows, 'collision / contact' is the main type of accident.

Table 1 Fatalities/injuries and ship damage statistics in Kaohsiung port

Year	Injuries	Missing	Fatalities	Ship damage	Shipwreck
2014	3	1	6	52	3
2015	10	1	2	62	1
Total	13	2	8	114	4

Source: Ministry of Transportation and Communication http://www.motc.gov.tw/en/index.jsp

When the causes are unknown, they are categorized into other types. In sum, human carelessness is recorded as the main cause in these accidents (cf. [8]). Regarding Port State Control ship checks, in 2015, there were 330 ships checked by Kaohsiung port authority. Of these, 286 ships were found to have shortcomings that needed to be improved and 44 were judged as "ship detention", i.e. they were deemed to have safety shortcomings and were prevented from sailing until these had been rectified.[3]

The remainder of this paper is structured as follows. Section 2 reviews literature around maintaining and researching port safety. Section 3 outlines and explains the approach to interviews with port operators and government officials. In section 4 results are presented and discussed alongside the literature, in the context of the challenges of both maintaining and researching port safety, and of illustrating the interdependencies of such factors and therefore the importance of studying and considering them as a whole. Finally, these challenges are drawn together into a conclusion and approaches to future research to help improve and research port safety are made.

2 Literature review

2.1 Maintaining port safety

The Maritime Safety Committee of the International Maritime Organisation (IMO) stipulates that its members adopt Formal Safety Assessment (FSA) and International Convention for the Safety of Life at Sea (SOLAS) to help improve ship safety and reduce accidents. SOLAS, introduced in 1974, has been developed and modified over the years to keep pace with the developing technology of the ship-building world. For example, in 1994, Chapter IX, entitled 'Management for the Safe Operation of Ships', was added to modify and expand safety operations to ships and additionally ports, following a number of events, but particularly after fire swept through the Norwegian vessel *MV Scandinavian Star* in April 1990, with the loss of 158 lives [13]. The shipping industry is required to operate by these codes, yet according to some studies, many

[1] Ministry of Transportation and Communication http://www.motc.gov.tw/en/index.jsp

[2] Shanghai Maritime Safety Administration http://www.shmsa.gov.cn/Index.aspx

[3] Maritime and Port Bureau, MOTC. http://www.motcmpb.gov.tw/MOTCMPBWeb/wSite/mp?mp=1

Table 2 Accident type statistics in Kaohsiung port

Year	Total	Collision/ Contact	Stranding/ Grounding	Fire	Explosion	Loss of containment	Capsized/ List	Machinery failure	Others
2012	70	25	5	1	1	2	2	7	27
2013	30	18	2	1	0	0	0	2	7
2014	21	19	0	0	0	2	0	1	1
2015	37	14	4	0	0	0	0	8	11
Total	158	76	11	2	1	2	2	18	46
%		48.1	6.9	1.3	0.6	1.3	1.3	11.4	29.1

Source: Ministry of Transportation and Communication http://www.motc.gov.tw/en/index.jsp

"maritime regulations are not adequately implemented worldwide" ([14], pp. 389). Moreover, many shipping operators need to implement such regulations in an unstable regulatory environment [14]. In other research, studies have attempted to provide benchmarking and management tools for ships to indicate their safety levels [15] or more specifically to create safety preparedness for cruise ships [16], and other safety studies have modelled the impact of generic training on improving evacuations in a transport system [17]. Also, ports need to balance implementing new initiatives with not discouraging shipping operators through burdensome costs that may not be implemented elsewhere, for example emissions taxes [18]. Thus, studies reveal many factors from a regulatory perspective that impact on safety.

Generally speaking, although accidents that take place far away from the coastal area and in darkness lead to greater fatality, collision, fire / explosion, contact, grounding and sinking that also lead to fatality [19] can occur in ports. Sometimes, accidents are more common with passenger than freight maritime transport, particularly when vessels approach land masses or travel through narrow waterways [20], through fog [21] or with increased vessel traffic [22]. Also, *force majeure* events such as typhoons, earthquakes and tsunami can create huge threats to port safety. Many studies thus highlight the importance of all these factors and have shed light on how they occur, and their severity.

Regarding human factors, in addition to fatigue, carelessness, stress, health, situation awareness, mistakes, inadequate training, and safety culture, others relate to tug boat drivers' skills, and the English communication abilities of VTC regulators and marine pilots [23]. Both individual and group factors are important. One key element is safety climate, or how employee perceptions and expectations relate to organisational safety [24]. This can be influenced by many factors. For example, institutional and social behaviour were noted to underpin the swift responses to the Fukushima nuclear disaster [25]. Often, 'culture' is considered highly important, especially in terms of having a safety culture (e.g. [26]) and not one that 'blames the victims' [27, 28]. It is argued that management must be proactive in implementing training and safety culture, and should not wait "for it to come from somewhere else in the organisation" ([6], pp. 446). Further, employment conditions can influence port safety. For example, in the Fukushima disaster, swift communication by workers from the German Hapag Lloyd company with strong unions greatly emphasising employee protection were found to improve safety [25]. In contrast, temporary employment conditions, less experience amongst the workers, and downsizing, have been argued to place greater strain on workers and adversely affected port safety [4]. Thus many studies show the importance and relevance of a huge range of human factors.

In specific studies of safety in Kaohsiung port, safety performance related research shows that safety training and management oriented container terminal operators (as opposed to, for example, those who are job safety and supervisor safety oriented) display optimum safety performance [29], cf. [30, 31]. Elsewhere, diagnostic research shows that "*safety climate onboard the ship, crew self-regulation, crew safety knowledge, safety drill onboard the ship* and *the condition of ship's machinery*" ([32], pp. 74 italics in original) were key factors needing improvement. Other research draws on the Hofstede's cultural dimensions' models [33] to consider how national culture can influence safety climate, and finds that for Taiwanese seafarers, safety can be more effective when power distance is low, and collectivism and uncertainty avoidance are high. Thus, studies of these elements show their fundamental importance in port safety.

2.2 Researching port safety

Risk analysis is key to researching port safety. Many debates remain around risk analysis in relation to validity, practicality, methodologies and other areas [20]. Research can be broadly divided into qualitative and quantitative risk assessment, although some studies use a combination (e.g. [21]), or use a hybrid of qualitative-quantitative or semi-quantitative [34]. Regarding qualitative methods, these are used when the phenomena of interest are relatively rare, as "judgments of experts and experimental support are critically important" ([20], pp. 34), although their results may be subjective (ibid.) and limited (ibid.). In addition, qualitative methods may be used as initial methods of exploration, and then more complex semi-quantitative and fully quantitative investigations can be used on a larger scale [35]. Qualitative methods used are interviews, often more survey type rather than in-depth interviews (e.g. [36]) and are often said to produce quantitative data. Indeed, qualitative techniques "are based both on analytical estimation processes, and on the safety managers-engineers ability." ([34], pp. 477). Sometimes, conversely, quantitative style interviews are used to also produce qualitative data to help understand Human Factor elements [6]. Also, surveys are used to gather qualitative data (e.g. [37]), as are in-depth interviews (e.g [25, 38]), and sometimes qualitative approaches such as interviews are used in quantitative methods (e.g. the Clinical Risk and error Analysis method [34]). Quantitatively, attempts to quantify risk have incorporated fuzzy unclear elements in risk analysis [39], and structural equation modeling has investigated marine accidents [40]. Risk Based Decision Modeling is also used [20], along with Analytic Hierarchy Protocol (AHP). AHP [41] is often used to ascertain risk factors (e.g. [21, 23, 32]) and is often based on questionnaires (e.g. [32]).

Mathematical methods are also widely used. Reliability analysis is used to test structural aspects such as hulls, and mathematical and simulation models are used aiming to prevent accidents such as collisions and oil spills [20]. Statistical data analysis is used in regression models, Bayesian analyses and clustering, as well as in analysis of historical data [20]. Other mathematical simulation approaches calculate the probability of groundings or collisions on narrow waterways using geographical data and increasing numbers of vessels in a simulation (e.g. [22]). Significantly it is claimed that Fuzzy Rule-Based Bayesian Networks can quantify the unquantifiable elements of risk [39]. Often, although some methods are said to be qualitative or quantitative, the distinctions may be blurred. For example, many studies use qualitative human decision based historical data to create mathematical models (e.g. [19]) or conversely create quantitative models on the basis of subjective in-depth interviews (e.g. [21]). This is often an advantage given the complex nature of risk and the need to consider many qualitative and quantitative elements in port safety.

There are many issues involved with any approach to researching port safety. One challenge is that the quality of data available can be influenced by the approach of a specific country or company. For example, in Taiwan, attitudes of safety motivation and safety concern have been found to positively affect self-reported safety behaviour, and safety policy has been found to positively influence safety participation [42]. Also, apparently similar words can have many underlying meanings, for example, although 'accident' or 'risk' have official or dictionary definitions, individual understandings may differ greatly (cf. [43, 44]). Undoubtedly, many glossaries and international definitions exist for key terms associated with risk. Marhavilas et al. ([34], p. 477) note that risk "has been considered as the chance that someone or something that is valuated will be adversely affected by the hazard", as "a measure under uncertainty of the severity of a hazard" and also as "a measure of the probability and severity of adverse effects". Other research highlights how "risk, as it is internationally recognized by far, has three main components: occurrence, vulnerability and exposure" ([45], p.280). Elsewhere, risk is defined mathematically, for example "Risk = f(scenario(s), consequence, likelihood)" ([35], p. 27), or, in words, that risk is "a measure of human injury, environmental damage, or economic loss in terms of both the incident likelihood and the magnitude of the loss or injury" (ibid). Moreover, these definitions are noted as being constant over time and are "consistent with those found in the Guidelines for Chemical Transportation Risk Analysis (CCPS, [46]) and "Guidelines for Chemical Process Quantitative Risk Analysis, Second Edition (CCPS, [47])" (ibid, p.28). Nevertheless, as Ozbas [20] notes, 'risk' and 'risk analysis' are defined differently by different fields, authors and times; a health care definition of risk is determined by frequency, whereas a financial definition of risk defines it as variance in financial systems [20]. Further, over time, whilst some elements related to risk have increased in size (e.g. bridges), others have become smaller (e.g. pesticides) [20]. It is possible that individuals may have quite different interpretations of key language and terms. Illustratively, the 21 managers interviewed by Teperi and Leppänen's [6], "were found to have disjointed and vague conceptions of HF" ([6], pp. 438). Significantly, although language issues such as English proficiency (e.g. [23]) are highlighted, individual perceptions and variations of words in the 'same' language are often assumed not to be an issue. For example, Karahalios et al. [14] note that their mathematical hierarchical model can be used by many ships without a need to understand the mathematics as "the mathematics can be avoided by entering linguistic terms". Nevertheless, what the above section illustrates is that there are many methodologies chosen to research port safety and shed light on individual aspects. Also, as noted in the introduction above, it is also essential that such research be contextualized within a wider context of city development, and theoretical justification and legal implementation [1]..

3 Methodology

Many previous studies have adopted quantitative approaches to investigate port safety issues (e.g. [9, 12, 23, 42, 48, 49]), and the use of qualitative approaches is still relatively rare. The primary data for this paper is qualitative, and came from in-depth interviews with key stakeholders. The objectives of the interviews were to explore how port safety was approached in the port of Kaohsiung, and to compare this with the literature, to see if the way Kaohsiung approached safety is mirrored in the literature, and whether there were unique challenges involved. To do this, the questions for these interviews were based on the historical data outlined above, and as such, constituted a case study in that a range of resources were drawn upon with the objective to generate theory to be applied elsewhere in the field [50]. The qualitative and in-depth nature of the interviews afforded access to the participants' wealth of knowledge and experience. Their in-depth nature recognized the purely social nature of language [51] and allowed for the generation and exploration of dialogue [52]. The intention of generating and exploring free dialogue and discussion was to allow space for comments relating to events and aspects not considered or revealed in the literature. Procedurally the result that some interviews lasted much longer than others. Structure and content were very much guided by the answers and subsequent dialogue of the interview following the initial open questions asked, such as 'How do you deal with dangerous cargo?' or 'Today our topic is how to reduce accidents in the port, do you have any comments on it?'

Analysis adopted a constructivist grounded theory analysis [53] as this afforded analysis of the interview data through looking for emergent themes rather than draft themes on to the data. Such themes emerged diffractively [54] after many readings and considerations of the data. For example, it was not initially intended to consider the challenges of researching port safety and so this was not directly asked about, yet this emerged as a key theme after the many diffractive readings.

Interviewees were terminal operators and governmental officials in Kaohsiung port. Interviews in face-to-face meetings at their working sites were conducted during November to December 2014. Interviews were conducted in the participants' native language of Chinese for ease of communication [55] and then translated into English using a goal oriented, or 'skopos' approach [56]. The interviewees were selected based on their background (e.g. operation department of terminal or labor safety and health management department) and involvement in the topic being researched, i.e. the maintenance of port safety in Kaohsiung. Terminal operators (3) had an average of 18 years' experience were interviewed, and their job types included president, senior director, and senior onshore manager. Government officials (5) averaged 16 years' experience and their job types included director, senior deputy director, and supervisor. Both government officials and terminal operators were interviewed to provide a more comprehensive picture of maintaining port safety than would have been possible to gather from interviewing one group alone. Concomitantly, more groups of stakeholders (such as ship captains or tugboat operators) were not interviewed, as this would have widened the focus too greatly for a qualitative study of this nature. All interviews were conducted in line with appropriate ethics procedures of assured anonymity (cf. [57]), and each interview lasted 30–45 min. Interview questions focused on port accident or safety issues and their related factors from a holistic perspective. For example, 'Could you provide an example to describe the Standard Operation Procedure of safety regulation?'; 'How do you deal with dangerous cargo in port?' or 'Could you provide an example to describe any accidents you have seen?' (for more details on the questions and interviews see Appendix 1 The results are now presented and analysed in the next section.

4 Results

Port safety was, understandably, considered fundamentally important, and that "*from the perspective of service, we must approach safety as the highest priority*". If accidents occurred whereby a ship blocked a channel, "*overall cargo movement in the port will be affected and cannot operate. For example, soy bean, corn, wheat, flour cannot be imported and will result in serious food problems….management is very important*". Nevertheless, the challenges of maintaining port safety were notable through the language used by interviewees, which was often expressive of uncertainty or of regulations would be followed theoretically. For example [our underlining to highlight], "*we think he did not conduct correct and safe instruction*", or that "*I think the preventative management is important*". Further that "*theoretically, the ship should be checked by the company*". The results from the interviews are now presented and analysed further in five main sections: regulations, facilities, human factors, force majeure events, and management and governance. These sections were considered not so much in direct response to the outline of the key factors in the literature, but rather, because these were the emergent themes that arose to us through the analysis. Nevertheless, we compare them with the literature throughout, and they are summarized at the end before the discussion and conclusion section.

4.1 Regulations

International conventions were noted by government officials as being the basis for how they approached safety: "*ships are regulated by port authorities based on the rules of international conventions. For example, the International Convention for the Safety of Life at Sea (SOLAS) stipulates that the ships must follow traffic separation schemes to arrive and depart from the port*". Similarly, port operators highlighted the importance of following Standard Operating Procedures (SOP): "*people in the port will follow SOP to operate. Vessel Traffic Control Section (VTCS) has its own SOP. For example, the pilot procedure (for entering the port) can not exceed 30 minutes. The time of ship leaving port can not exceed 20 minutes*". Further, that ship calling and existing times were all recorded and checked, which "*is done to check the responsibility… if there is someone who cannot finish their job on time, it will affect the ship calling time and ship safety*". Otherwise, one government official noted that the International Ship and Port Facility (ISPS) had six categories and different grades of security risk: "*if there is any risky situation, the port authority could prevent the ship's calling and the ship would have the right to refuse to call at the port….when the ship has risky situation, it may raise the security grade (e.g. to grade two or grade one). There is a standard rule to regulate it*". Such risks could involve diseases, for example, "*if the ship has visited an epidemic area before… and it is still during the incubation period when the ship comes… then the port authority will be very serious about checking this ship*". Regarding cargo, some regulations applied, for example "*LNG (Liquefied Natural Gas) ships must be regulated and be isolated by 500 meters in case of potential collision risk….also, when a chemical ship arrives to the port, the bow of the ship must face the outside of the port through the Turning Basin*".

Another aspect of regulations could be that ports would focus on particular issues according to IMO stipulations: "*the International maritime Organisation (IMO) will set a topic every year. For example, ballast water regulation will be presented next year and ports will operate accordingly to fit the new regulations. The 80-20 rule will be adopted…which means that ports spend 80% of their effort on meeting these new regulations and 20% to focus on other topics*". Nevertheless, despite the many regulations that are followed and adhered to in Kaohsiung, accidents and fatalities still happen. One port operator noted that "*although there are many rules in port, the key point is the problem of implementation. Also, sometimes the accident's cause is due to problems with the facilities*".

Thus, regulations were followed but their implementation could be complex (cf. [14]), and other factors could nevertheless emerge to affect safety. This is evidenced by the continued occurrence of accidents (see also Tables 1 and 2) despite the adherence to regulations. Thus, in terms of risk reduction, regulations by themselves thus need to be contextualized, and arguably studied in the context of other factors such as, for example, facilities.

4.2 Facilities

As the port operator immediately quoted above notes, "*sometimes the accident's cause is due to problems with the facilities*". Indeed, "*port facilities must be maintained well, since old facilities always have some problems after they have been used for a long time*". These facilities could be technical, for example having an effective and up-to-date computer system. Both government and port operators related how all procedures were part of a long and complex chain; from detailed reports submitted 24 h before ships arrived detailing their type, size, draught, purpose, to announcing its arrival 20 miles away and being guided by a pilot from 5 miles in, and that such work is now done in Kaohsiung using an iPad to check information before the ship calls or leaves the port, and all the information "*will directly send the message to the computer system*". Such a system requires up-to-date and expensive technology. Sometimes, budget constraints were felt to have a direct impact on safety. One government official talked at length regarding CCTV equipment: "*We would ideally like all the port gates to be equipped with CCTV (closed-circuit television). However, CCTV could only be installed step by step due to the limited budget*". Further, that such CCTV technology was different, as it had been installed over a period of time, and that the limited manpower meant that images had to be spot-checked retrospectively rather than monitored continually. This meant that, "*some places we might miss. For example, people may easily go for fishing. It is illegal to fish in the port area. Although it is not dangerous if it is just fishing, if people would like to conduct illegal actions, that would be a problem. We will collect related data based on past experiences and control these areas more strictly in the future*". Here then, not only do facilities affect how port safety can be maintained, but it is also the case that some events may occur and that there may be, as this official noted "*some places we might miss*".

Here then, facilities clearly are affected, or were felt to be affected, by budget and resource constraints. At the same time, investment is clearly being made in up-to-date facilities and "*expensive*" advanced computer systems. Thus, there is a balance between continually advancing and at the same time still covering all areas of safety and possible risks. Thus, although facilities are felt to be key in risk reduction, issues of cost and coverage need to be considered. What is more, in the context of regulations and facilities, human factors also were felt to play a key role.

4.3 Human factors

When asked about a recent accident where one ship had hit a rock, creating a hole in the hull, and sank quickly, one port operator felt, "*the captain must be responsible for this accident. He did not prepare well before the ship sails and did not have a clear electronic chart…. we think he did not conduct* *safe instruction*". Often, it was the responsibility of particular 'Humans' in particular roles to be responsible for particular aspects of safety. When correctly instructing ships wanting to enter Kaohsiung that the draught was 16 m, one port operator felt that the "*Port Authority must be responsible for this issue since the ship owner or other stakeholders will protest against it*". In other words, the ship owner of other stakeholders would not consider it their responsibility to check this. For other aspects of safety, different 'Humans' were felt to be responsible. For example, regarding the responsibility for unloading cargo, "*terminal operators must check their facilities and safety procedures, including work rules, and dangerous cargo movement*". Regarding other aspects, ship owners would be responsible, for example "*if officials find some problems exist regarding the ship's seaworthiness, they would ask the ship owners to repair and fix these, since dangerous ships may bring risky situations and affect other ships and port operations*". Further, and at a higher governmental level, different bodies of 'Humans' were responsible for checking different aspects, or more than one body was responsible to check certain aspects. For example, with regard to checking ship safety, "*it is the job of Port State Control (PSC)… we will focus on particular ships which had illegal records in the past and they have high likelihood to be checked when they call at the port… Maritime and Port Bureau (MPB) take charge of this job. The MPB has governmental power to regulate the ships, and the Taiwan International Ports Corporation (TIPC) takes charge of port businesses*". At an even wider level, a large number of bodies needed to coordinate effectively to ensure safety. For example, one official noted that maintaining safety "*involves coast guard administration, the center for disease control, the national immigration agency, the port station, the maritime and port bureau, the Taiwan International Port Corporation etc.*"

'Human' factors were also noted in the need for specific training for each individual port, for example that, "*if a pilot in Kaohsiung is assigned to Keelung port, they must retrain again since the port environment is different*", or that "*the fairways and port designs are different in global ports*", and, "*the tide range and hidden reef are different in every port*". Moreover, 'Human' factors were also noted to be combined with computer factors, for example that "*human made decisions determine decisions regarding the ship. These cannot fully depend on the computer although the computer will provide suggestions and indications regarding which ships have a high or low risk*". Often, 'Human' factors were said to be connected to wider issues such as safety and maintenance management. For example, in a fatality related by one of the port operators when a sailor died after being hit by a thin rope that had snapped in a tug boat fixing operation: "*I remember one accident in the tug boat operation. The rope of ship was broken and hit ship control station. The sailor died immediately. There are two types of ropes: rough and thin. The thin rope may be broken if it is not fixed well. This is related to safety and maintenance management*".

Human factors [5–7] themselves were thus critically important. Yet, to study human factors alone would be insufficient, as these would need to be considered in the context of how they operated with broader governmental levels, and also in tandem with facilities such as computers, and individual levels of training (cf. [17]) for specific ports and the underwater geological conditions relevant to them. Thus, with regard to risk reduction, in the area of human factors, the issue of training and consideration is indeed key, but also needs to be contextualized within these wider factors. Another theme that emerges from the above is that of culpability, specifically, ascertaining which 'human' (e.g. captain or port operator) is the 'factor' to help in reducing risk.

4.4 Force majeure events

Some natural disasters were considered insurmountable and irresistible, whereas others were felt manageable. For example, one port operator talked of how the Kobe earthquake in Japan destroyed all the gantry cranes in the port, and little could be done about this, but in contrast, when a typhoon had hit the port and one ship had slipped and hit other ships, "*this problem is caused by poor management*". Another issue related to the unpredictability of such events, and it was suggested that preparations may be perceived as being unnecessary; that much effort was spent to protect Taiwan from the expected tsunami from the Japanese earthquake in 2011, but that "*the water level rose only 4 centimeters in Hualian port. You may think we spent lots of time to prepare for a potential disaster, but nothing happened….yet we continue to learn through doing by learning*". As this official noted, "*no one can predict what will happen until you experienced it*". In addition, sometimes unexpected localized events would happen, for example, "*sometime we will have a sudden incident. For example, during one holiday, one fishing ship burst into the port without permission, although it did not have any bad intentions*".

Thus, force majeure events are sometimes predictable and manageable and at other times not. In both cases reactions to them will very much depend on the individual, human factors, the facilities, and the regulations involved. Thus, in terms of risk reduction, it is not so much any ability to minimize the possibility of the events themselves, rather, it is preparing for them by supporting and developing the other factors related to safety that is key. Notably, all these factors can again be influenced greatly by individual country specific governmental changes.

4.5 Management and governance

Management was considered pivotal to ensuring and maintaining safety. Some accidents could result in others happening, in that "*if one oil tank explodes, it will affect other oil tanks and result in a chain of dangerous accidents*". One way management helped ensure a safety culture and up to date knowledge was through training conducted each year drawing on a combination of international guidelines, port-operators, and sometimes the government: "*Each unit will conduct their business and will share necessary information with each other when it is important about safety or security issues. It is like a war game [simulation] and every unit will cooperate to solve potential safety or security issues*".

Policy implementation at the highest level can impact upon safety. One government official commented on how they Taiwan had recently changed port governance: "*the Taiwan International Ports Corporation (TIPC) and the Maritime and Ports Bureau (MPB) have been separately established since 2012. They are still in an adjustment period*". The finer details of this change had implications for safety, for example, that "*pollution ban and fines are MPB's job, however, the MPB think they are in charge and that the TIPC should collect evidence about pollution which the MPB can then use to fine pollution producers. Yet, as I know, after consultation with a lawyer, a risk exists here, since the law enforcer should collect the evidence themselves. If there is a reliance on another organization's evidence, there could be a dispute, although to date this has not happened*". In addition, another issue was felt to be a lack of sufficient manpower to maintain safety. One government official commented that "*I think the police capacity is not enough is a current problem. The working burden is very high for each police man. Even some port gates depend on monitors since the number of police is limited*".

Thus, continual training and approaches to safety do take place (cf. [17]) but these need to be placed within a wider context of governmental policy initiatives and how these affect governances. Changes in port governance policies can have an impact on safety (cf. [4]) through creating uncertainty and a lack of clarity about responsibility for decisions. Furthermore, working conditions can impact on the ability of the port to maintain safety.

4.6 Summary of results

The above results show that with regard to approaches to maintaining port safety in Kaohsiung, there is undoubtedly a certain amount of uncertainty involved and also much reliance on what should happen in theory. Nevertheless, regulations are followed and adhered to, from the IMO and from SOLAS, and also SOPs are followed. Ships can be prevented from docking at the port if there are safety issues, and ships carrying chemicals or LNG are treated differently for safety purposes. Nevertheless, implementation was considered a key issue. In addition, in terms of facilities, many advanced systems and CCTV are used in Kaohsiung, but the high cost of such facilities was noted, and it was also felt that the coverage of some of these (e.g. CCTV) could be more comprehensive. In terms of Human Factors, many different people were responsible for different areas; sometimes captains were responsible for particular areas, other times terminal operators or ship owners. In Kaohsiung, the issue of whether it was the MPB or the TIPC who should be responsible was also a consideration, and also the fact that the port itself was unique (e.g. in contrast to Keelung) was a key consideration in approaching safety. With regard to *force majeure* events, reactions were commented on as being key, and where accidents had happened these were attributed to poor management. The difficulty of making predictions was also highlighted, and the issue that often preparations for safety were made but transpired to not be needed was also raised. With regard to training, much of his was done through simulation, but issues of whether the MPB or the TIPC should be responsible, and the pressure on people to work more were raised.

Such results, when taken as a whole, show exactly how complex and interrelated maintaining and researching port safety is. Not only this, but they also show how significant their potential impact is on risk reduction, and specifically how risk reduction is best achieved by a holistic consideration and addressing of all these factors. Such complexity and interrelatedness arguably means that in addition to studies that focus on one particular area, or use one particular method, there need to be more holistic studies that draw on a range of methods and focus on a wide range of factors.

5 Conclusion and discussion

Many studies into port safety focus on many specific aspects and shed much light on how safety can be improved and what the underlying causes of accidents can be. Nevertheless, these studies, and any study, are faced with the complexities of gathering data in a field whereby some may be withheld for lawsuits, and where some data may be missed. For example, the above case study of Kaohsiung would suggest that where CCTV coverage is not comprehensive, or when there is a lack of police personnel, some infringements may go amiss. Furthermore, although these studies shed valuable light on many factors, it is possible that the interrelated nature of all the elements involved in contributing to port safety mean that it would be fruitful for more holistic studies to be undertaken. As the above results show, in Kaohsiung, the approaches to port safety cover all these areas, and practices are very thorough with regard to following international regulations, updating facilities, ascertaining who is responsible for which area, attempting to respond to force majeure events, and in ensuring due diligence and governance. However, it may well be the case that it is the complex interconnection of *force majeure* events, the state of facilities, human factors, governance policies and the implementation of international regulations that, when combined, all contribute to port safety. With regard to the value of the above findings for port operators and government officials, we would argue that what the above shows is the complex interrelated nature of all the elements we have looked at, and how it is important to be aware of this in any approach to risk reduction and port safety. We do not, however, make the claim that the full extent and impact of these factors on port safety is revealed by our study. Rather, we argue, in line with the recommendations of the literature [35, 46] that the above study represents a qualitative study that shows the need for more in-depth semi-quantitative and quantitative studies to fully explore the relationships between the factors involved. Moreover, that the results can be considered as key to aiding city development, but to be contextualized within appropriate theories and planning to help achieve practical implementation [1]. In this way they can be most effectively integrated into an overall process designed to consider port safety as part of developing the city for the future.

Much of the literature into port safety focuses on specific aspects of safety, adopts specific methods, or relies on the assumption that the data analysed is representative of all the possible data required. We would argue that the above case study, through its purely exploratory approach, reveals the importance of also considering the gaps in such data, and of also studying port safety from a more holistic perspective that considers the interrelationship of the many factors involved. We feel that more holistic and large studies would help shed light on these interrelationships. Studies that drew on a range of methods such as a combination of in-depth interviews with questionnaires, analysed using methods such as Analytic Network Process. Further, expanding the study to include port workers and sailors as well as the type of stakeholders interviewed here would make such a study more holistic. Such study would shed more light on how the many factors that have been studied so far can be seen to operate in combination, and thus help shed light on how to best enhance risk reduction and thus how to better improve port safety. They would in addition, help resolve issues such as how it is possible to ascertain relationships such as those between the failure to comply with rules and the causes of accidents in ports, and help with development of the city overall.

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Appendix 1

Table 3 Further details on the interviews and the questions asked

Category	Notes
Roles on interviewed people	Terminal operators (3) Government Officials (5)
Experience in job	Terminal operators (18 years on average) Government Officials (16 years on average)
Interview length	30–45 min
Language of interviews	Mandarin, translated into English
Initial questions asked to Port Operators (questions are described as initial as it was often the case that discussion followed from these initial questions)	Do you have any comments on accidents you have witnessed? What are your thoughts on the pilot system in Kaohsiung? Could you provide an example to describe the standard operation procedure of safety regulation? How do you deal with dangerous cargo in the port? How would you reduce accidents in the port? What are your thoughts on how accidents can be reduced?
Initial questions asked to Government Officials	What are your thoughts on port safety regulation? What are the criteria when conducting ship safety checking? How are decisions made whether to check ships? With large ships, how do you check key points? How does the port regulate ships? What is checked when ships enter the port? How does the port maintain safety? Maybe terrorists will stay on the ship, how do we know it is safe? What are the main problems in ports? How do you conduct safety training in order to prevent potential disasters in Kaohsiung port? How do ships submit data before they arrive in the port?

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