Institution: University of Strathclyde

Unit of Assessment: 12

Title of case study: Improving maritime safety through the implementation of new international rules and standards.

1. Summary of the impact (indicative maximum 100 words)

Research on the theoretical and experimental assessment of the stability of damaged ships in the Department of Naval Architecture and Marine Engineering from the mid-1990s to the present day has been pivotal in the development, adoption and implementation of the latest amendment of the International Convention on Safety of Life At Sea (SOLAS 2009) by the International Maritime Organization (IMO), the UN body regulating maritime safety. The impact of these regulations has been a significant reduction in the risk to human life at sea by enabling ship design and operation with higher standards of damage stability. SOLAS 2009 represents a step change from deterministic to probabilistic rules and from rule compliance to goal-based standards; it has improved design and operation of all commercial ships built worldwide from 2009, and has thus resulted in far-reaching and long-lasting impact on maritime safety.

2. Underpinning research (indicative maximum 500 words)

Context*:* Safety of Life At Sea (SOLAS) regulations were originally introduced in the aftermath of the sinking of the *SS Titanic* and have developed over many years, being periodically updated to reflect advances in maritime safety. The step change from deterministic to probabilistic rules has been considered for around fifty years, but was successfully implemented for the first time in SOLAS 2009, based on knowledge developed over 17 years through initiatives spearheaded by The Department of Naval Architecture and Marine Engineering (NA-ME), involving national and international research projects and working groups. These regulations target risk reduction, aiming for zero tolerance of risk to human safety.

Key Findings: After the 1987 capsize of the passenger-car ferry *Herald of Free Enterprise* with the loss of 193 lives, a new approach and numerical simulation tools were developed to study the behaviour and capsizing of damaged passenger ships, which take into account progressive flooding in waves as a function of time (Reference 1). After the capsize and sinking of *Estonia* in 1994 with the loss of 853 lives, UK, Germany, Norway, Sweden, Finland, and Denmark set up the Joint North West European Project with the aim of understanding rapid capsize of passenger-car ferries and developing improved survivability standards. In this project, NA-ME researchers formulated the first performance-based (quantitative) assessment of ship survivability, using first-principles tools, representing a landmark contribution in the history of maritime safety legislation. This research led to the establishment of a European standard known as the 'Stockholm Agreement' (Reference 2), the precursor of performance-based approaches to safety that led to the development of risk-based approaches and goal-based standards implemented in SOLAS 2009.

The cornerstone of the NA-ME contribution to maritime safety is the introduction of techniques for measurement of safety using first-principles tools to assess the safety performance of ships following collision/grounding and/or large scale flooding in realistic operational conditions. These techniques enable safety to be considered as a quantitative design objective rather than an attribute achieved by rule compliance, contributing to a fundamental shift in the perception of ship safety. NA-ME research, funded by the UK Department of Transport through a string of projects from 1995 to 2000, enabled determination of the survival time (time taken for a ship to capsize) of damaged passenger ships and the subsequent development of time-based survival criteria (Reference 3), allowing the development of ship designs and arrangements offering sufficient time for passengers to evacuate damaged ships. This research led to second and third generation numerical models to assess the survivability of damaged ships offering improved accuracy and flexibility in handling any damage scenario, in conjunction with improved computational speed. These technical developments, coupled with societal demands for improved maritime safety deriving from major maritime accidents (such as *Estonia*), led to the establishment in 1996 of the Ship Safety Research Centre (SSRC), by Vassalos & Turan, to provide a focus for international collaboration on maritime safety research, to support the implementation of the new standards being introduced throughout Europe via the provision of numerical tools, the development of experiment methodology, and provision of model testing facilities. NA-ME thus played a key role in supporting the EU maritime industry in re-designing existing ferries to the new standards. Between

2000 and 2003, the EU-funded projects ROROPROB (*Probabilistic Rules-Based Optimal Design of RoRo Passenger Ships,* Ref: G3RD-CT-2000-00030) and HARDER (RP1), initiated by NA-ME, provided the foundation for SOLAS 2009. These projects were truly international, involving European industry, research and regulatory bodies, IMO, the US Coast Guard and Japan. The IMO Working Group, with support from the HARDER project developed the harmonised regulations in draft form in 2004; following various amendments for ease and consistency of implementation, these entered into force in January 2009. NA-ME was involved in the Working Group and played a pivotal role in the formulation of the SOLAS 2009 rules.

NA-ME has continued to spearhead the implementation of probabilistic rules in practical ship design via a series of large-scale research programmes (7 projects between 2009 and 2013 amounting to some €1.5M). In addition, SSRC run SOLAS 2009 Passenger Ship Safety workshops to help industry understand the fundamentals and the implementation of the new rules to help ensure safer designs can be generated cost-effectively (References 5 and 6). Research has also focussed on development of global safety standards for damaged ships, to harmonise existing fragmented regulations and replace prescriptive rules-based standards with a performance-based approach.

Key Researchers at Strathclyde at time of research 1994 - 2009:

Vassalos, D. (Professor), Turan, O. (PhD Student, Research Fellow, Lecturer & Senior Lecturer), Konovessis, D. (PhD student, Lecturer & Senior Lecturer), Jasionowski, A. (PhD student, Research Fellow & Lecturer) – all were staff in the Department of Naval Architecture and Marine Engineering (NA-ME).

3. References to the research (indicative maximum of six references)

Outputs which best illustrate the quality of the research are References 1, 2 and 4.

1. Turan, O. & Vassalos, D. (1994) "Dynamic Stability Assessment of Damaged Passenger Ships", Trans. RINA, **136**, pp. 79-104.
2. Vassalos D., Turan O**,** & Pawlowski, M. (1997), 'Dynamic Stability Assessment of Damaged Ships and Proposal of Rational Survival Criteria', Mar. Tech., **34**, No 4, pp. 241-266.
3. Jasionowski A., Vassalos D. & Guarin L.(2003) 'Time Based Survival Criteria for Passenger Ro-Ro vessels', Mar. Tech., **40**, No 4, pp. 278-287.
4. Vassalos, D (2008) Chapter 2: Risk-Based Ship Design, in Papanikolaou, A (Ed): "Risk-Based Ship Design – Methods, Tools and Applications", Springer, ISBN 978-3-540-89042-6, pp. 17-98.
5. Vassalos, D, York, A, Jasionowski, A, Kanerva, M and Scott, A (2008) "Design Implications of the New Harmonised Probabilistic Damage Stability Regulations", Int. Shipbuilding Progress, **54**, No. 4, pp. 339-361.
6. Guarin, L., Konovessis, D. & Vassalos, D. (2009) "Safety Levels of Damaged RoPax Ships: Risk Modelling and Cost-Effectiveness Analysis", Ocean Eng., **36**, pp. 941-951.

Other evidence for research quality:

The importance of this research has recently been acknowledged by the award of the Royal Academy of Engineering 2011 Sustained Achievement Award to Prof Dracos Vassalos as well as the Gold Medal of the Royal Institution of Naval Architects.

The underpinning research was developed through more than a dozen projects with around £4M of total funding. Key projects were:

RP1: HARDER – Harmonisation of Rules and Design Rationale Ref:GRD1-1999 10721; (2000-2003) Vassalos & Konovessis; Funder: EC; (€518,768)

RP2: SAFEDOR – Design, Operation, Regulation for Safety Ref:TIP4-CT-2005-516278 (2005-2009) Vassalos and Jasionowski; Funder: EC (€1.52M)

RP3: GOALDS – Goal-Based Damage Stability Ref:FP7-SST-2008-RTD-1-233876; (2009-2012), Vassalos and Konovessis; Funder: EC (€822,000)

4. Details of the impact (indicative maximum 750 words)

Process/Events From Research to Impact: The underpinning research made a significant contribution to changing the practice of the profession from rule compliance to goal-based regulations with specific emphasis on ship damage stability (Source 1). This provided the platform

for introducing and developing a workable rule-set of probabilistic regulations via a series of large-scale international research projects. In particular the HARDER project provided all requisite input to IMO for SOLAS 2009. On this basis, the IMO Working Group, with the support of the HARDER project findings (Source 6) developed the harmonised regulations in draft form in 2004. Following various amendments for ease and consistency of implementation, these entered into force in January 2009. NA-ME researchers were involved in the Working Group and played a pivotal role in the development of the SOLAS 2009 rules. The underpinning research towards the development of SOLAS 2009 also proved instrumental in the eventual adoption of the regulations by the international maritime community (Source 2). This effort has thus resulted in new worldwide safety policy and improved standards; ultimately to safer shipping.

Successful spin out company: NA-ME research by Vassalos and Turan led to the formation of a spin-out company Safety at Sea Ltd (SaS) in 1999 to offer specialist safety services to the marine industry and this spin out has continued to have impact since 2008. Safety at Sea is now a wholly owned subsidiary of Brookes Bell Partnership following its merger with that company in 2011, and is a successful marine consultancy, specialising in marine and offshore safety, engineering and cost effective operation (Source 3).

Impact on International Regulations: All new ships built worldwide after 2009 must comply with SOLAS 2009 regulations. Given that damage stability failure represents 90% of the risk to human lives in maritime accidents, this affects over 2 billion people who travel on passenger ships each year, and around 100,000 commercial vessels, operated by around 1.5 million crew. In 2009-2012, over 10,000 ships were built under SOLAS 2009 regulations (Source 7). Currently, over 2,500 ships worldwide (worth $100Bn) are being designed and built to SOLAS 2009 regulations. The impact of the NA-ME research in Europe is even greater, as the performance-based standards in the Stockholm agreement have been applied to existing Passenger/Car ferries as well as new builds since 1997. In Northern Europe more than 200 existing vessels were upgraded to the standards set out in the Stockholm agreement in the period up to 2009. The impact continues as 300 existing vessels in Southern Europe are being upgraded to the standard in the period 2009 to 2015. More than 200 million passengers and 15 million cars/trailers are transported annually throughout Europe on these vessels.

Reduction in risk to human life: IMO statistics show a reduction of around 15-20% per annum in the loss of life in maritime accidents since the introduction of SOLAS 2009 (Sources 8 and 9). This equates to an average of 200-300 fewer fatalities per annum due to safety failures since the introduction of SOLAS 2009; this rate of reduction will improve further as new ships are being built to the new rules. Since 2009, two billion passengers are travelling in a safer environment at sea. IHS Fairplay's 2010 World Casualty Statistics publication shows that the number of lives lost at sea fell sharply in 2010 compared with the previous 12 months. In 2010, 250 seafarers lost their lives, the lowest figures for loss of life since 2003 (quoted in Source 9 p.18).

Improvement to build and design: Since 2008 NA-ME researchers and the spin-out company Safety at Sea Ltd (SaS) have contributed to upgrading of some 130 EU vessels to new damaged stability standards, as well as design of new-build ships owned by international companies including P&O Ferries, Stena Line, Caledonian MacBrayne Ferries, Viking Line, Color Line, DFDS Ferries, Irish Ferries, Grandi Navi Velocci, Grimaldi, VShips and Blue Star Ferries. These ferries continue to operate in the UK and European waters providing safer maritime transport to the UK and EU public (Source 3).

Using the new rules and expertise gained via research, SaS has been involved in the design of cruise vessels and RoPax for EU-based companies including Caledonian MacBrayne, P&O Ferries, Color Line, Stena Line, Carnival Cruises and Royal Caribbean Cruise Lines (RCCL) (Source 3*)*. SaS are involved with design of some of the most innovative passenger ships ever built e.g., Royal Caribbean Cruise Lines' *Genesis* class, designed on the basis of the new rules with safety as the main objective and demonstrating significant and cost-effective safety enhancement (see Reference 4). SaS is now responsible for all aspects of safety for *Titanic II*, a replica of the legendary ship currently being designed (2013).

Similar support has been provided to other organisations around the world, including the US Coast Guard, Daewoo and Samsung Heavy Industries (Korea), Mitsubishi (Japan) and NCL (Singapore), to help increase safety performance and standards. Since 2009 more than 15 cruise ships have been built in Europe to SOLAS 2009 regulations at a cost of $15Bn to the ship building industry.

Economic Impact – cost savings and employment: The SOLAS 2009 performance-based

standards enable cost-effective safety improvements. This incentivises the maritime industry to invest in safety whilst offering significant economic savings, including substantial savings in insurance costs. SaS Ltd employs more than 25 engineers offering services worldwide and has strategic partnerships with Lloyds Register of Shipping and Brookes Bell (UK); Deltamarin (Finland); Alpha Marine Services (Greece); Maersk (Denmark) and Panama Canal (Panama).

Embedding a safety culture in the shipping industry*:* An important contribution of NA-ME led research on safety has been in incentivising a change of the industry mind-set from rules-based to performance-based safety standards, enabling measurement of safety and offering a mechanism to facilitate and sustain a maritime industry safety culture. This has impacted on promotion of safety awareness and a proactive approach to effective life-cycle risk management; promulgating a maritime safety culture; enabling safer shipping in a cost-effective manner and reducing risks to life, property and the environment. International standards developed at IMO form the foundation for national standards and rules of related regulatory bodies, e.g. classification societies. The Executive Vice President of Royal Caribbean Cruise Lines notes that "*Performance-based approaches to addressing maritime safety, in particular damage stability, provided the foundation for innovative designs with demonstrable safety, achieved cost-effectively. This has enabled a step change in the profession's mind-set and practice in addressing maritime safety at large*" (Source 1). To facilitate understanding of the new rules and the ensuing safety regime, a series of CPD Workshops has been organised regularly by NA-ME with participation from professionals worldwide. The training material developed is now a reference on maritime safety for the industry while training workshops have been attended by over 150 industrial practitioners. The Marketing Director, Deltamarin Ltd notes "*I was one of the designers called upon to help NA-ME combine theory and practice and to offer a course that has helped make a step change in design practice with focus on ensuring high levels of damage stability*" (Source 4).

Reach and significance This research reaches the worldwide shipping industry through IMO regulations. The IMO's rules are the most important international instrument addressing maritime safety today, covering such areas as ship design, construction and equipment, subdivision and stability, fire protection, radio-communications, safety of navigation, carriage of cargoes (including dangerous cargoes), safety management and maritime security. NA-ME research is promulgated through IMO, National Regulatory Bodies, Classification Societies, ship designers and builders, ship operators, and most importantly 2 billion passengers and 1.5 million seagoing crew worldwide (Source 5). Performance-based safety allows the introduction of safety as a design objective, which leads to improving the overall performance of ships, i.e., better designed and operated ships, finally, addressing safety rationally incentivises safety investment and encourages a safety culture, leading in turn, to a sustainable and continuous improvement (as evidenced in the SAFEDOR Project website, Source 10).

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Statement from Executive Vice President, RCCL will corroborate the impact of NA-ME research on maritime safety perception and implementation
2. Statement from Chairman of the Maritime Safety Committee, IMO will confirm the influence of NA-ME research
3. http://www.safety-at-sea.co.uk/case-studies/ Safety at Sea website - case studies
4. Statement from Marketing Director, Deltamarin Ltd. will corroborate the significance of the training workshops in facilitating the introduction of the new rules
5. Statement from Technical Director, Lloyds Register of Shipping will corroborate the significance of the NA-ME research in affecting maritime safety at large
6. http://ec.europa.eu/research/transport/projects/items/eu_funded_safety_at_sea_project_has_worldwide_impact_en.htm
7. http://www.fairplay.co.uk/solutions/ships on order by ships type (Subscribed Magazine)
8. http://www.marineinsight.com/shipping-news/imo-calls-to-halve-seafarers-death-rate/
9. http://www.imo.org/KnowledgeCentre/ShipsAndShippingFactsAndFigures/TheRoleandImportanceofInternationalShipping/Documents/International%20Shipping%2020Facts%20and%20Figures.pdf
10. www.safedor.org