WHAT'S BEHIND HUMAN ERROR?

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Abstract

Society is obsessed with blame. Every mishap is accompanied by a demand, often from uniformed reporters and politicians, for the culprit to be identified even before any investigation is carried out.

The hunt for the culprit in our industry often focusses on the seafarer who may be traumatised by the very events they are blamed for. In the extreme, they may be detained a long way from their home pending investigation.

In the shipping industry, when human error is discussed, it is almost always the seafarer who is considered. This paper stresses that human error affects all in the industry not just the seafarer. The industry has attempted to address 'seafarer error' and has developed, with the help of the airline industry, programmes such as Bridge Resource Management. However, a deeper understanding is required.

Behind human error is a wide subject area, 'the human element'. While the shipping industry first considered the human element 15 years ago, some aspects of its application to the industry have not progressed to a conclusion. These include technical factors such as the reliability of equipment and the design of control interfaces and organisation factors such as workload, complexity and commercial pressure.

The paper aims to explain why the shipping industry has not fully considered what's behind human error and what steps can be taken to remedy this with the view of improving safety in the shipping industry.

This paper is one of four written to support the IMarEST Livestream 'What's Behind Human Error?'. Other papers will discuss the individual, technical factors and organisational factors

Keywords

Human Element, Human Contribution, Seafarer Error, Resilience, Human Centred Design, Organisational incidents.

Introduction

Shipping safety has, generally, improved over the last forty years. Improvements have resulted from improved hardware, procedures and improved training and competency.

The way these 'ingredients' have been mixed has changed substantially over this period and to understand this requires an understanding of the history.

Improving Safety-The Last Forty Years

Figure 1 illustrates the improvement in safety over the last forty years. While the improvement is good news the absolute number of total losses, if translated into the airline industry, would reflect the loss of one airliner every two weeks. Pomeroy 2018. Research by The Seafarer's International Research Centre suggests that while the rate of fatalities has reduced, a seafarer on a UK flag ship is still 12 times more likely to suffer a fatality than the average in UK industry. Further improvement in safety is required.

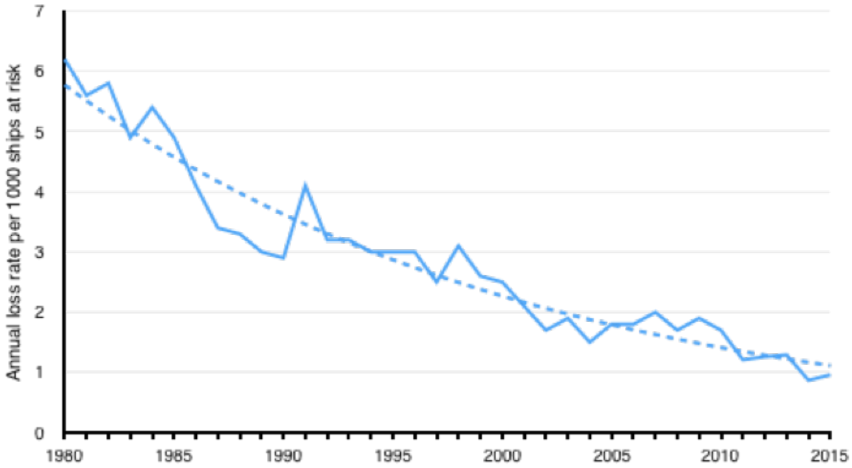

Figure 1 Ship Total Loss Rate 1980 to 2015 (source Pomeroy)

Loss and accident rates may vary considerably by flag, trading area, vessel type and age of vessel. To ensure consistency in the narrative, and due to the authors familiarity with the sector, this paper focusses on the oceangoing tanker sector.

Figure 2 shows incidents in the tanker industry. Both the amount of pollution and the number of incidents has reduced. The reduction in accidental pollution from tankers is particularly creditable and has much to do with the introduction of the double hull. The protection of

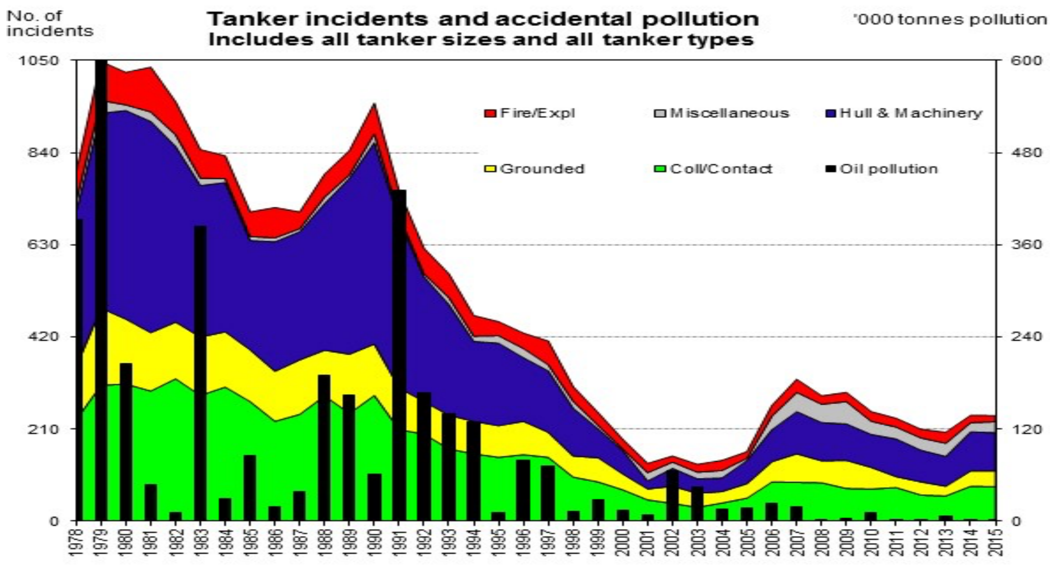

Figure 2 Oil Tanker Incident Statistics (Source Intertanko)

double hull is limited in high energy collisions, as illustrated recently in the 'Sanchi' incident, emphasising that prevention of incidents continues to be vital.

Beyond 2003 the absolute number of incidents increased, albeit in an expanding fleet. Adjusting for fleet size it seems likely that incident rates have increased slightly.

The reducing accident rates above may be considered a proxy for reduced risk. How has this reduction been achieved?

Reducing Risk in Shipping

The shipping industry can be seen as a complex adaptive system (Johnson 2007 Chapter 1). Such a system adapts to changes in the context and environment as well as to the needs of its stakeholders. Changes in society, trade and technology over the last forty years have caused the shipping industry to evolve.

It seems likely that the industry developed in phases rather than as one continuous trend. Figure 3 illustrates a model of the reduction of risk over time.

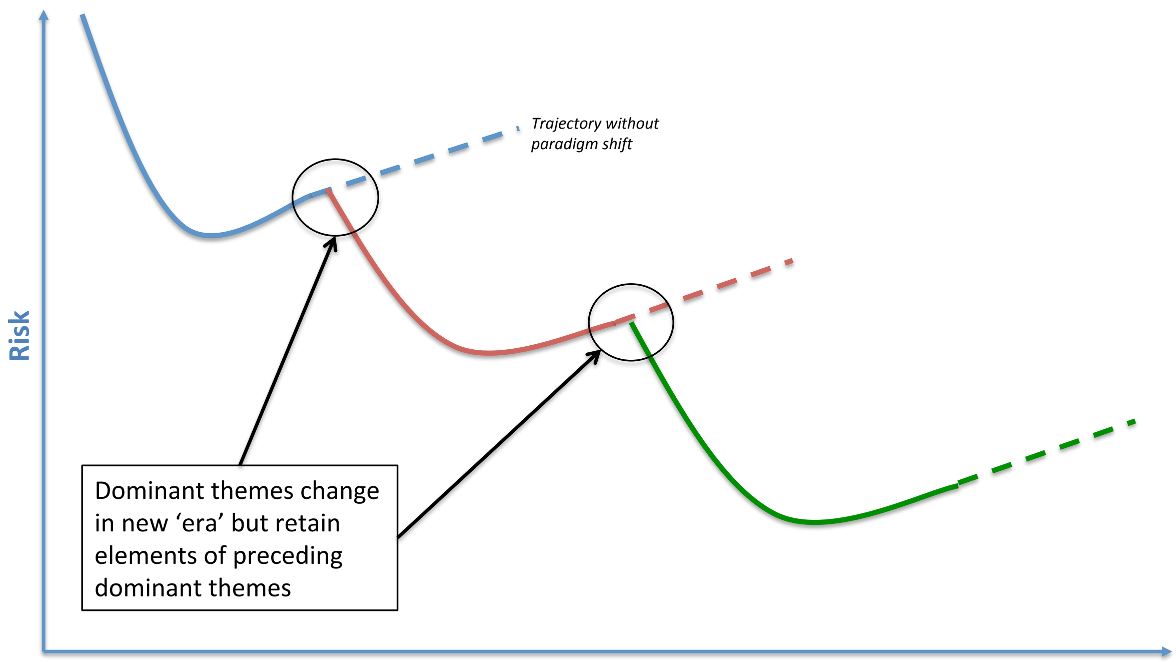

Figure 3 Reduction of Risk Over Time (Author)

Each phase or era is underpinned by a paradigm exhibiting dominant themes or characteristics. The success of that paradigm in reducing risk encourage wider adoption.

Over time, either as a result of the 'law of diminishing returns' or due to a change in the operating or industry environment, the paradigm become less effective. Continuing reliance will mean expending more resources for a smaller result. This may result in taking resources from other areas which, in a resource constrained industry such as shipping may cause risk to increase.

Eventually incident trends, possibly reinforced by high-profile events, will highlight the need for a new paradigm. The 'paradigm shift' will not be a sudden event, it will evolve over time and will take some of the components of the previous paradigm along with it.

It should also be stressed that the shipping industry does not evolve uniformly and in different geographies and industry sectors the timing of the paradigm shift will vary and older paradigms may endure. This may be particularly the case in non SOLAS regimes.

Paradigms and Era's.
The figure below illustrates industry evolution showing paradigms underpinning three era in the tanker industry.

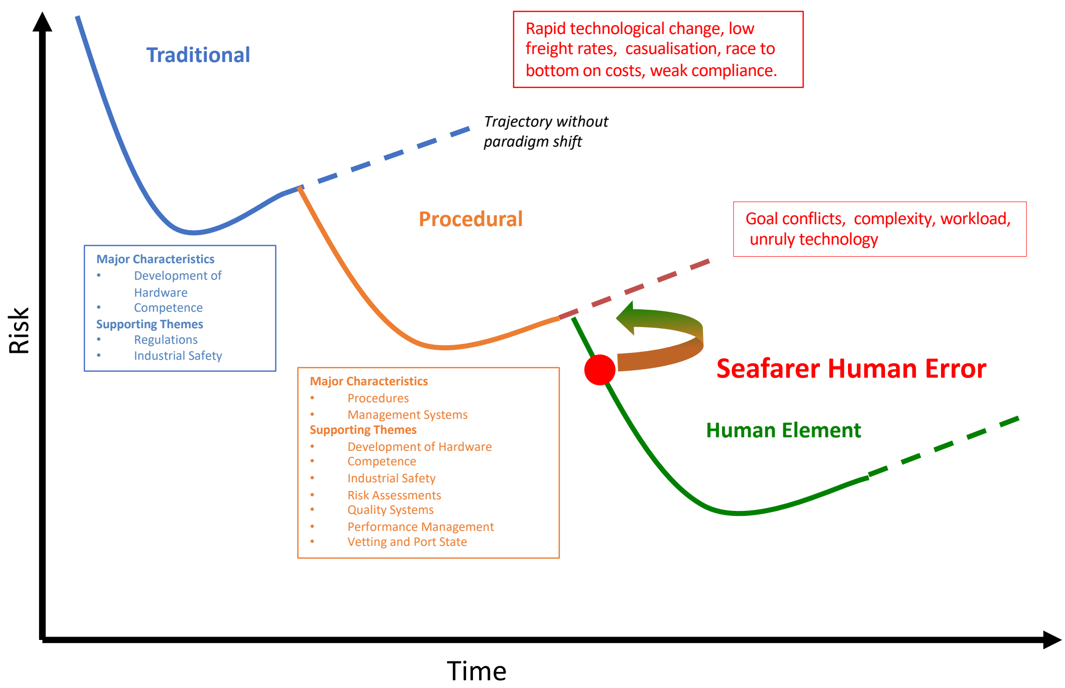

Figure 4 Changing paradigms (Author)

'Traditional'
The first paradigm is described as 'Traditional'. The discussion in this paper focusses on the end of that period, which marks the beginning of the 40 years covered in the narrative. Earlier periods are neglected.

The major characteristics of this paradigm were a focus on developing hardware and a reliance on the 'competence' of the seafarer.

Development of Hardware
In oil tankers, for example, there was a gradual evolution of ship design from midships accommodation, cargo ballast tankers with open loading to a safer all aft, SBT unit with closed loading, inert gas and crude oil washing.

Navigation equipment evolved from visual sights of coastal features, celestial navigation and dead reckoning to the use of collision avoidance radar, Loran and Decca Navigator and ultimately satellite navigation.

Propulsion systems evolved from mostly steam to predominately motor vessels. Systems became increasingly automated and monitored. Automation was generally pneumatic and simple electric/electronic.

Competence

The relatively slow rate of technology development meant that competence could keep pace. An engineer studying for his certificates of competency could expect to study equipment that they were familiar with and use that knowledge onboard when they returned to sea. Ships had relatively large complements and watchkeeping facilitated training and mentoring. Longer 'trips' increased familiarity. In the tanker industry, the 'oil majors' and other specialist tanker owners maintained large, generally homogenous, fleets with large pools of competent, staff.

Supporting Themes

In this era, knowledge was contained in 'regulations' rather than procedures. The distinction being that regulations stated what should not be done rather than explaining how things should be done.

Industrial safety philosophy was introduced into the shipping industry in the 60's and 70's. A full explanation of industrial safety has no place in this paper but the following were important developments: -

- The accident triangle, which implies a causal link between near misses, minor incidents, major incidents and fatalities. A discussion of the limitations of this model can be found in Chapter 3 of Hollnagel (2014). Understanding of the accident triangle encouraged reporting beyond that required by law and introduced near miss reporting.
- In the UK shore legislation, such as the Health and Safety at Work Act (1974) inspired the development of safety committees, safety training, safety regulations and inspections as well as the Code of Safe Working Practice for Merchant Seaman.
- In the tanker industry the 1st edition of the International Safety Guide for Oil Tankers and Terminals (ISGOTT) codified best practice.

The 'Traditional' to 'Procedural' Transition

The large number of tanker pollution incidents in the 80's and 90's, shown in Figure 2, encouraged the transition to the 'Procedural' paradigm. Passenger ship incidents in the early 90's were also a factor and influenced the development of the International Safety Management Code (ISM).

In the tanker industry, these incidents had their roots in changes to the trading model following the oil price 'shocks' in the 1970's. These 'shocks' resulted in global recession leading to reduced oil consumption and lower freight rates. The industry model evolved from one of integrated supply chains, using owned and time-chartered vessels, to a trading-based system using spot vessels. This system recognised no differentiation in operating quality and the long period of low freight rates resulted in cost pressure which found weakness in flag and class compliance regimes. Cost pressure led to reduced manning, 'casualisation' of ship's crew and loss of competence and experience. Maintenance suffered as ships aged and were not replaced. The increasing pace of technology change meant that the relatively few new ships entering the fleet were a step change over those they replaced. This presented a challenge to the already undervalued crews. Many companies that clung to the previous paradigm and its higher cost model went out of business.

The stage was set for industry to adapt and move on to the procedural paradigm.

The 'Procedural' Paradigm

In the tanker industry the move towards procedures started in the 1980's, ten years before ISM was implemented in the late 90's.

The procedural paradigm evolved from the 'scientific management' model prevalent in manufacturing industry, as evidenced by the adoption of ISO 9001 quality systems. The underlying assumption was that a task may be deconstructed and analysed to produce instructions which can be easily followed by a minimally skilled operator to deliver a repeatable result. Following these procedures would improve safety. There may have been an implicit view that 'deskilling' the seafarer could be tolerated if procedures were provided.

The emphasis on procedures, however, did not eliminate the development of hardware as illustrated by the transition to double hulled tankers (triggered by the Exxon Valdez incident) Nor did it result in the neglect of competence as demonstrated by further developments of STCW. The integration of industrial safety concepts also continued.

The 'Procedural' paradigm had a number of components, with particular reference to the tanker industry: -

Safety Management Systems

The International Safety Management Code (ISM) set expectations for safety management systems in the shipping industry. It did not, however, create a standard delivery methodology. The tanker sector, encouraged by charterers, introduced 'quality management' to manage delivery of ISM and underpin compliance.

Performance Management

Performance management systems, a prominent feature of the business environment in this period, were expanded to include safety indicators both as input (numbers of inspections, numbers of investigations etc.) and output measures (lost time injuries, fatalities etc).

Risk Assessment

ISM emphasised 'risk assessment' as a proactive adjunct to the more reactive accident investigation.

Vetting and Port State Control

Uniquely, in the tanker industry, charterers concern about liability created a system of vetting approval. The 'stick' of 'vetting approval' enforced compliance to statutory requirements as well as with ISGOTT and other tanker industry best practice and guidance. Port State, concerned about the risks to their ports, citizens and coastlines, also provided enforcement across all vessel types. 'Enforcement' created a consequence for non-compliance.

Evolving Themes

The early 'procedural' era was characterised by a focus on safety and oil pollution avoidance. Later in the era increasing concern for the environment resulted in new environmental legislation on such areas as CFC's, biofouling, emissions, greenhouse gases and ballast water treatment. Following '9/11' the ISPS code was created which also required integration into management systems. The rise of piracy in the Horn of Africa and other areas also created new process. There can be little doubt about the importance of these issues but their inclusion in the management system created further workload, complexity and goal conflicts.

The Transition from 'Procedural' to 'Human Element'

The introduction of the 'Procedural' paradigm was driven by physical events. The next step was less dramatic. Reporting, backed by performance management systems, drew attention to the fact that 'continuous improvement' in safety metrics had 'stalled'. As can be seen in Figure 2, in the tanker industry this happened in the early 2000's. The industry turned to the study of human error and the human element.

Before discussing the human element, we should consider whether the procedural paradigm worked. Clearly the answer is yes, at least initially, as can be seen by the remarkable reduction in tanker incidents. But as with the previous paradigm the law of diminishing returns took control. This is illustrated in Figure 5.

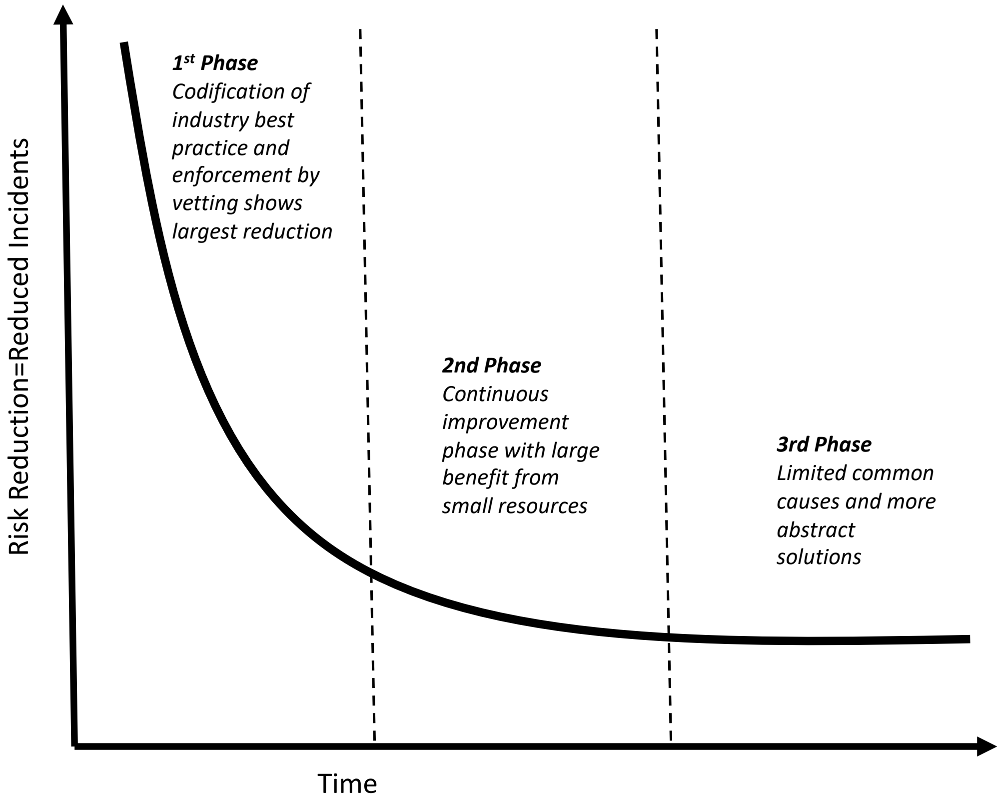

Figure 5 The law of diminishing returns (source author)

The 1st phase of the 'Procedural' era re-introduced rules and best practice that had been neglected over the previous 10-15 years. In the tanker industry, vetting inspections revealed smoking, welding and hot work as well as poor chart corrections and passage planning. Over a relatively short period of time under the threat of losing vetting approval, these poor practices were stamped out reducing the number of incidents.

Having (re-)integrated generic industry knowledge into their management systems, in the second phase, owners began to benefit from their own reporting and improvement systems. The amount of data helped identify common causes which, when rectified, could address a number of potential risks thus 'leveraging 'safety performance.

The third phase was characterised by low levels of reported incidents and limited data to draw conclusions from. Incidents were often unique with no wider learnings to be drawn. Investigation became more sophisticated and often causes and actions became more abstract. This drew attention to the only remaining common factor, the 'human element'.

As well as identifying the importance of the human element, there were a number of issues recognised with the procedural paradigm: -

Goal Conflict

Goal conflict may cause poor decisions which result in incidents. The classic goal conflict is safety versus profit explained in Reason (1997). After a period of about 10-15 years of focus on safety, the shipping industry faced an increasing number of new goals as illustrated in figure 6.

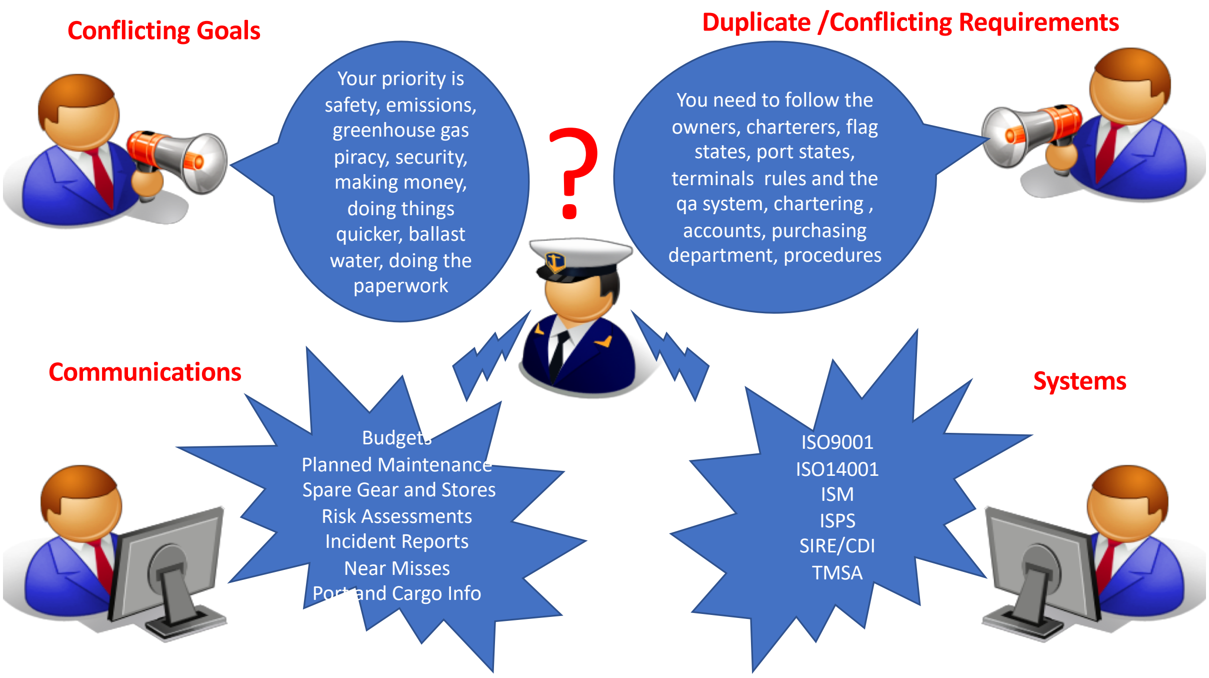

Figure 6 Goal Conflict (Source Author)

Workload, Complexity and Complex Adaptive Systems

There has been a great increase in the understanding of complexity over the last twenty years. There is a growing body of knowledge of the impact of complexity in industrial accidents. (Perrow 1984) Complex systems are difficult to understand and changes made may often have the opposite effect to that intended. This will be discussed further in a companion paper.

Technology

A feature of shipbuilding is that every ship is a 'prototype'. Lack of standardisation in the industry, combined with smaller crews and shorter trip lengths reduced the understanding of vessels and their equipment. Reliability of equipment has also reduced.

The Human Element Paradigm

What is the human element?

The IMO's vision and goals for the human element includes the following statement: -

The human element is a complex multi-dimensional issue that affects maritime safety and marine environmental protection. It involves the entire spectrum of human activities performed by ships' crews, shore-based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties, all of whom **need to cooperate to address human element issues effectively** *(IMO Res. A 947(23)).* This statement was produced in the early 2000's and was supported by other IMO circulars and process.

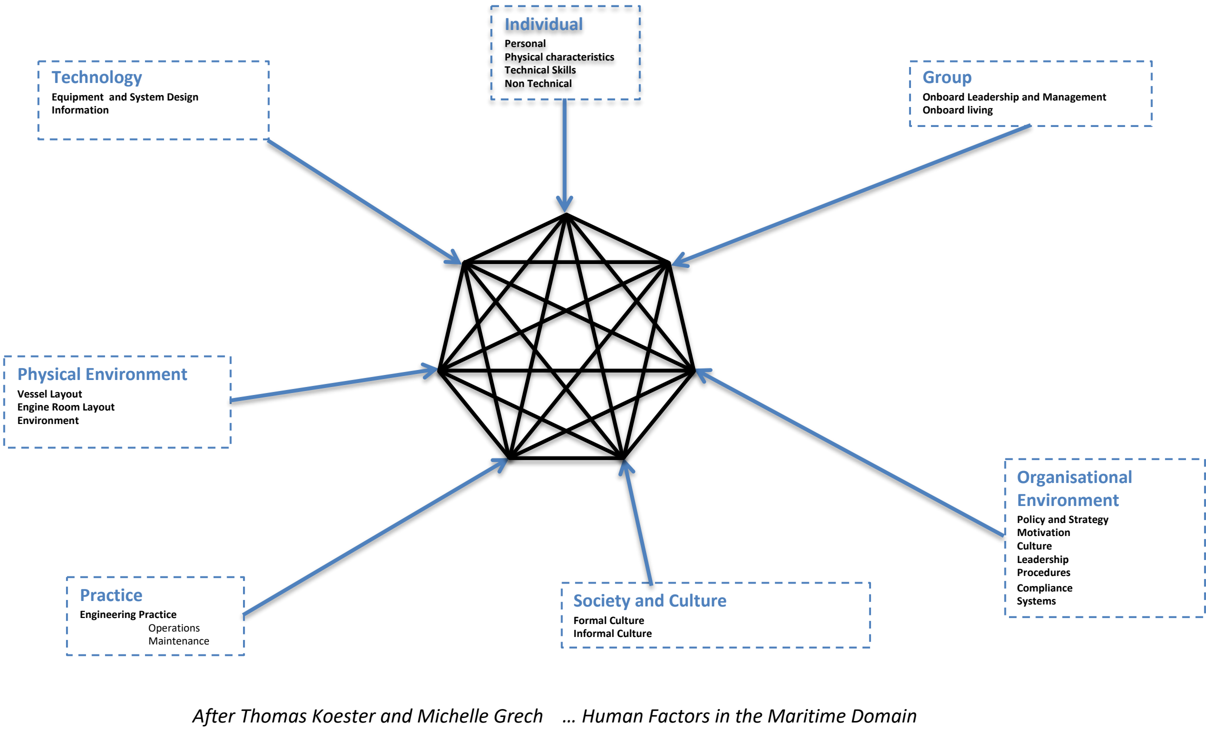

Figure 7 The Human Element

The above figure illustrates human factors in the maritime domain. There are a number of key points which support the IMO definition. All the 'cardinal points' are linked and each influence the other. A change to one affect all.

The individual, the seafarer, is only one piece of the puzzle and if considered in isolation it Is easy to create a blame culture to explain seafarer error. The seafarer is part of an organisational environment created by the ship manager and this reflects in the onboard organisation, the company's processes and culture. Organisational culture is not optional. If the organisation does not deliberately create and reinforce a culture then an informal culture may develop. The mention of 'Practices' is interesting because they are, to some degree, informal understandings passed on orally and the mechanism by which that takes place currently is not clear.

The seafarer may be a 'victim' of the technology and the ships layout and design. The drive for cheaper ships may result in a ship optimised for 'performance' and not for operation. Control console interfaces may be poorly designed and, in many cases, unique to that ship/installation. The aviation industry has had a standardised layout for the main instruments for about half a century which the shipping industry could learn from.

An understanding of this model provides a real opportunity to move safety forward in the marine industry.

Where are we now?
So, have we entered the era of the 'human element'?

In the authors view, the shipping industry commenced the journey but has become 'stuck' at seafarer error. While new tools, such as bridge resource management, have been created and understanding of human error has been improved the industry has stopped short of addressing the organisation and technological factors mentioned previously. Incidents investigations, in many cases, still generate procedural solutions and blame.

Why has the human element not progressed in the shipping industry?
There are many reasons why the shipping industry has not embraced the human element.

There is little wrong with IMO's vision statement above. The problem is that delivery has stalled over the last ten years although some flag states and industry groups are independently making progress.

It is clear the blame culture predominates with major incidents. This often leads to criminalisation of seafarers. Liability regimes may also encourage blaming the seafarer rather than running the risk of a breach of 'limitations' by suggesting the owner's management system is to blame. Performance management systems can encourage a blame culture where companywide performance measures are linked to a bonus.

The Safety/Cost tension also plays its part. It is perceived that introducing Human Centred Design and improving reliability would be costly. On the other hand, standardisation could reduce costs as well reducing accidents. There is an irony that equipment suppliers are proposing high cost solutions such as autonomy instead of relatively modest investment in improving existing machinery.

Finally, it should be said paradigm shift is not easy. The old paradigm is well established and invested in. Attempts to evolve may be met by the 'if it ain't broke don't fix it' argument. Existing statistics will be capable of re-analysis to prove the paradigm is robust but the application of it is not. More and more detailed analysis and more and more complex and expensive solutions may be generated to maintain the status quo. The procedural paradigm is a strong one to break free of.

Seafarer Error or Seafarer Contribution?
Is the seafarer an 'error prone component' or the only 'hero' that allows a modern ship to work.

It is naïve to suggest that seafarers do not make errors, just as it is naïve to suggest that seafarers are the only humans in the system that make errors. Are those who specify, design, build, test, classify and provide management not humans prone to error?

As James Reason said in 1990: -

Rather than being the main instigators of an accident, operators tend to be the inheritors of system defects created by poor design, incorrect installation and bad management decisions. Their part is usually that of adding the final garnish to a lethal brew whose ingredients have been long in the cooking.

Simplistically, we are looking at two views of ship operation. In one view the seafarer is provided with a perfectly designed, functional ship that is easy to use and procedures that are models of clarity. If he follows the procedures nothing will go wrong and anything that goes wrong is because of some wanton desire to rebel. This is the world of 'work as imagined' (Hollnagel 2014 pp 40-41.) and focusses attention on seafarer error. The other view is that ships are far from perfect and reflect compromises between costs, operability and safety. Management systems are also imperfect and reflect compromises, goal conflicts, resource constraints, liability and legal concerns. Human error exists in all parts of the system, not just at sea. This is the world of 'work as done'. In this world the only reason a ship operates is because the seafarer is constantly supervising, managing, adjusting and maintaining it. My own experience of fleet management is that seafarers save the day more often than they are the sole cause of incidents. As an analogy, the 'goalkeeper' may have a high 'saves' to 'goals' ratio but only the goals scored against him are remembered. The rest of the football team determines how many times the goalkeeper has to make a save so how do we get the rest of the team to contribute more and keep the ball away from the net!It is interesting to note the final paragraph of James Reasons book on the Human Contribution.[i]

'After studying human unsafe acts within hazardous enterprises for more than three decades, I have to confess that I find the heroic recoveries of much greater interest and in the long run, I believe potentially offer more to the pursuit of improved safety in dangerous operations'

Why has the human as 'error prone component' view persisted in the shipping industry where other industries, notably aviation, have rejected it?

Conclusion. How do we find out 'What's Behind Error?'
A new paradigm is not required. The human element brought up to date is adequate and consists of creating an integrated approach to the organisation, the ship and the seafarer, a 'human centred approach'

The industry needs to take account of the organisational factors behind seafarer error and consider the seafarers workload. We need to consider the limitations placed on the seafarer by organisation requirements

Technology discussion needs to focus on improving the equipment provided to ships today. Reliability and interfaces need to be improved. Suppliers need to take on more ownership of their equipment. When you can get a ten-year warranty for a car why do ships have 1-2-year guarantee period,

We need to help the seafarer to increase his resilience. We need to invest more in training to deal with modern technology and its inbuilt problems.

Finally, we need to respect the seafarer as a professional, as the final barrier between hazards created by the whole industry and disaster, and as the ultimate goalkeeper.

References

Bloor M (2008) Fatalities at Sea: the good the bad and the ugly. 'The Sea' Issue 194

Grech MR, Horberry JT, Koester. (2008) Human Factors in the Maritime Domain. Taylor and Francis. Chapter 1 Page 9-32.

Hollnagel E. (2014) Safety I and Safety II. Ashgate.

Johnson N. (2007) Simply Complexity: a clear guide to complexity theory. One-world. Chapter 1.

Reason J. (1997). Managing the Risk of Organisational Accidents. Ashgate. Chapter 1. PP 3-6

Reason J. (1990) Human Error. Cambridge University Press.

Reason J. (2008) The Human Contribution. Ashgate. Chapter 1

Perrow C. (1999) Normal Accidents, Living with High Risk Technologies

Pomeroy (2018) Presentation for IMarEST Livestream 'What's Behind Human Error?'