What's Behind Human Error? -- Organisational Factors

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Introduction

This paper looks at the organisational issues that may lead to seafarer error. These issues can be created at an industry or shipowner level and may manifest themselves in the operating environment aboard ship and in the attitudes and behaviours of those aboard. It is important to note that this paper uses the term 'seafarer error' when referring to error on board ship. It is obvious, but sometimes forgotten, that human error is a feature in all parts of the shipping domain.

Much of the analysis in this paper is drawn from the tanker sector the conclusions have value across the wider shipping industry.

Organisational Factors

The understanding that organisational factors can influence safety is not a new conclusion. The longest Chapter in Perrow (1984)[i] is devoted to Marine Accidents. Perrow's book highlighted the increasing dangers of complex technology and complex organisational models. He also introduced the concept of a 'Normal Accident' which suggests that even when the operator follows all normal procedures the complexity of the system can cause an accident to take place. Reason (1987)[ii] included 'organisational factors' in his 'Swiss Cheese model of accident causation (Figure 1)

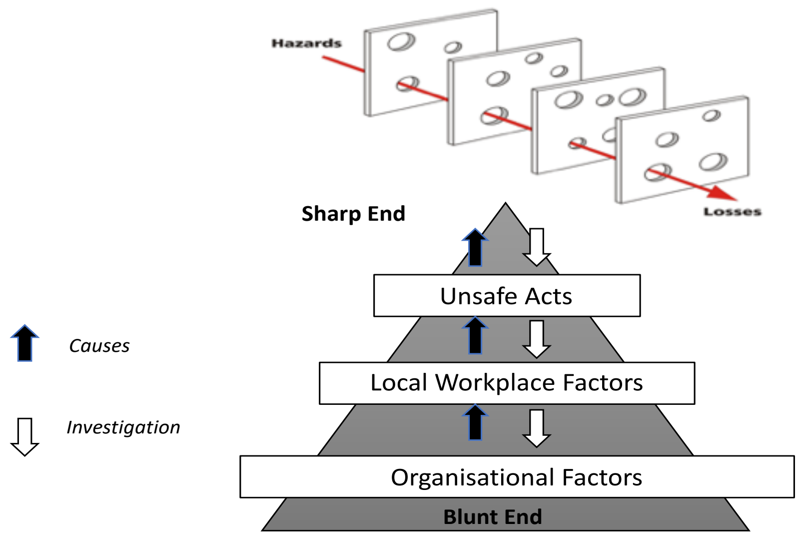

Figure 1 The Swiss Cheese Model (Reason 1997)

Reviews of the space-shuttle disasters highlight organisational factors within NASA that contributed to those events, as do reviews of the Texas City and Deepwater Horizon incidents[iii].

In the shipping industry the formal report of the enquiry into the loss of the Herald of Free Enterprise[iv] highlighted a number of organisational factors. This enquiry was one of the pre-cursors to the International Safety Management Code.

The Safety/Profitability Conflict

A major organisational factor is the conflict between safety and profitability.

The figure below [v], based on Reason 1997, illustrates the balance between Performance (Reason uses Production) and Protection, and is modified to reflect the tanker sector.

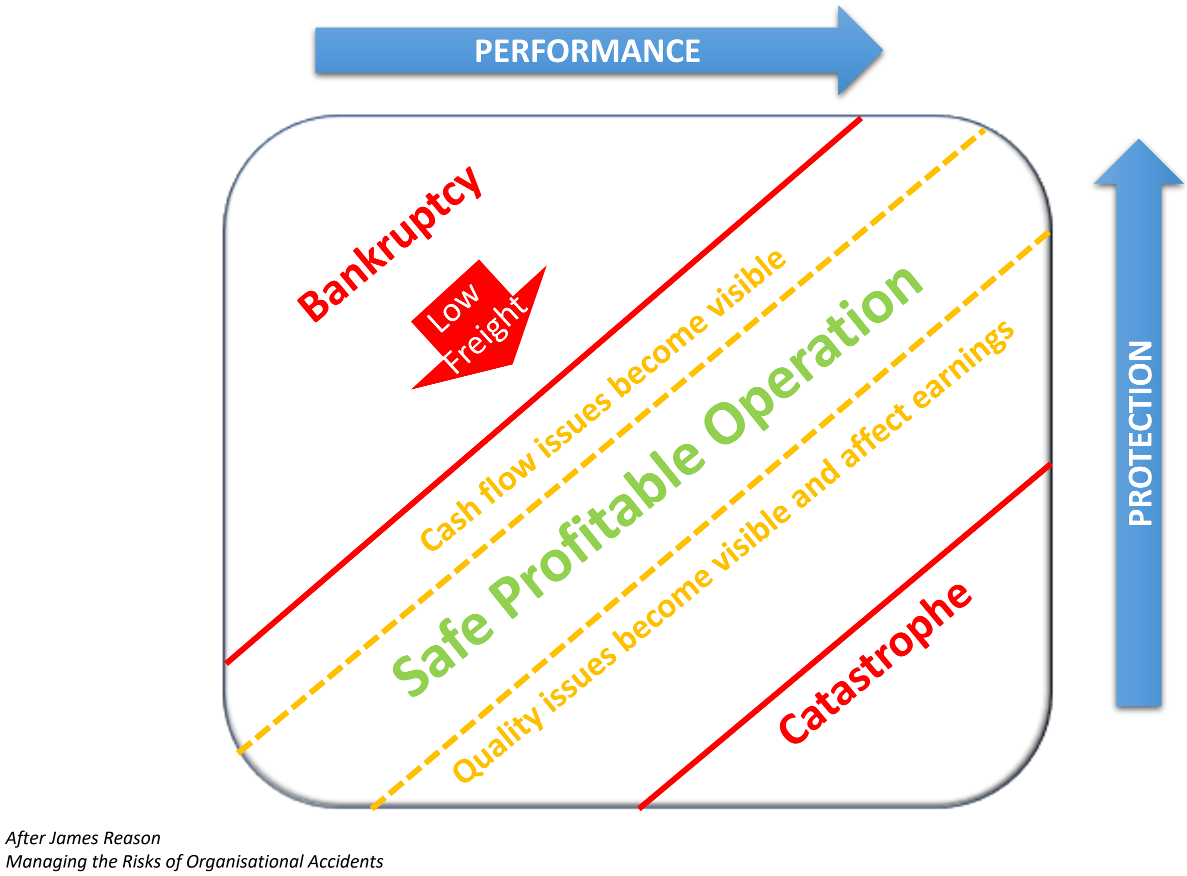

Figure 2 Protection Vs Performance

The shipowner navigates between the perils of catastrophe and bankruptcy. In fact, companies need to do more than avoid bankruptcy, they need to be profitable. While it is possible to predict, with (possibly spurious) accuracy, financial results it is seldom possible to predict a, hopefully rare, serious accident. Over a period of time without serious incident (what Reason calls the 'unrocked boat'!) the company may gradually reduce protective barriers to such a level that a serious incident happens. Resources available for 'protection' may be further reduced by low freight rates. This is often called 'Drift to Failure'. [vi] Following a major incident, the organisation, if it survives, may be forced to invest heavily in protection as with BP following the Texas City Refinery Explosion[vii] Investing in protection at the right time can save massive costs later.

There are many further models and examples that illustrate this drift and inform the whole subject of organisational incidents.

The Procedural Paradigm

In a previous paper the author [viii] suggested that the shipping industry adopted a procedural paradigm following serious tanker and passenger ship incidents in the 80's and 90's. There are three major components to this paradigm: -

The International Safety Management Code

The International Safety Management Code (ISM) was introduced by IMO in the 1990's. ISM reinforced the ship managers ultimate responsibility for the safety of the vessel as well as supporting the Masters responsibility.

The Code also required the creation of operating procedures, maintenance systems, compliance systems. The owner was required to provide resources for safe management.

The Code also created the Designated Person Ashore (DPA) to ensure that concerns raised by those aboard ship were properly addressed and that resources are available for 'protection'.

The components of the systems had to be subject to audit both internally within the shipping company and by the Flag State.

While ISM mandated the need for a safety management system, it did not specify the system. This was left to the discretion of the shipowner.

Quality Management Systems

At the same time that ISM was being created, some sectors were already introducing ISO 9001 quality systems, mainly to deal with product quality. The combination of ISM, which set expectations, and quality systems which could be used to manage, communicate and verify those expectations became the standard. The early systems had their origins in production and were not specifically designed for the shipping industry. Nevertheless, they were widely adopted. Quality systems created a language which was, initially, alien to seafarers.

A central theme of the quality system is to be able to demonstrate 'continuous improvement'. ISM only uses the expression once and that relates to the development of skills. In most systems, however, it was the 'continuous improvement' of process that was encouraged and audited. The ISO 9000 model has developed significantly since the early versions used in the 1990's.

Industrial Safety Model

ISM created expectations for safety. Quality management systems provided a means to deliver on expectations. There was a need to translate the expectations into system objectives. This was done by importing the industrial safety model including safety reporting and investigation underpinned by the accident triangle.

The accident triangle is based on research on incidents attributed to Heinreich in the early 21st century. The original premise was that there was a relationship between fatalities, major and minor accidents and that analysis of minor accidents followed by remedial action would assist in reducing major accidents and fatalities. Over time 'near misses' were added to the bottom of the pyramid. One version also includes 'material damage'. In general, as a result of the data available, much analysis and monitoring effort was expended on occupational accidents as distinct from 'process safety accidents.' In shore operations such incidents as the Texas City Refinery Explosion drew attention to the fact that addressing root causes related to personal injuries did not address major process risks. Once more the industrial safety model has evolved since the 1990's. While many shipowners take account of this there is an increasing gap between the imported model and latest practice.

The Success of the Procedural Paradigm
As mentioned, the current paradigm is primarily procedural. Has it been successful?

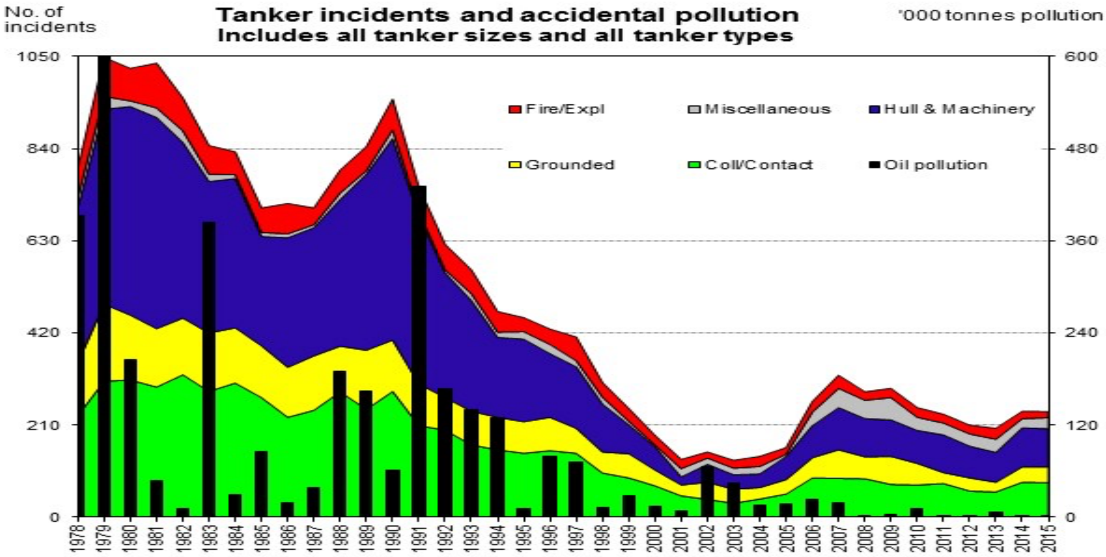

Figure 3 Incidents and Pollution in the Tanker Industry

As figure 3 suggests, the reduction in incidents from 1990 to 2002/2003 is creditable but there is a question as to whether the improvement can continue.

The 'law of diminishing returns', and the tendency to trade away 'protection 'gains to improve 'performance' suggests not. Figure 4 below illustrates this. In the first three phases: -

1. Procedures captured existing learning and ensured its dissemination and compliance reinforced by ship vetting inspections.
2. Owners benefitted from better data and reporting to reduce company level common cause risks.
3. Lower level of accidents and a lack of common causes meant that trends were difficult to identify. Systems still required analysis to generate actions from ever more unique incidents. The, sometimes, abstract causes identified resulted in more process and workload with little reduction in risk. The only common cause that could be identified was human (correctly seafarer) error.

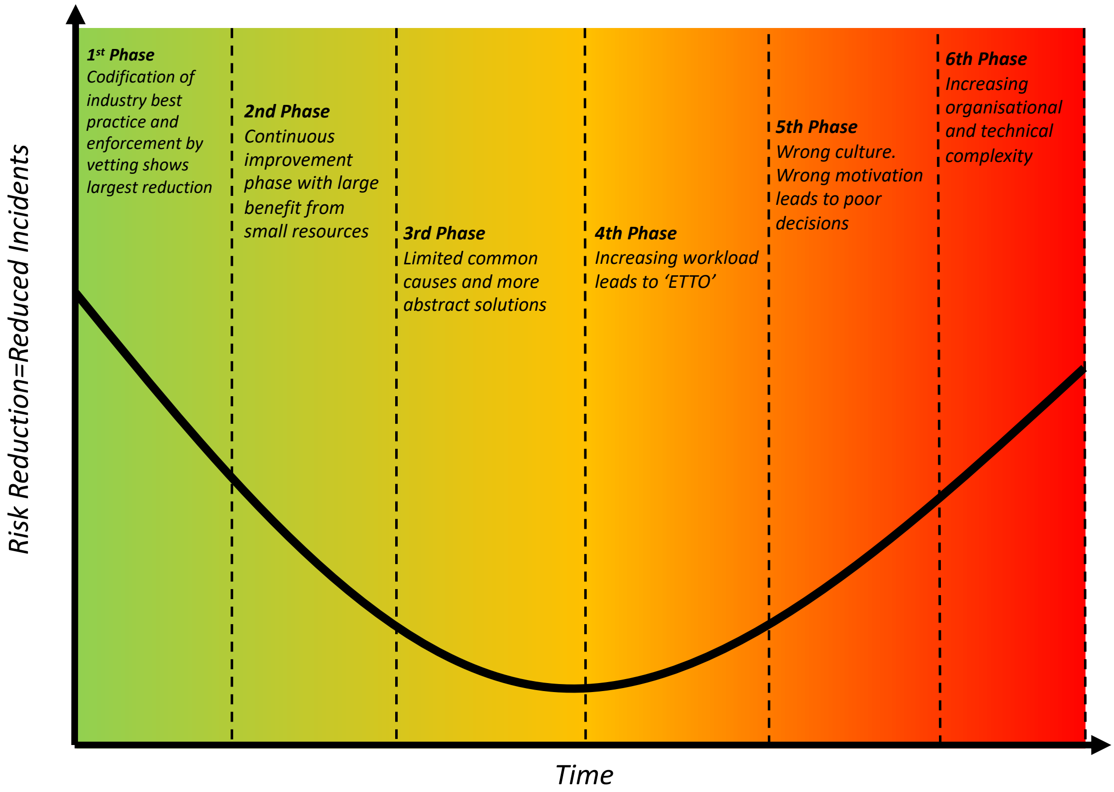

Figure 4 Diminishing Returns followed by Increasing Jeopardy

Unintended Consequences of the Procedural Paradigm

Over time the increasing workload and process, if left unchecked, will increase risk and lead to three further phases: -

4. Excessive workload
5. Flawed decision making
6. Complexity

Excessive Workload
Shipboard workload is the balance between the activity require to operate, maintain and administer the vessel and the onboard resources available. When the workload is too great then the quality of the work carried out will be affected and those involved may become stressed, fatigued and prone to human error.

Excessive workload may drive 'corner cutting' and 'box ticking'. Hollnagel describes this as the 'Efficiency -Thoroughness Trade Off (ETTO)[ix]. This is not, usually, the product of evil intent or negligence, but a coping mechanism to manage an overlarge workload in a limited period of time.

Figure 5 illustrates the type and sources of that workload.

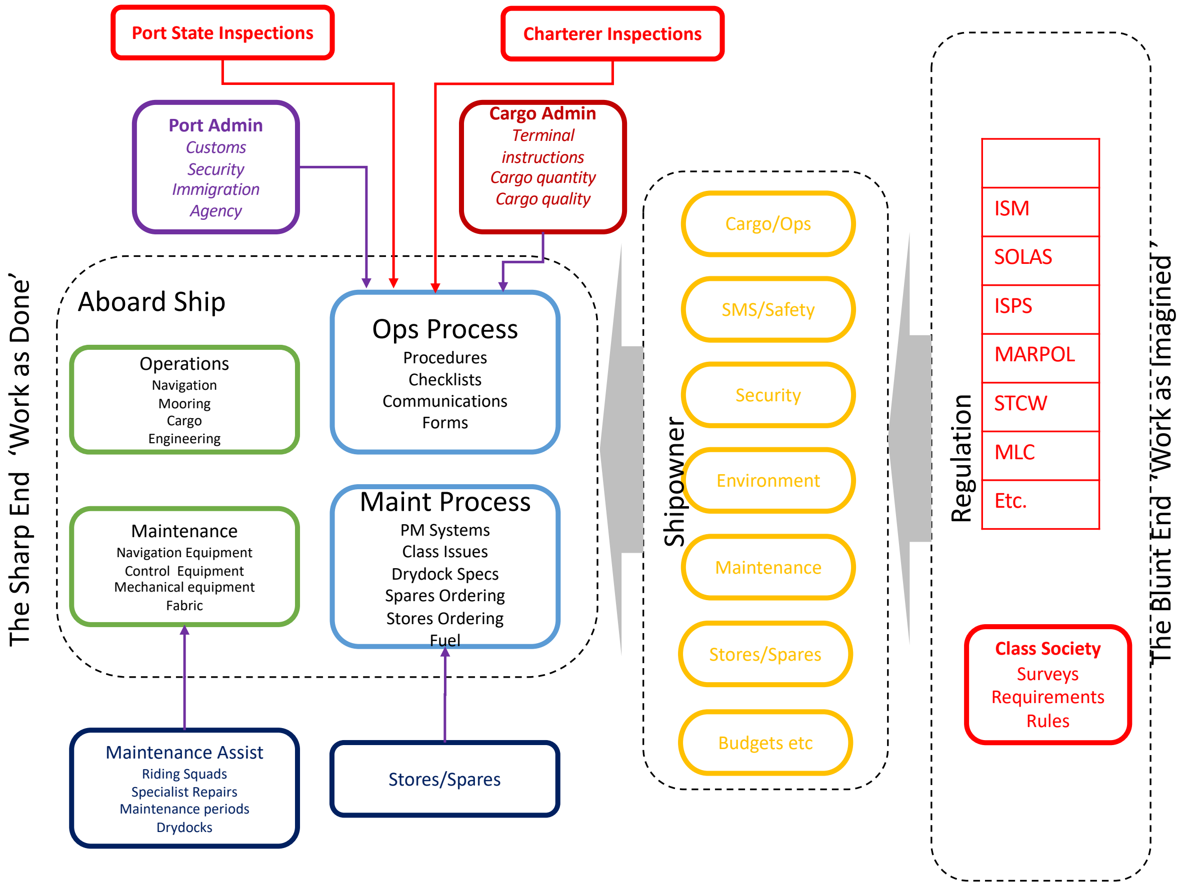

Figure 5 Workload (Source Author)

The figure is to a great degree self-explanatory. A few points should be made.

The Blunt End and the Sharp End
The 'sharp end' is where operations and maintenance are actually 'done', the 'blunt end' where regulations and process are produced to 'control' the sharp end. Hollnagel [x] describes these, respectively, as 'work as done' and 'work as imagined'. His premise is that those at the 'blunt end' may be so remote from the 'sharp end' that they may create process based on a false or outdated view.

Operation and Maintenance

It is not the intention to discuss hotel workload in this paper.

Operations

Workload can be influenced by many factors including trading pattern, intensity of operation, equipment breakdowns and casualties, level of automation and the number of crew. Operational workload cannot be 'sub contracted' and falls solely on those aboard in 'real time'.

Maintenance

Workload can be influenced by many factors including vessel and equipment design, planned maintenance system and reliability of equipment. The same resources are often employed for maintenance and operations so intensive operations may reduce maintenance. Equipment failure not only increases maintenance but may also increase operational workload. This may lead to deferment of planned maintenance leading to further failures.

The shipowner has the ability to support onboard maintenance staff either during port visits or be carried seagoing maintenance teams. Clearly this has a cost.

Operations and Maintenance Process

Much of the admin. falls on the most senior and knowledgeable people on board. This limits the opportunity to lead, mentor, train and observe the condition of the vessel and its machinery.

Cargo and Port Documentation

Cargo documentation is often unique to individual ports and terminals. Cargo documentation must be dealt with quickly as it determines the length of port stays and influences the vessels earnings.

Port and national authorities also demand immediate attention and inspections by port and vetting inspectors also intrude on port time.

The use of technology and such practices as 'single window' make reduce pressure in port.

The Shipowner

The owner has some freedom to make choices that will influence, trade, resource allocation, process management and leadership.

The shipowner is responsible for ensuring the operation is adequately resourced. Resource decisions made by the shipowner can determine manning, training, operating budgets, spares and stores. Decisions related to the safety management and planned maintenance systems will also critically affect workload.

Regulators

Flag states and Class Societies incur substantial administration to implement IMO regulations.

Flawed Decision Making

Decision Making

While excessive workload may lead to 'sins of omission', this section considers the question 'why do competent well-trained people make the wrong decisions?' Decision-making is complex and decisions are often taken with an imperfect view of what the decision maker believes the shipowner wants.

Direction, Leadership and Management

Figure 6 shows a management model of a shipping organisation. The organisation needs to Direct, Lead and Manage. All three functions are required and need to be balanced. Overemphasis of one without the others will lead to unexpected results. An organisation with weak leadership may rely on management process to deliver all results and may create large amounts of, ineffective, process. Overemphasis on management process disempowers front line staff and reduces their resilience. The Procedural Paradigm in the shipping industry encourages the use of management process as the primary 'tool in the toolbox'. This may drive the culture of the organisation.

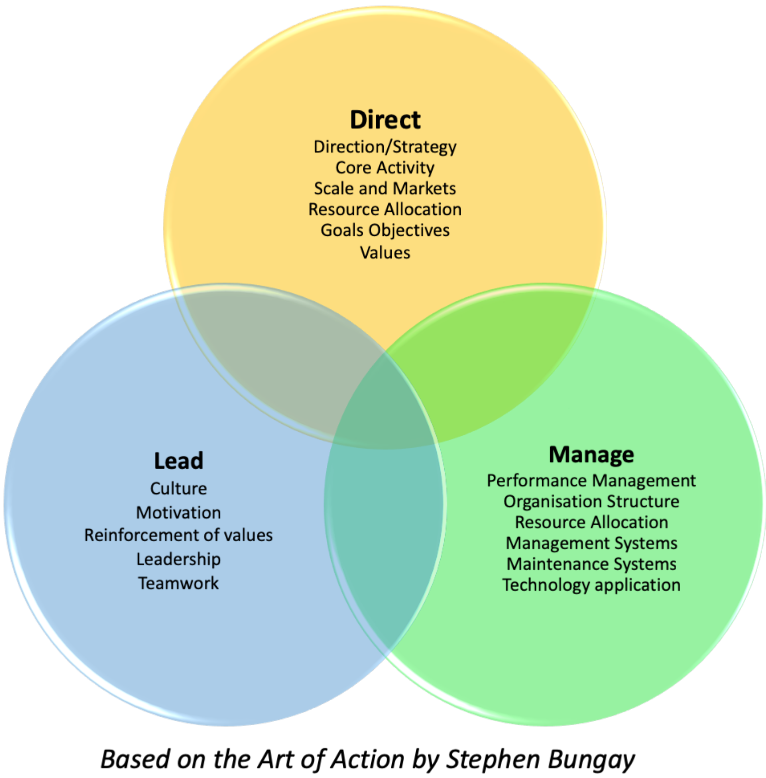

Figure 6 Shipowner Management Model

Culture

Organisations have a culture, the only question is whether it is the culture the leadership intends. Considerable research has gone into the development of safety culture. It is not intended to review this but rather look at the particular issues of culture aboard ship that affect decision making.

Seafarers exists aboard a remote operating unit with limited face to face access to shore senior management. Communication relies on senior officers to have a strong relationship with, and understanding of, the organisations intentions. The organisation may communicate safety as its first priority but by its behaviours emphasise costs or quick turnarounds. Those onboard may be further confused when different messages originate from different departments or levels within the organisation. Miscommunications can easily be shared informally through modern communications and social media undermining the formal message. Bad news travels fast.

Confused communications, inappropriate targets and bonus can undermine the formal culture and reinforce an informal belief that 'what the company really means is…….' In any investigation formal communications about the culture will be emphasised and the informal neglected.

Time Pressure

Ships and ports are high costs assets and their owners wish to maximise their return on investment. Demurrage and 'off hire' costs encourage owner and ports to minimise port time. In a series of intense port turnarounds, possibly involving long approaches in restricted waters those aboard can become fatigued. A responsible owner may allow the ship to incur downtime for crew rest. The crew may have a bonus structure that emphasises 'up time' which may give a hidden message that the real message is to keep going. Once more,when an accident happens, and is investigated, the bonus structure, and the potential for conflicts with procedures, may not be considered as relevant.

Laydays

Contracts that encourage arrival at an anchorage at midnight may interrupt rest and result in fatigue. There is a goal conflict between being on time and not using too much fuel to arrive early. This may result in all daywork staff being on 'stand by' late at night and then being up early to berth the ship. Changing to 1200 hrs Laydays could result in staff being better rested.

Performance Management and KPI's

In parallel with the development of procedures, many companies developed increasingly sophisticated performance management systems. As mentioned above, culture can result from conscious statements or unintentional actions. There is little point in making statements to the workforce that 'safety is above all' when seafarers reward is based on financial performance. This was clearly demonstrated in the banking crisis where traders were motivated to bend the rules and moral hazard and a culture of non-compliance became commonplace.

KPI inspired bonus systems can have mixed results. There can be positive results when the indicator reflects an easily measured metric that the employee can directly influence and where clear boundaries limit deviant behaviour. If, however the metric is 'soft' or loosely derivative of the result required then measurement is difficult. If the indicator is capable of being 'gamed' or cheated then the headline measure may be achieved but with unexpected consequences. For example, a bonus linked to a KPI to reduce injuries may result in a reduction because some incidents are not reported. Where the KPI is linked to, say, lost time injuries a considerable amount of time can be spent 'case managing' to re-categorise incidents.

Blame, Punishment and Liability

Just as motivation can encourage the wrong decisions so can fear of punishment. Clearly fear may also discourage reporting incidents. Over time as 'common cause' incidents reduced and human error became more exposed then tolerance of 'no blame' diminished. 'No blame' was replaced by 'Just Culture' which recognised that some errant behaviour should be punished.

Additionality there is a 'materiality' test for blame. More serious incidents that generate high cost or which cause environmental damage and involve regulators and insurers may move quickly into blame and criminalisation. In liability terms if the owner systems are found to blame then 'limitation of liability' may not be used as a defence. Under such systems the seafarers may be expected to 'take one for the team'.

Goal Conflicts

Figure 7 illustrates the conflicting goals and requirements that the seafarer has to resolve when making decisions.

The 'safety/profitability' conflict was mentioned above; many other conflicts exist. The use of razor wire aboard ships to deter piracy clearly has an impact on the safety of those deploying it and may impeded abandoning ship or rescues.

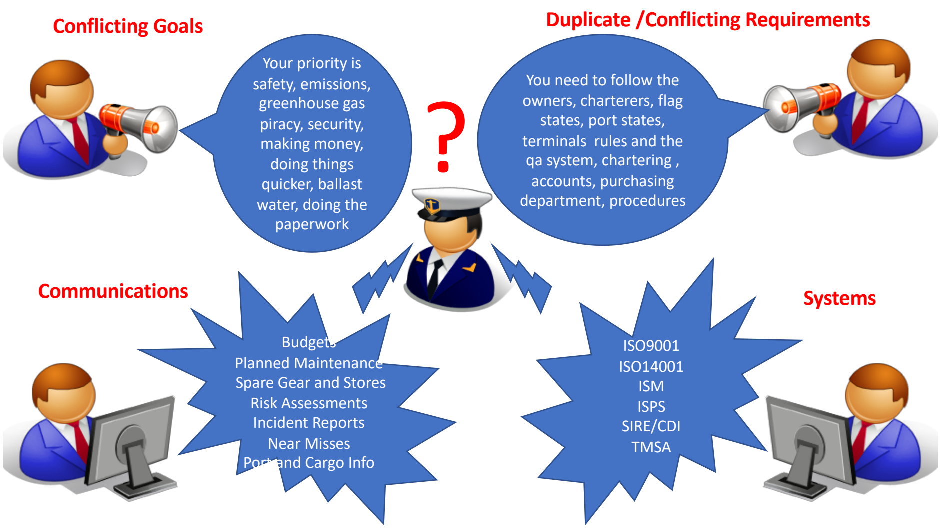

Figure 7 Goal Conflict

The requirements to operate vessels on low sulphur fuels in SECA's introduced in 2010 causes some issues with main engine operation. Most engines were optimised to run on heavy fuel and their design reflected this. Changing from heavy fuel to distillate caused some vessels to lose propulsion power often in restricted water. The potential for incidents and oil pollution conflicts with the longer-term goal of reducing sulphur in the atmosphere.

Complexity

A great deal of research has been carried out over the last twenty-to thirty years into complex adaptive systems. Figure 8 provides some definitions. Perception is important and providing the individual with the right tools and context can improve their understanding and ability to cope with complexity.

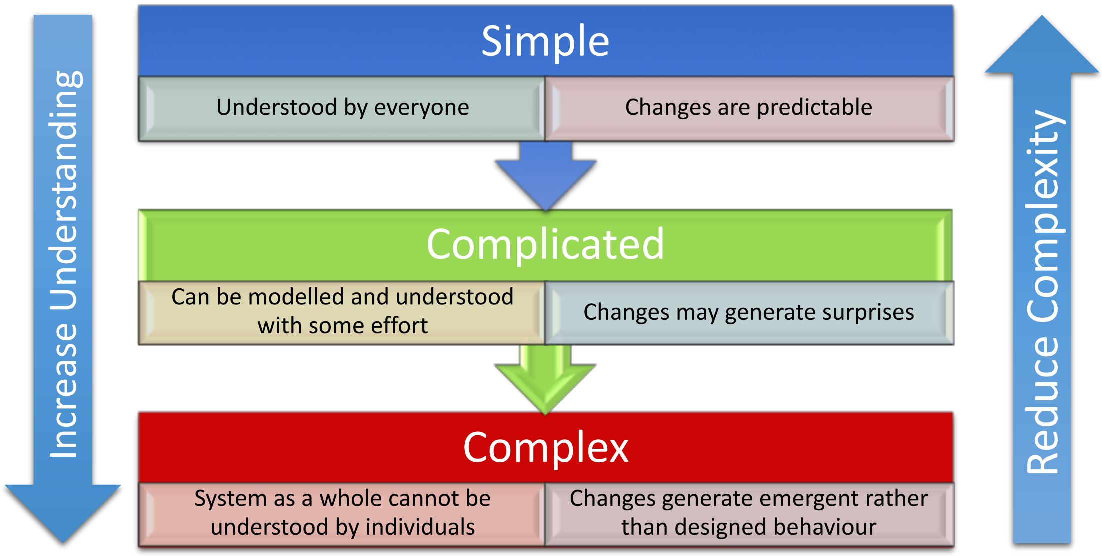

Figure 8 Complexity

Figure 9 illustrates the features and behaviours of complex adaptive systems. The global banking collapse is often seen as an example of a complex adaptive system being adapted to suit the 'agents' in that system. There are numerous examples of organisations whose complexity has resulted in their collapse. Nokia, once the market leader in mobile phones, is seen as an example of when a company suffers from complexity.[xi]

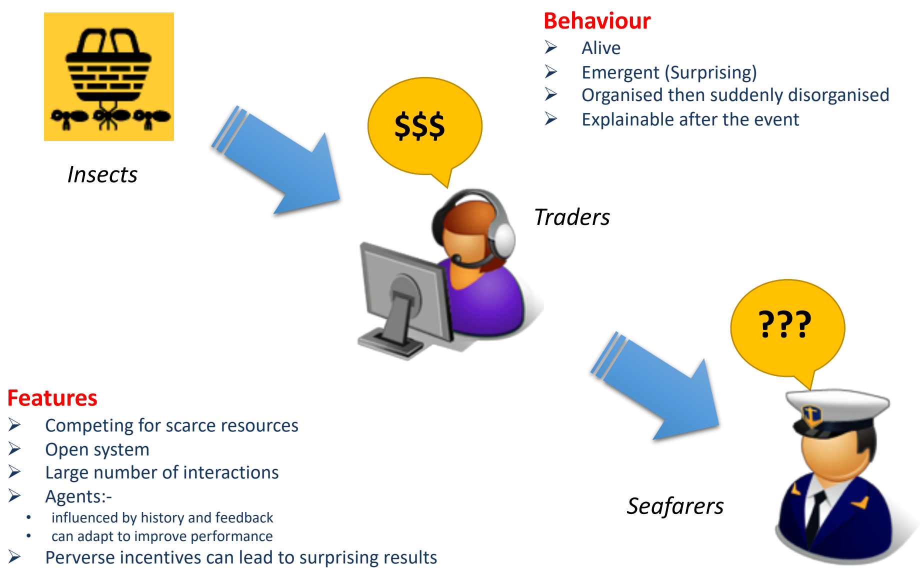

Figure 9 Features of Complex Adaptive System

Shipping Industry-A Complex System?

The shipping industry is a global industry that is part of the international trading system. That interconnectedness results in instabilities within the shipping industry and can create periods of very strong and very weak freight rates. Strong rates encourage building which can often cause market collapse when ships are delivered in a market. Ship operations often operate under severe financial constraints.

How should Industry Regulation work?

It is worth considering how complexity can evolve with a real example. The figure below shows a representation of the regulatory systems that developed to manage safety and oil pollution in the tanker sector. The left-hand side of figure 10 shows the 'designed' regulatory system, which relied, ultimately, on flag states and class societies to set and enforce standards.

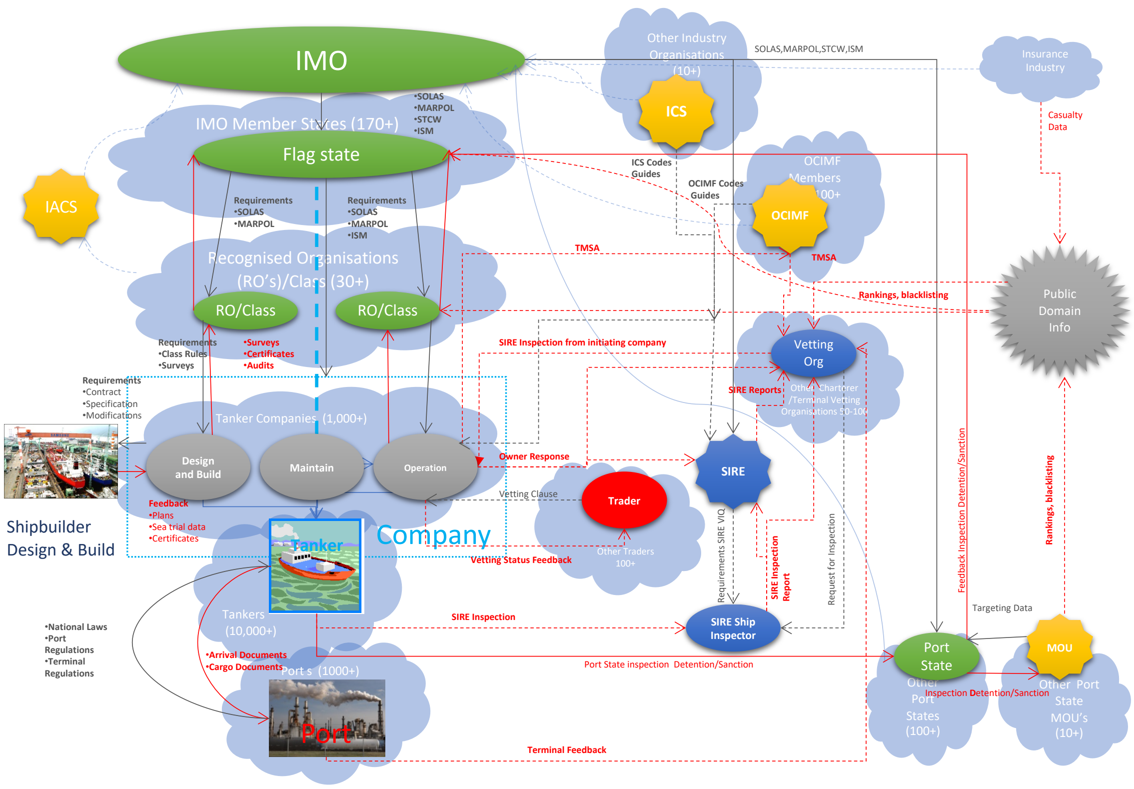

Figure 10 The Tanker Industry - a Complex System?

How does Industry Regulation Work? - The Tanker Sector

Perceived weakness in the designed systems were seen as a root cause of major tanker incidents. In pollution incidents, the clean-up and loss of amenity affected coastal states not flag states. This resulted in the development of a strong port state inspection regime to ensure compliance with international regulations. The creation of regional 'memorandum of understanding' (MOU) leveraged port state by targeting repeat offending shipowners, flag states and classification societies. This created a 'feedback loop' which forced improvement as good shipowners left flags and class societies that were on 'black lists'.

Charterers feared they would be held to account for chartering vessels that subsequently became involved in spills. To avoid incidents on charterers business they created ship vetting systems. Ship vetting systems relied on inspections, audits and data from a variety of sources to decide whether a vessel could be used on oil company business. While compliance with IMO regulations and certification was important, there was substantial focus on industry best practice to avoid fire, explosion and pollution.

Neither port state nor vetting inspection cover the whole of the shipping industry, just those that touch their shores or their business. They therefore do not provide a global solution to ship quality.

Vetting 'acceptability' became a currency for trading and other chartering organisations required owners to maintain a certain number of oil major 'accept abilities'. Originally advice of acceptability for a period of time was routine. This changed after the Erika trial when oil majors stopped advising acceptability. This led to the situation where vetting clauses required something which did not exist. The system continues to evolve with the introduction of the Tanker Management Self-Assessment system.

There is little doubt that the system reduced oil pollution substantially but there were also side effects in the workload created. The creation of 'vetting departments' in shipowners to manage acceptability also created effort. It is sometimes not clear whether owners are running a safe operation or 'gaming' the vetting system. In the latter case the 'preparation' of ships for inspection gives it all away.

Complexity is what Complexity does

The previous section demonstrates how a systems characteristic can 'emerge' to meet the needs of the 'agents' within it. At no point in the 1990's did anyone design the system that emerged. Increasingly we create systems which are often technologically linked. Goals for sub systems are created which influence the operation of the whole system and cause it to evolve further, often in an unexpected way. The creation of an organisations culture is influenced by the goals set for it, the motivation of those involved in it and, often, regulatory requirements. This can result in 'emergent' behaviour which comes as a surprise to those who believe they are 'pulling the levers'.

Complex technology is also a consideration which will be covered in detail in another technical note.

What is the way forward?
How can organisational factors that may lead to human error be managed? -

Understand and apply the Human Element in its widest sense
The IMO vision and goals for the human element needs to be applied in full. Regulators and owners need to recognise that seafarers are the last defence against the accumulation of errors and flaws in technology and organisation not the sole source of error. IMO quite correctly points to the human element as an issue that involves all in the marine industry.

Excessive Workload
Excessive workload can be dealt with by reducing that workload or increasing the resource available. It seems simple.

Operational and maintenance workload, as well as being influenced by the trade the ship is on, is influenced by the original design of the ship and modifications, repairs and maintenance carried out after build. The ship and its equipment need to be constantly reviewed and high operating workload or maintenance equipment replaced. Operational workload takes place 'in the moment' using only those resources aboard but can be reduced by design. Maintenance can be prioritised and managed to some degree. Adequate equipment and spares can reduce workload as can using 'offboard resources' such as specialist contractors, repair periods, drydocks and seagoing maintenance teams.

There is nothing new in the above. The problems with administration workload are however different.

Opportunities exist to deal with cargo and port workload and to ensure that ships arrive and sail with rested crew. Charterers and ports need to share responsibility for ensuring workload is properly managed.

The amount of new regulation and whether it is 'human centred' is something being considered at IMO but will take some time. The multiple layers of compliance involving flag state, class, port state and charterers inspections needs some consideration.

Much of what can be done rests with the shipowner. Management and maintenance systems have a tendency to grow as a result of learning. Process is seldom removed. Many organisations are carrying out reviews of their process and reducing their process by as much as a half as well as creating better tools. Modern technology so far has made it easier to create process. Many are making use of 'apps' to make process easier.

Continuous improvement is a laudable aim but there is the risk that, combined with performance management processes, they 'supercharge' the management system and create continuous change not improvement. Continuous change is not an objective in itself. The 'multipliers' need to be reviewed from time to time and a 'holistic 'view taken.

The shipowner can make a difference by keeping process off the ship. The simple concept of 'single point data entry' can reduce workload onboard.

Finally, there is need to support senior officers, on whom much of this workload lands. Removal of such roles as the Catering Officer and Radio Officer has exacerbated this. For many years there has been consideration of an onboard 'administrator'. Modern technology would allow such a role to exist in the owner's office. If we can have a virtual assistant at home why could we not make one available for ships.

Flawed Decision Making

Addressing workload as considered above should reduce fatigue. It should also reduce the need to 'cut corners' to get through the day. Both of these should create better decisions.

Clearly, as a starting point the seafarer needs to educated in his profession. This means not just the technical aspects but the ethical and managerial. They have to gain experience of using that knowledge and exercise its application. This may mean real world or simulation. Releasing time from admin for senior officers to train and mentor will lead to safer ships.

The emphasis on accident reporting points out the times where decisions went wrong. Safety 2 [xii] proposes analysing when things go right. Giving more examples of good decision making will reinforce good decision making.

Many incidents have their roots in conflicting requirements. It is the shipowner's responsibility to resolve goal conflicts at a strategic level. Seafarers should not have to resolve these conflicts. Seafarers should understand the priorities where safety, cost, environmental and regulatory requirements collide. A deep understanding of the organisation's goals will allow better decisions to be made onboard.

Time pressure, real or perceived, is behind many accidents. Workload may be part of this. Whether true or not the story of a ship colliding while the watchkeeping officer writes up the safety minutes is a warning. Ships sailing in bad weather, with defective equipment or a tired crew result from time pressure. Those onboard need to be given the real 'right' to make decisions in potentially high cost scenarios. They should be supported in those decisions by knowledgeable staff ashore. It is not a ship programmer or ship operators' job to dictate operational decisions.

Behind all of this is the creation of the right culture. Good decisions reflect the organisations culture. Creating the right culture is difficult, destroying it is easy. The culture needs to be understood and adopted onshore and onboard. Too often those aboard are expected to have a certain culture which those ashore do not live up to. Leadership requires those onshore to show an example and support good decisions even to the extent that some may be economically sub optimal.

Leadership needs to support culture but so does the Direction and Management of the organisation. Performance measurement linked to bonus should be avoided. Performance measures should be real and practical and things that cannot be measured should also be managed. From the opposite point of view a 'Just Culture' should exist. The seafarer should feel supported when external parties are involved in looking at an incident.

Complexity

The company needs to be looked at as a system that has the potential to evolve by itself. Complex equipment and complex process can hide risks.

Regulatory complexity should be reduced by simplifying the regulatory structure. The shipowner should absorb some of that complexity.

In a complex system resilience is required. [references]. Systems should fail in a predictable manner and seafarers should understand the consequences of failure and practice operating in failure modes. There should be enough capacity aboard to operate in a degraded mode.

And finally

Ships work because of the people onboard them. The Human Contribution[xiii] is more important than Human Error.

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