International Transport Forum

# Safety Management Systems

## Summary and Conclusions

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# The International Transport Forum

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# Introduction

Safety management systems (SMS) have attracted much attention as a framework to identify hazards, vulnerabilities and risk and to put in place the appropriate mitigation measures to enable the highest level of safety performance in transport systems. Many experts consider SMS to have improved the management of safety within organisations. While it is generally acknowledged that SMS can be an effective strategy to reduce risk, and by extension to improve safety performance, it can be difficult to demonstrate this empirically due to a lack of availability of relevant safety statistics (Lappalainen, 2017). There are also many misconceptions associated with the SMS that come from an inconsistent and incomplete understanding of the concept, its vocabulary and definitions.

The exact origins of SMS are unclear and have evolved organically from a series of best practices (Thomas, 2012). SMS has gained prominence as regulatory regimes have gradually shifted from prescriptive regulations to performance-based regulations, placing the responsibility for safety on the shoulders of the organisation. Practices linked with organisational safety management were grouped together as a holistic system that could help demonstrate that an organisation was implementing all reasonable and feasible measures to ensure the safety of its customers and employees. Hale and Hovden (1998) argue that an organisation's own responsibility for safety management was perhaps only first realised after the Robens Committee report in the 1970s that recommended that a company's management must assume responsibility for how that company manages risk, leading to the 1974 UK *Health and Safety at Work Act.* This act introduced the challenging notion of self-regulation and a duty of care by the organisation for the health and well-being of its employees (Thomas, 2012).

Thus began the notion that an organisation is responsible to think beyond simple compliance with laws and regulations and actually take responsibility for safety and for managing risk. Starting as a technique to address general workplace and occupational health and safety issue, the SMS approach was extended and developed particularly in the chemical industry after the 1976 Seveso disaster, a large-scale release of toxins at a chemical plant in Italy, and in the offshore oil and gas industry after the 1988 Piper Alpha oil platform explosion that killed 167 workers (Cullen, 1990). Eventually, SMS principles made their way to the transport sector, first in maritime transport through the ISM Code, then in rail, for example through, the *Railway Safety Act* of Canada in 2001, in aviation through Annex 19 of the Chicago Convention (ICAO, 2013) and eventually to transit and the road sector.

The point of departure for this report, supported by the view of many roundtable participants, is that the SMS should be a tool for management. This tool is used to identify hazards and evaluate risks and comprises various subcomponents related to safety, such as safety assurance, promotion or documentation. Throughout, we endeavour to present SMS under a lens that is not related to any particular mode of transport, or restricted to the transport sector. Naturally there is much in common in how an SMS is implemented in other high risk industries, such as the nuclear industry, the oil industry or the medical industry and how it is implemented in transport. The philosophy behind SMS and the strategies underlying its use probably transfer quite well between sectors, even if the hazards and risks that are being mitigated are industry and mode specific.

In this report, the SMS is considered as a suite of systematic, explicit and comprehensive processes for managing safety risks. An SMS provides management with a directed and focused approach to safety with a clear process for setting goals, planning, and measuring performance. Within the organisation, the proper application of an SMS and safety engagement by senior executives, can, over time, affect the enterprise culture, placing a higher emphasis on safety. Combined with notions such as a just culture, an SMS can provide the necessary impetus to make safety part of the work of everyone within an organisation and elicit a strong safety culture.

The mechanisms and procedures that support an efficient SMS are found throughout an organisation. Every employee contributes to the SMS in a way that is commensurate with the task they perform. Accountability for safety may be retained within the management structure of the organisation, but the responsibility to maintain a safe operation is shared amongst all employees. The SMS approach ensures that authority and accountability always co-exist and are clearly defined. It can also help develop a safety culture by linking safety intent (or policy), actions and accountability to convey a clear commitment to the importance of safety within an organisation. Commitment is demonstrated visibly, when senior management communicates clearly that transport safety matters are an important company requirement and allocates necessary resources and attention to related safety issues. Aligning vision and commitments with actions and deliverables helps develop trust in the safety culture of the organisation.

## Issues addressed

The International Transport Forum (ITF), at the request of its member countries, organised a roundtable on SMS on March 23rd and 24th 2017 to better understand the concept of an SMS, identify obstacles to its implementation and how to overcome them and explore how lessons of safety management systems in one mode of transport or one non-transport sector can be applied to other modes of transport.

The roundtable brought together 50 experts representing all transport modes as well as the military. A number of different stakeholders were present, including operators, regulators, accident investigators, trade associations, international organisations and experts in psychology, resilience engineering, human factors and human behaviour. All share a passion for safety. A full list of participants is available at the end of this report.

The impetus for a roundtable on safety management systems came from a proposal from the United States Department of Transport who suggested:

> *A roundtable is convened to share experiences of applying risk assessment to system safety management in different countries and modes. What has been found to work well and what barriers have been encountered? This is of interest to administrations such as the U.S. Federal Railways Administration that are moving from prescriptive standards to system safety assurance.*

The content of the roundtable was expanded from that proposal to cover five key questions, supported by the same number of discussion papers written by leading experts in the field. These discussion papers form the next five papers of this roundtable. The key questions the papers were meant to address were:

1. What are safety management systems and why are they useful? (Maurino, 2017)

2. What is the role of the regulator in the SMS? (Kelly, 2017)

3. What are the obstacles to implementing an SMS and how do we overcome them? (Lappalainen, 2017)

4. How can we measure the impact of the SMS and the role resilience engineering plays in safety management systems? (Lofquist, 2017)

5. How can accident investigations help us improve the SMS? (French and Steel, 2017)

In addition, four related questions were examined by our roundtable participants, namely:

1. How do you know what you don't know, or can we identify hazards and risks that we do not perceive as such?

2. What is the economic and financial rationale of investing in safety in sectors that already enjoy a very strong safety record?

3. How do you balance employee privacy with safety requirements when studying the issue of the use of audio, video and operational data recorders for purposes other than accident investigations?

4. How can a safety management system be applied to an entire mode, namely road transport, rather than a company operating within a mode?

The five discussion papers that framed the roundtable discussion address in depth the first five questions raised. The current paper does not attempt to thoroughly summarise those papers; readers are invited to read the full discussion papers. Rather, it will incorporate the points raised by the respective authors and the inputs from participants to construct a narrative on SMS. It will then discuss some divergent thinking on SMS, before concluding with some observations and recommendations for policy makers to help them better implement and support safety management systems.

## Defining a safety management system

"SMS is a management tool to make better safety decisions" – Roundtable participant

Roundtable participants could not agree on an exact definition of what an SMS is, but there was consensus that it is a corporate tool to improve decision-making by incorporating safety into a business function. More specifically, it is a systematic approach to manage safety that includes the necessary organisational structure, management accountabilities, safety policies and processes needed for successful identification of hazards and management of safety risks. hazards are defined as "*a real or potential condition that could lead to an unplanned event or series of events (i.e. mishap) resulting in death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment*", whereas risk is defined as "*a combination of the severity of the mishap and the probability that the mishap will occur*" (DOD, 2012).

An SMS should be viewed as a strategic framework that can support the development of specific tactics and methods by service providers to manage safety risk, with the assistance and oversight of the

regulator. With the proper use of SMS, both regulators and service providers can evolve from a substantially compliance (rule) based approach to a performance-based safety management system. This entails reframing the responsibilities of the service provider, from that of compliance focusing on following the rules, to one of performance where an organisation shows that it has established and documented management accountability and the appropriate risk management procedures to ensure safety.

SMS represents the integration of several disciplines, system safety, human factors, and business management. It is designed to work within an organisational framework. As discussed by Maurino (2017), an SMS must seamlessly integrate safety management processes and institutional arrangements by turning safety into a critical business function – at the same level of importance as finance, marketing, and the mission operations of the organisation. It strives to identify safety deficiencies and hazards in a process of risk management that understands the consequences of hazard exposure and methods for mitigating risk.

SMS represents a shift in the approach to safety management. The shift in emphasis places less reliance on a prescriptive, or compliance-based regulatory approach, and focuses more on a performance-based strategy. Some of the key features of this change in focus include:

- Management commitment to establishing safety policies and objectives;
- Inclusion of explicit safety (non-punitive) reporting procedures;
- Safety performance monitoring and measurement;
- Identification of accountable management employees;
- Appointment of key safety personnel responsible for safety oversight and promotion;
- Implementation of a risk management process to identify hazards and associated risks;
- Documentation of the SMS structure and safety assurance processes and procedures;
- Coordination of the SMS safety with emergency response planning;
- Safety training at management and employee levels; and
- Effective management of change.

Making safety a part of “the way things are done here” requires a coherent safety policy, well-designed procedures and a clear, proven and often demonstrated commitment from the topmost executives of the importance of safety in all aspects of the organisation’s operations. In so doing it can help establish a strong safety culture. In larger organisations, safety management activity will be more visible in some departments than in others, but the system must be integrated into “the way things are done” throughout the establishment. This will be achieved by the implementation and continuing support of a coherent safety policy that leads to well-designed procedures.

Designing safety procedures requires an understanding of how hazards generate risks. This understanding has been evolving. Reason (1990) presented the Swiss cheese model, where defences against risk are layered like slices of cheese; there are holes in the defences like the holes in the cheese slices but they don't usually align and the successive layers normally prevent risks turning into accidents. However, the gaps in the defences can sometimes be aligned and a hazard can escape all the layers of safety defence and result in a safety failure. More recently, Dekker (2014), building on work by Amalberti (2013) suggested that in complex, dynamic and already very safe systems, failures can be the result of normal work, which includes some workarounds that do not adhere to set procedures, and eventually lead the system to drift towards a safety failure without any breach of specific safety defences. In those cases, the workarounds have created new and unforeseen hazards against which no safety defences had been designed.

There is no "one size fits all" method for SMS implementation but at the same time some elements of any SMS are transferable to other companies, both in the same sector and in very different industries. Transferability is thus possible across modes of transport but the SMS process needs to be tailored to the needs of each business and the industry in which it operates. SMS are designed both at the industry and individual company level. This creates two levels of transferability, one within the industry where best practices can be shared and one across industries where some principles from one industry can be adapted to other industries.

It should at the same time be noted that an SMS is a management tool that needs a management context in which it can be applied. SMS can and is used by companies and safety oversight authorities to help structure their internal culture. It cannot, however, provide a framework for safety policy as a whole, which must take into account the safe co-existence of all stakeholders within a given ecosystem.

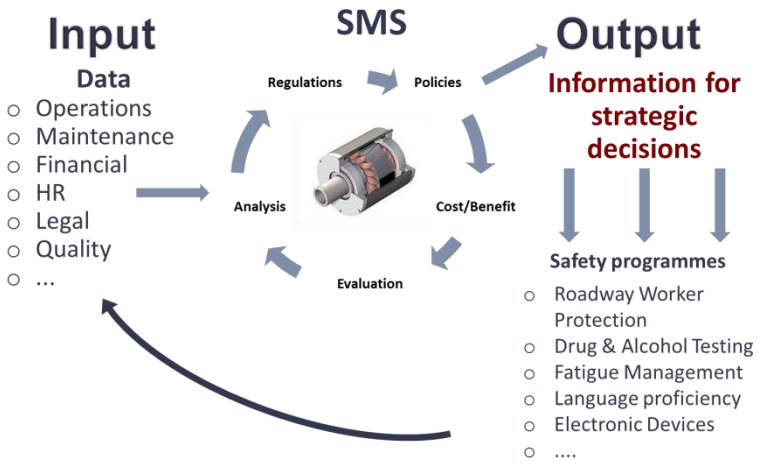
Maurino (2017) provides a comprehensive review of safety management systems, including a description of the SMS model and structure, definition of key terms, a description of processes and safety activities, institutional arrangements, and SMS implementation strategies among transport systems. Maurino (2017) presents some of his key ideas and points of interest in defining and elaborating on the SMS. For example, he emphasised that the SMS is a "management system for managers to use in decision making" concerning how to plan and execute safety management. The main focus of the SMS is for managing risk, through the identification and control of hazards and their untoward consequences. Safety management systems require the organisation to provide the means to monitor and to measure the SMS implementation progress and safety status.

## The SMS Generator

Maurino (2017) presents a very interesting analogy, *the SMS Generator,* as a means to communicate the intent and the process of 'generating' SMS initiatives. Maurino uses the metaphor, styled after an electric generator that produces electric current, to depict a process of creating safety programmes, processes and procedures necessary for an effective SMS. The generator is conceptualised as a cyclical flow process that functions to formulate safety policies and programmes, based on analysis of risk management requirements, consideration of regulations and the cost – benefits of various solutions to managing safety risk. In other words, management engages in an orderly process using the *SMS Generator* depicted below, as a point of departure to analyse risks associated with their operations, and to generate appropriate safety management programmes to include within the *SMS Framework*

presented earlier. SMS also stresses the use of performance monitoring, measurement and assessment in order to identify hazards and to mitigate risk of on-going operations.

Figure 1: The SMS Generator




Source: Maurino (2017a)

A good SMS seamlessly integrates safety management processes with the institutional arrangements to support (safety) processes. However, one must recognise that within both the regulatory and the service provider communities there are some misunderstandings, and some resistance, regarding the rationale and appropriate application of the SMS. There are likely many reasons that some organisations do not embrace safety management systems, such as:

- The SMS is perceived as an additional 'regulatory burden' that requires more paperwork;
- Some service providers believe that they are already meeting the requirement and do not need to bother incorporating yet another safety management initiative;
- There might be a shortage of personnel that have the knowledge and skills required to successfully carry out implementation and management of the SMS; and
- There might be a shortfall in resources made available to enable successful SMS implementation.

One roundtable participant suggested that two areas of the SMS generator stand out as having potential for transferability across operators, modes or industries: data and cost/benefit analysis. The type of data collected varies from one operator to the next, but there should be some core data sets associated with the same definition and methodology. Similarly, mitigating a risk comes at a cost and the cost/benefit analysis enables the evaluation of whether the benefits of mitigating the risk outweigh the cost

generated by the risk. Policies and regulations also come with their own inherent costs and benefits. SMS practitioners should strive to adopt common methodologies in conducting these cost/benefit analyses to ensure that results are consistent across companies and that, all else being equal, a different methodology does not yield a different outcome.

Maurino (2017) also emphasises the critical importance of establishing measurable safety objectives and a need to provide the means to monitor and assess performance against performance targets. Maurino discusses the fact that the SMS is a data driven approach to safety management, stating that "Data is the blood that nurtures SMS and simply put, no data, no SMS". Employee safety reporting is the single most valuable activity for safety data collection under the SMS.

However, evidence from field studies indicates that it might be harder than first realised to establish a reliable safety reporting system. A system that employees trust is always a 'non-punitive' system, grounded in the concept of a 'just culture'. Ciavarelli (2010) reports findings taken during safety climate surveys across several civil aviation organisations that show employees are often reluctant to report safety concerns because they do not trust that they are truly protected from reprisal when reporting a safety error or concern, or employees have submitted safety concerns but have not received any feedback that their report was received and/or appropriately acted upon.

## Ingredients for a 'Good SMS'.

Core ingredients of establishing a successful SMS begin with hazard identification and risk assessment processes, similar to those employed in system safety engineering. This approach structures a risk management strategy around the identification and analysis of hazards and then applies mitigating measures to address the associated risks. The SMS goes further by adding a socio-technical framework and includes organisational issues, such as leadership commitment, adequacy of safety resources and other factors under the direct control of management.

A good SMS also incorporates human factors in safety risk evaluations, by considering human performance capabilities and limitations, and possible human errors. Risk analysis might include factors that affect human performance, such as worker fatigue, and safety deficiencies such as possible unmet job training needs. The human factors aspect also includes raising the importance of safety in the corporate structure and increasing management engagement with employees regarding the safety of operations by establishing a safety governance structure that is adequately resourced and staffed with professional safety personnel.

Finally, a good SMS would evaluate the need for safety training at all levels of management and workers and would monitor and record lessons learned – good and bad – and keep a corporate history regarding what works and what does not work in managing safety risk.

It is worth noting that Maurino's recommendation to consider a more 'socio-technical' approach coincides closely with the school of thought known as High Reliability Organisations (HRO). The HRO is an organisation that has an established reputation for conducting safe operations in highly risky domains, like aviation and nuclear energy. Roberts and Bea (2001), and Weick and Sutcliff (2007) describe key characteristics of HROs that include leadership commitment to safety with clear accountability and management engagement; setting safety policies as a priority; providing adequate safety resources; promoting open non-punitive communications that enable workers to report deficiencies without fear of

reprisal; and giving the most qualified employees the authority and responsibility for risk decision making.

The roundtable participants raised a number of issues around defining SMS. Some service providers do not fully understand the SMS intent and its changing orientation toward performance-based safety processes. There are variations in how well an SMS is implemented. As mentioned earlier, workers fail to report safety concerns, and there is a lack of management engagement and employee participation. Some organisations face significant resistance in accepting an SMS culture change (Lappalainen, 2017, Ciavarelli 2010).

- There is considerable interest in the rise of 'resilience engineering', as an emerging discipline under which safety is re-conceptualised. A key aspect of the resilience approach is the change in focus for the collection of safety data. Discussions at the roundtable centred on over dependence on accident investigation and hazard and incident recording (referred to as Safety-I). Resilience engineering suggests that there is a need to collect more information about success. We should document what is working to achieve success, not just what has led to mistakes and failure. This belief is referred to as Safety-II (Loftquist 2017, Hollnagel, 2014, 2013).

- Questions were raised regarding the need to clarify specific criteria used to determine what is and is not an acceptable risk, or an acceptable level of safety – ALOS, or as low as reasonably practicable– ALARP. These terms were deemed by some in the audience to be too ill-defined and open to various interpretations. ICAO (2009) suggests that ALARP should be addressed by conducting a thorough cost-benefits risk analysis – but ICAO gives no specific quantitative criteria for an ALARP determination.

There was agreement with the emphasis concerning the importance of safety reporting as the cornerstone of SMS data collection and safety risk assessment although there was interest in whether or not we can expand and improve the types and methods of safety data collection. Resilience engineering (Lofquist, 2007) recommends the use of predictive measures but no examples of the kinds of measures and assessment methods were presented or discussed.

It was noted in the roundtable discussions that civil aviation is further ahead of other transport domains in SMS implementation, even though the maritime mode first introduced the SMS at a global level through the ISM Code. Some specific differences in transport areas were also discussed. For example, as was mentioned, shipping has an SMS foundation that is built upon the 1993 ISM Code. The ISM Code appears to be substantially compliance-based rather than the performance-based as emphasised by the current SMS approach. Also, there are issues with the chain of command and responsibility of safety in the maritime industry, due to poorly connected communication protocols between the ship owners and operators, and the significant number of multicultural ship crews who come from different national cultures and language origins. Transit and roadways also pose particular problems of SMS implementation in some countries because there is no single governing regulatory agency, but rather a combination of state and local government units representing different community interests, governing practices and transport options.

In understanding what an SMS is, we should also mention what an SMS is not. The SMS borrows from system safety but is not the same – system safety is focused on avoiding technological failure by eliminating system and equipment design defects. Also, the SMS is not a quality management system. Its

intent is not in improving product quality or service but rather on improving the safety of the entire organisation.

SMS in action: a concrete example

It can be difficult, especially for a lay audience, to properly understand how an SMS operates in real-world conditions. While it will not be possible here to detail the whole SMS of a given operator, and even less so to discuss the ways various operators across modes of transport implement their SMS, the following example from Skiles (2012) shows how different inputs to the SMS generator can procure a safety-improving output.

Over a decade ago, the Federal Aviation Administration, which provides air navigation services in the United States in addition to being the civil aviation authority, instituted a new arrival procedure in Philadelphia. The procedure included having the aircraft fly at a given altitude over a given waypoint and at a lower altitude at another waypoint 25 km further down the approach path.

US Airways, which operated a hub in Philadelphia, had an SMS in place. As part of the company's safety culture and SMS, the company had a policy to give full disciplinary immunity to pilots who self-reported errors, such as missing an altitude target; the FAA granted these pilots the same level of immunity. Pilots would forfeit this immunity if an error was reported by another source, such as an air traffic controller and not by them. Thus US Airways pilots had a very strong incentive to report every single issue that would have happened during a flight, including missed altitude targets.

US Airways pilots operating one type of aircraft began reporting a number of altitude misses on the new approach path; they would often fly higher over the second waypoint than what the procedure asked for. They reported the missed altitude because of the immunity they had from their employer. By doing so, they generated data that indicated that the cause may have been systemic, caused by an organisational hazard, rather than an isolated mistake by a single pilot.

It turned out that those aircraft were not designed to descend quickly enough between the first and second waypoint, while other types of aircraft were. This situation prompted the FAA to change the approach procedure to one which all aircraft could follow. Had there not been an incentive to report the missed altitude target and had there not been a management system in place to track and analyse safety-related data, it may have taken much longer to realise that the approach path was poorly designed. Without an SMS in place and a safety culture that valued self-reporting over recrimination, pilots may not have reported these missed altitude targets and even if they did, there would be no system in place to collate and analyse the data and determine the true cause of these incidents. In the meantime, the repeated altitude target misses would be introducing a hazard into the system that pilots and air traffic controllers would have to compensate for.

## Current state of SMS across modes of transport

Having now defined what an SMS is, this section provides a short overview of how a SMS is applied across each mode of transport.

**Air transport**

Improvements in air safety began with aircraft design from the 1950s, better management of human factors from the mid-1960s, better organisational management from the mid-1970s and enhanced digital technology in recent years. In the process, the fatal accident rate in aviation has improved dramatically, going from about 8 per 100 million passenger kilometres to practically zero today. Aviation thus matured from a fragile system at its inception to a safe system from the 1970s, to an ultra-safe system since the mid-1990s, at least when limiting the analysis to Western-built jets operated by major air carriers[1]. Meanwhile, the cause of accidents has shifted, from inadequacies in design or in human behaviour to now random and multiple causes which cause a cascade of events leading to a fatal accident.

The changing nature of accidents and increasing complexity of the system has reduced the ability to learn from past experience and reduced the linear relationship between hazards and risks. While accidents may be caused by human or technical malfunctions, these malfunctions can be the result of an organisational failure which is what the SMS aims to mitigate.

Regulated SMS in aviation began at Transport Canada with the development of the four-pillar concept of safety management, namely safety policy, safety risk management, safety assurance and safety promotion that still form the foundation of the modern aviation SMS. NAV CANADA, Canada's fully-privatised civil air navigation service provider was the first commercial entity in aviation to introduce an SMS in 1997-98 and Air Transat became the first airline to operate an SMS, from around 2001. Transport Canada introduced the SMS as a regulatory requirement for airlines in 2005, the first civil aviation authority to do so.

The current framework for safety management systems originated in, and is currently promulgated by, the International Civil Aviation Organization (ICAO). ICAO was established under the United Nations representing 191 member nations. The basics of ICAO's SMS are detailed in the ICAO Safety Management Manuals which were first published in 2009. While the origins of the ICAO framework are rooted in the civil aviation domain, the SMS has evolved as a general approach to safety management that can be used in other transport systems.

The ICAO framework builds on the overarching SMS standards and practices, in compliance with prescriptive requirements. In some jurisdictions, the SMS was interpreted as safety deregulation, but it is in fact a complementary approach based on consensus. It contains provisions for the protection of safety data and its sources in order to make the system work. The basic ICAO SMS framework is presented below. It includes a section on change management which is often lacking at the national level.

Table 1. Four components and twelve elements of the ICAO SMS Framework

| I. Safety Policy and Objectives | III. Safety Assurance |
|---|---|
| • Management commitment and responsibility<br>• Safety accountabilities<br>• Appointment of key safety personnel<br>• Coordination of emergency response planning<br>• SMS documentation | • Safety performance monitoring and measurement<br>• The management of change<br>• Continuous improvement of the SMS |
| **II. Safety Risk Management** | **IV. Safety Promotion** |
| • Hazard identification<br>• Safety risk assessment and mitigation | • Training and education<br>• Safety communication |

In 2010, the International Civil Aviation Organization's High Level Safety Conference concluded that safety management processes under the responsibility of member States should be centralised in one Annex of the Chicago Convention, Annex 19, which would include all the requirements for an SMS for the various areas of activities of international aviation. This annex became applicable on November 14th 2013.

The implementation of an SMS is highlighted in ICAO's Global Aviation Safety Plan. The safety plan and Annex 19 apply to a variety of service providers operating within the aviation safety ecosystem, including commercial aircraft operators, general aviation operators[2], training organisations, maintenance organisations, aircraft designers, aircraft manufacturers, air navigation services providers and aerodrome operators. ICAO is currently working on 4th edition of the GASP manual. It is placing emphasis on internal and external system description and how they interface with companies that have or do not have an SMS.

Implementing an SMS in aviation can be a complex process requiring at least five years to phase in (ICAO, 2013a) but it is also a process of continuous improvement that requires adjustments as the system gains maturity. This is particularly difficult as aviation, more than any other mode, has been built on prescriptive requirements and global standards that together have driven improvements in safety. SMS shifts the focus from compliance to performance and is built on top of prescriptive regulations commensurate with the size and complexity of the organisation.

As previously stated, there is no "one size fits all" method for SMS implementation. It is for this reason that it begins with a system description that identifies organisational structures, processes, and business arrangements. It also includes both internal and external interfaces and needs to take into account that

the organisation's SMS may need to interact with that of its partners and be impacted by how these external safety management systems manage and mitigate risk.

An SMS in aviation is thus highly structured and based on global guidelines. Most of the major service providers involved in aviation, such as aircraft operators, air traffic control providers, airport operators and maintenance organisations each have their own SMS. Complex systems shall, as a matter of course, increase the likelihood of hazards being generated or transferred within the system. The challenge therefore is to make all these different, operator-centric, safety management systems work together harmoniously and ensure that actions taken in one area do not create hazards that go unidentified or poorly managed in another.

**Maritime transport**

In maritime transport, the International Management Code for the Safe Operations of Ships and for Pollution Prevention (ISM Code) establishes a framework that replicates much of the spirit and substance of an SMS. Contrary to the situation in other modes of transport, safety management systems in maritime transport are vessel-centric, meaning they are developed for the individual ship rather than the shipping line.

An important component of any safety management system, including the ISM Code, is the ability of a company to measure its safety performance. To that effect, the ISM Code requires companies to maintain a documented SMS that may be subject to internal and external auditing. This documented SMS is also necessary for companies to obtain a document of compliance from the flag state and for the ships to receive a safety management certificate. Together, these documents form the licence to operate the ship and the shipping line. Thus the shipping line has a strong incentive to document its safety management system, lest it loses its right to operate a commercial venture.

The link to pollution prevention reflects the potential for maritime accidents to result in significant environmental damage, for example through oil spills, even if the 16 elements of the ISM Code do not have specific environmental clauses except in relation to compliance with the MARPOL convention. MARPOL is the International Convention for the Prevention of Pollution from Ships adopted at the UN International Maritime Organisation (IMO).

The ISM Code places a greater emphasis on compliance than performance. Operating in the maritime industry, it is adapted to suit an industry structure where the ship owner and operator may be two different entities and where a vessel crew can be composed of a dozen or more nationalities, each with their own social cultures which may translate differently in the implementation of a ship-wide safety culture. Initiatives with safety management systems in maritime transport first started in the 1980s, when different industry groups proposed the SMS in order to make more systematic efforts towards improved safety. Since these were industry-defined standards, they relied on voluntary implementation by industry partners. This did not result in high implementation rates in the shipping business. The situation changed in the early 1990s when maritime regulators decided that a mandatory requirement for an SMS was needed following some significant accidents. Subsequently, SMS was introduced on a worldwide scale for ships subject to the IMO International Convention for the Safety of Life at Sea (SOLAS); vessels of 500 Gt and above and involved international trade.

The ISM Code was adopted at the 18th Assembly of the International Maritime Organization in 1993 in response to the capsizing of the MS Herald of Free Enterprise in 1987. That accident killed 187

passengers and crew. The direct cause of the accident was found to be negligence by a crew member, but the investigation also pointed out serious flaws in the shipping line's safety culture and communication. The UK Wreck Commissioner, the Honourable Mr. Justice Sheen, found that the Board of Directors did not appreciate their responsibility for the safe management of their ships and that "From top to bottom the body corporate was infected with the disease of sloppiness."

Table 2: The ISM Code is made up of two parts and 16 elements as shown in the table below

| | **PART A – Implementation** | 9 | Reports and analysis of non-conformities, accidents and hazardous occurrences |
|---|---|---|---|
| 1 | General | 10 | Maintenance of the ship and equipment |
| 2 | Safety and environmental protection policy | 11 | Documentation |
| 3 | Company responsibilities and authority | 12 | Company verification, review and evaluation |
| 4 | Designated Person(s) | | **PART B – Certification and verification** |
| 5 | Master's responsibility and authority | 13 | Certification and periodical verification |
| 6 | Resources and personnel | 14 | Interim certification |
| 7 | Shipboard operations | 15 | Verification |
| 8 | Emergency preparedness | 16 | Forms of certificates |

Source: ICS-ISF, 2010

A key element found throughout the ISM Code is the supremacy of the ship's master. In fact the second paragraph of the preamble to the ISM Code states that "Governments are to take the necessary steps to safeguard the shipmaster in the proper discharge of his responsibilities with regard to maritime safety and the protection of the maritime environment". The ISM Code thus clarifies the position and roles of individual parts of a system. The master, for example, is given an overriding authority when it comes to safety of the ship. Safety is made a management priority and a designated person has to deal with the SMS in a shipping company. There are many elements in the ISM Code that could, if a shipping company wishes to interpret the ISM Code in that direction, be used to set up performance-based SMS.

The ISM Code sets in place the basic safety construct to operate a ship, however ships that operate riskier missions can augment this Code. For example, the ISM Code is but the first of four levels required by the Tanker Management and Self-Assessment Programme.

The ISM Code requires companies to develop and implement safety management procedures to ensure that activities conducted afloat or ashore and which affect safety or the environment are planned, organised, executed and verified in manner that is compliant with both legislative obligations and company policies (ICS-ISF, 2010). In fact, some maritime industry organisations felt the need to provide some additional guidance for the implementation of the ISM Code in the shipping sector. The Oil Companies International Maritime Forum (OCIMF) is such an organisation that developed an industry standard called Tanker Management and Self-Assessment (TMSA). They felt that the original text of the ISM Code is probably too general and allows for a wide spectrum of possible interpretations regarding the design of the maritime SMS. TMSA is stimulating a continuous process for the development and improvement of an SMS. It suggests that the SMS can have four different levels of development.

Compliance with the ISM Code is considered to be level one (the lowest) in TMSA. Three more levels of further development are possible and shipping companies are encouraged to make all efforts to finally reach level four. In order to determine at what level an individual shipping company is, specific KPIs are set out, describing common practices and arrangements that OCIMF feels should be available at a specific level.

There are advantages and disadvantages to such an approach. The ISM Code in the maritime sector has specifically been written in a very general way in order to allow different shipping companies with different sizes and different activities to develop their own individual systems. In order to facilitate this flexibility, the ISM Code is not written with the usual prescriptive focus of technical standards in the shipping sector. Unfortunately, not all shipping companies have made use of the potential that such an approach offers. In order to avoid minimum level compliance, OCIMF has created its TMSA for the tanker part of world merchant shipping fleet. By providing KPIs, this standard is more prescriptive than the ISM Code. However, TMSA is also written in a way that allows for a number of different and flexible interpretations in respect to its application.

The ISM Code has helped define minimum safe conditions for operating ships and has confirmed safety as a management responsibility. It has introduced risk-based thinking and enhanced safety awareness in shipping operations. In the process, it helped change the culture in many maritime lines from evasion where possible to compliance, and a more proactive safety culture (ICS-ISF, 2010). In so doing, it has helped the maritime industry significantly improve its safety performance despite increased activity.

**Rail transport**

ITF (2010) found that infrastructure providers and train operators are principally responsible for rail safety, with the regulator having a role of overseeing the process and ensuring that the safety systems in place are adequate. This combined safety arrangement has been labelled co-regulation and eventually led to the introduction of SMS, which covers the safety system and its underlying documentation. Meanwhile, it found that railway accidents were increasingly caused by a series of human and technical failures that may have had their origins in the safety arrangements and safety culture of the organisation in which they occurred rather than simply being an isolated technical or human failure.

Safety management systems in rail transport vary by region, but enjoy a strong level of harmonisation within regions, recognising that rail transport requires some standardisation therein.

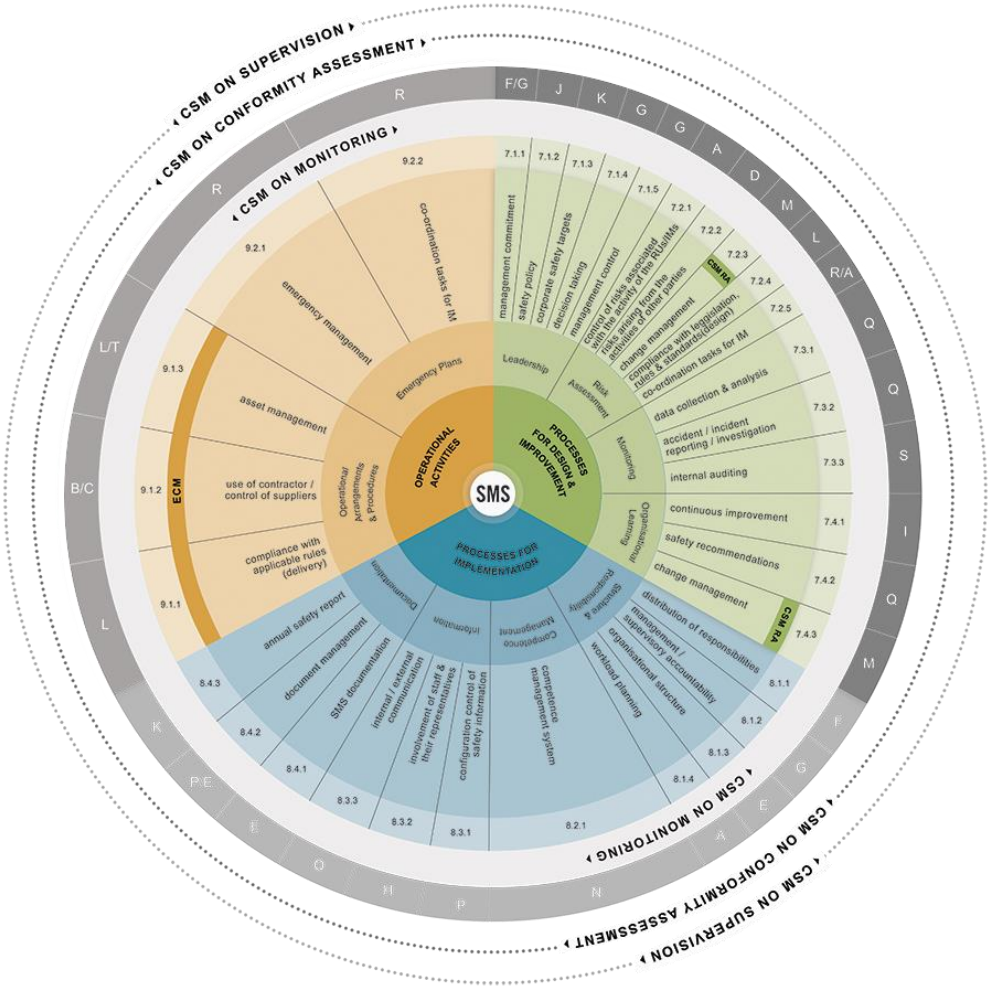
In the EU, Directive 2004/49/EC requires both railway operators and infrastructure managers to have their own SMS. These safety management systems are then assessed by the appropriate national safety authority using an assessment method that is common throughout the EU.

The following image is the SMS wheel from the European Union Agency for Railways. It is built on three pillars: design, implementation and operations and from each one a number of activities fan-out. Interestingly, the wheel begins with leadership and a management commitment to safety that is a necessary condition for the successful implementation of an SMS in any mode, or any industry for that matter.

This SMS wheel, initially designed with rail safety in mind, does not have any rail-specific elements to it. This clearly illustrates the transferability of the SMS as a concept that can be applied to any industry that

operates within a context of having some safety hazards and risks that it needs to proactively manage and mitigate.

Figure 2: The SMS Wheel




Source: ERA (2012). Available at http://www.era.europa.eu/Document-Register/Documents/120525_SMS_wheel_leaflet%20v3.pdf

The EU directives and regulations naturally only apply to EU members, however there is a significant amount of rail traffic between EU and non-EU countries which requires a certain degree of cooperation in order for the transport system to operate efficiently despite varying safety regulatory regimes.

For traffic between an EU and non-EU members, a new appendix, Appendix H, of the Convention concerning International Carriage by Rail is being developed to allow safe and seamless operations between EU and non-EU countries. It will require infrastructure managers and railway undertakings to share safety responsibility, establish their own SMS and be certified and supervised by the regulatory unit of the country where the traffic is taking place.

In Canada, the *Railway Safety Management Systems Regulations* (2015) clearly layout the requirement for an SMS for railways under federal jurisdiction[3]. The regulations detail 12 different processes that

make up the SMS of a rail operator and include *inter alia* processes on accountability, safety policy, risk assessment, reporting of contraventions, safety concerns and safety hazards and for managing knowledge.

In the United States, the Federal Railway Administration does not a require operators to have an SMS per se but rather a system safety programme as per regulation 49 CFR Part 270. The regulation requires each railroad to "establish and fully implement a system safety programme that continually and systematically evaluates railroad safety hazards on its system and manages the resulting risks to reduce the number and rates of railroad accidents, incidents, injuries, and fatalities" (GPO, 2016).

In Mexico, railways operate under standards that are compatible with those present in Canada and the US. This helps the rail system operate at a continental level and makes it easier for trains to move from one country to the other. ITF (2016a) recommended Mexican rail safety regulators develop performance-based regulations, rather than prescriptive regulations, something in keeping with the philosophy of SMS. In Australia, Part 3, Division 1 of the Model Rail Safety Regulations 2007 requires all rail operators to have a safety management system in place. The regulation calls for 27 different elements to be included in an SMS, including a safety policy, risk management, human factors and employee fatigue (Thomas, 2012). Safety culture will become the 28$^{th}$ element once there is national agreement on its definition. The level of detail found in the regulation makes the SMS requirement look more like a prescriptive regulation than a performance-based one.

According to that regulation, a system safety programme includes risk-based hazard management and analysis and proactively identifies hazards and mitigates or eliminates the ensuing risks. The railroad system safety programme also has to promote and support a positive safety culture within the railway undertaking. System safety programmes contain many of the features found in an SMS, including a safety policy, accountable executives, safety risk management, safety assurance, safety promotion and safety training and thus, for the intent of this report can certainly be considered equivalent to an SMS.

**Transit**

The use of SMS in public transit is a relatively new concept and one of the leading countries implementing it is the United States. Public transit presents interesting challenges from a safety perspective: it operates across modes, with undertakings usually having a road operation (buses), many having a rail operation (tram, funicular, subway, commuter rail) and others also having a maritime component (ferries). From an enterprise perspective, they are often run as a single organisation, although possibly with multiple modal divisions.

In the United States, regulatory responsibility for transit is split between the Federal Railway Administration for commuter and intercity rail and the Federal Transit Administration (FTA) for most other operations. The FRA conducts its own regulatory enforcement whereas the FTA has delegated the enforcement of national regulations to each State. The FTA uses SMS to determine how organisational factors contribute to incidents, accidents and near misses. The SMS builds on this experience together with advances in safety thinking to update basic system safety principles establish specific organisational and management processes. The FTA believes that the use of SMS in transit by the operators it regulates can increase the focus on hazard identification across the organisation, broaden the scope of data collection and integrate data from other parts of the organisation into safety analysis, emphasise the importance of managing risk across the organisation, promote the participation of frontline employees and foster an organisation that promotes safety culture and safety risk management.

While public transit is relatively safe and professionally operated in developed economies, Joewono and Kubota (2006) remind us that this does not hold everywhere. In some developing African and Asian countries, public transport vehicles are frequently poorly maintained and often overloaded. Many vehicles, such as converted vans or trucks, were never designed to carry passengers safely. Driver training is limited or non-existent and operators are often either unregulated or unlicensed, operating illegally. In this context, developing an SMS would certainly be unrealistic, but adopting some basic elements of an SMS, such as training or safety culture awareness building programs along with the development of a system safety framework could help improve safety outcomes.

**Road transport**

Road transport results in more fatalities worldwide, about 1.25 million per year, and more injuries, about 50 million per year, than all other modes of transport combined. It is also, by far, the most widely used mode of transport. Road crashes are one of the leading causes of death of people under 30 years of age (WHO, 2017). Over 90% of these fatalities take place in low to middle income countries, generating economic losses of the order of 2% to 5% of their GDP (ITF, 2016), representing about USD 500 billion annually (UN,2011) or nearly three times the value of development aid from OECD member countries (OECD, 2017). These statistics must of course be taken within the context that road transport is, by far, the most prevalent mode of transport for all our daily activities and encompasses not only those in motor vehicles but also cyclists, pedestrians and anyone else using the roadway or sidewalk. Globally, about 4 out of 5 road traffic fatalities in urban areas are vulnerable users such as pedestrians and drivers of two-wheel vehicles, but that proportion varies greatly between countries. Therefore, national priorities differ based on each country's condition and existing infrastructure.

Road transport differs from all other modes of transport because of its extensive use by operators with little or no training. Here, we define road transport in its broadest sense and include non-motorised transport, such as cycling and walking. Operators vary wildly, from a large multinational operator of fleets of trucks or buses, to a single individual out for a leisurely walk. In that sense, each one of us is an operator on the road network. The sheer magnitude and breath of operators cause this sector to be the subject of far less oversight and control than other sectors. Infrastructure service providers are also quite heterogeneous and can include villages, cities, regional, sub-national and national governments and private sector companies, e.g. for many toll roads. Enforcement varies by locality; while some areas have dedicated traffic police, in most places road safety enforcement is one of many functions for the local or regional police force and, as such, competes with resources with other functions performed by the police force.

Another major difference between road and other modes is the general lack of a formal, independent accident investigation body as found in other sectors. Police may investigate individual accidents but the depth of the investigation is often not as detailed as conducted by an accident investigation body.

The United Nations, in their Sustainable Development Goals (SDGs), have set the target of reducing global road fatalities and serious injuries by 50% in 2020, compared to 2010 levels. This target will be particularly challenging to achieve given the rapid rate of motorisation in low and middle income countries and increased demand on the road network of most of the world's larger cities (ITF, 2016).

The level of injuries and fatalities associated with road transport has made road safety a public health issue. This issue is particularly pronounced in developing economies compared to high-income countries where some basic preventive policies, such as the mandatory use of seat belts in automobiles or helmets

on motorcycles, better vehicle and road design and stricter enforcement of laws against driving while intoxicated have all contributed to significantly improving road safety (Peden et al., 2004).

When looking at SMS in road transport, it is important to distinguish the company-centric approach from the system-wide approach. Some large fleet operators have adopted advanced SMS practices, particularly companies transporting dangerous goods including oil and chemical products. Tenets of SMS for air carriers, shipping lines or rail companies transpose directly to such road transport operations. In that sense, the European Union Agency for Railways' SMS wheel (see Figure 2) applies very well. A key consideration is determining if the level of complexity and maturity of the organisation makes implementing an SMS worthwhile. There is no clear threshold to make such a determination, but one would expect the SMS to be a helpful tool in organisations where the senior management already has other company-wide reporting systems to track performance. This explains why best practice in the sector is often to be found in the own-account road transport operations of businesses with a strong safety culture because of the nature of their core activity, mining, oil refining, etc. Many road transport companies are, however small and medium enterprises or owner-operator businesses with only one or two vehicles. A less elaborate approach to safety management may be more appropriate for their type of operation.

There is no international regulatory or standard setting body in road transport of the kind responsible for aviation (ICAO) or maritime transport (IMO). However, the International Organization for Standardization (ISO), working with national standard agencies developed a standard for road traffic safety management: ISO39001:2012. This standard specifies the requirements for a road traffic safety management system to enable an organisation that interacts with the road traffic system to reduce deaths and serious injuries related to road traffic crashes that it can influence. ISO39001 does not replace national or local road safety legislation and regulation; rather, it adds another dimension to road safety and can help deliver a system to manage safety in the same way an organisation has systems to manage the other components of its operations. It takes into account legal and other requirements to which the organisation subscribes, and information about elements and criteria related to road safety that the organisation identifies as those that it can control and those that it can influence.

ISO39001 recognises road safety as a shared responsibility. It calls for the development of a road safety policy, objectives and an action plan. The standard applies to any organisation wishing to improve road traffic safety and does not limit itself to vehicle or infrastructure operators. ISO39001 aligns within the same logic as ISO5001 (occupational health and safety), ISO9001 (quality assurance), ISO14001 (sustainability) and Safe Systems. Similarly, it does not speak about accidents but rather about crashes, since the term accident implies a degree of unplanned randomness and the purpose of ISO39001 is to plan how to prevent crashes and how best to respond to them when they happen.

ISO39001 can apply to any type of organisation but has so far been used mainly by fleet operators. It helps organisations set structured targets, better understand the various risks to which they are exposed and what their final safety outcome is. It can also help build a culture of safety as, when properly applied, it can send a strong message within the organisation of the management's commitment to road safety. Being ISO39001 compliant is not a mandatory requirement, but companies with inherently strong safety cultures may demand that their subcontractors and partners be ISO39001 compliant.

The ISO is also working on developing a new standard, ISO39002 for commuting, under the leadership of Malaysia and Sweden. The new standard, due out by 2018-19, will help companies better manage how their employees commute back and forth from work. This standard would be innovative in a number of

jurisdictions where the employer is not responsible for the safety of a worker's commute but would certainly suffer from the impacts of commuting accidents in terms of lost productivity and reduced manpower.

While an SMS may be more appropriate for large fleets, Australia's Queensland Trucking Association developed an SMS guide for small operators (20 employees or less) with funding from the Queensland Government. The SMS guide combines transport safety management with occupational health and safety concerns (QTA, 2009).

Roundtable participants noted that in the trucking industry, an additional challenge is the employment relationship, or lack thereof between a truck driver and a trucking company. Owner-operators make up to 90% of truck drivers in Mexico or Korea, 50% in the US, 40% in Canada and between 10% and 35% in EU countries. In the US, 90% of trucking companies have ten trucks or less (OOIDA, 2017). Many companies that used to have their own fleets now subcontract all their transport needs. Trucking companies have, in recent years, seen increasing revenue coming from their subcontracted labour force rather than from their employees.

With a significant number of truck-drivers being either owner-operators or contracted workers, it becomes challenging for trucking companies to implement an SMS. In addition, the responsibility for safety is often placed squarely on the shoulders of the drivers and not shared with the many stakeholders involved in the industry, such as large logistics service providers, brokers, shippers, receivers, and other road users who may have some road safety responsibility. Absent of a chain of responsibility similar to that in place in Australia, each stakeholder limits their concern for safety to their area of operation, leaving only the truck driver responsible for road safety. But one could imagine that if there were a chain of responsibility, then large shippers or large logistic services providers would likely develop an SMS for the road transport component of their operations. This issue is expected to be discussed at an International Labour Organization meeting in 2019, a tripartite meeting looking at developing a code of practice that will improve and better define responsibility for safety in the road transport sector.

In the Safe System approach, favoured by New Zealand with its Road Safety management System Program, the Netherlands with its Sustainable Safety programme, Sweden with its Vision Zero programme and an increasing number of countries, the focus is on improving road safety system-wide. This approach is discussed in more detail below, when we look at sectorial SMS. It differs from the company-centric SMS and resembles more either the system safety approach, or what in aviation is known as State Safety Programs, rather than a system focused on reporting safety to management. Safe System has a normative character of an ideal end-state whereas SMS focuses on operational processes and risk mitigation. The challenge for an SMS in road transport, as it looks to aviation, maritime and rail for lessons learned, is the lack of standardisation in the overall road sector. A truck driver may work for a company with a very strong safety culture and a well-developed SMS, but when sharing a road with private cars and motorcycles that may not have drivers that are safety-conscious, the truck operator will have to balance his company's SMS requirements with the realities of the roadways. For this reason, a system to manage road safety for all users could provide some grounding for a company-specific SMS around which it can be articulated while still respecting the individual characteristics and needs of a given company.

Road transport thus seems to operate at the intersection of safe systems in terms of design and overall safety policy and in road traffic safety management systems when looking at individual large operators.

## The functional state of the SMS

Having looked at how SMS is implemented on a modal basis, we will now focus the discussion on the important roles played by the regulator and the operator in the implementation of SMS and the lessons learned from occurrence investigations involving those transport operators that have adopted an SMS. This section draws largely on roundtable discussions resulting from the discussion papers prepared for this roundtable: Kelly, (2017) Lappalainen (2017) and French and Steel, (2017).

### The role of the regulator

"*If an SMS is not properly regulated, it can undermine the safety of the system*" – Roundtable participant

Kelly, (2017) establishes that under a safety management system regime, "it is the industry's responsibility to manage safety-risks; and the regulatory authority's responsibility to *oversee* the industry's management of safety-risks."

While it is true that SMS enables less prescriptive regulations, almost every SMS has been shaped by a prescriptive regulatory requirement, especially in air, maritime and rail transportation. Therefore, one of the first roles of the regulator is often to make SMS mandatory and then it's working with industry and labour to implement it in an effective way.

Kelly (2017) finds that to a great extent in the past, prescriptive "regulations, standards and rules codified the [safety] defences, and formalized [risk] mitigation". At the international level, regulations and standards enabled harmonised, predictable cross-border operations that have raised the global safety bar, particularly in aviation, maritime and, in North America and the European Union, rail transport. However, it is now generally accepted that strict compliance with regulations and standards alone cannot prevent, or further reduce the risk of, adverse outcomes, as regulations cannot foresee every possible hazard, or how combinations of factors and conditions may coincide randomly and lead to an accident. The transition to an SMS arose largely from an evolved understanding of the causation factors that can lead to incidents and accidents in safety-critical industries. The full rationale is discussed at greater length in Maurino (2017).

In some cases, forward-thinking transport operators decided to implement an SMS voluntarily, either following an accident, or in the belief that the SMS would enhance their ability to identify and manage safety risks in their operations. However, for the most part, regulators have led the requirement to adopt an SMS, either at the State (e.g., Transport Canada, DGAC) or international (e.g., IMO, ICAO, European Union Agency for Railways) level. This was largely prompted by the realisation that, with increasing transport activity and an already low accident rate, this 'step-change' offered a way to further reduce the accident rate. In some cases, limited regulatory resources also drove the change, allowing regulators to focus their efforts on higher risk sectors of the transport industry.

The characteristics of an operator's SMS are mostly driven by the regulatory requirements and there are some significant differences from regulator to regulator and therefore, from sector to sector within the transport industry. How regulators implement and assess an SMS is also evolving. SMS has wrongly been described as self-regulation; in fact it is more akin to self-awareness by the organisation of its own safety risks and its responsibilities to mitigate them to the extent possible. For the regulator, the SMS transforms its role from one who enforces regulations to one that attempts to support and evaluate the

strengths and weaknesses of an SMS (Thomas, 2012). The regulator's focus thus changes from enforcing legal compliance to system-wide evaluation. These changing roles also reset the relationship between regulator and regulated entity, focusing less on compliance with letter of the law and more on safety performance. As responsibility for safety explicitly shifts to the regulated entity, it also increases the reliance of the regulator on it.

Regulators may initially adopt a compliance-based strategy to introduce and regulate the SMS, where the SMS requirements/components/processes are prescribed in regulations and inspectors use a checklist to confirm that the operator has implemented all of the required components/processes. With time and experience, this compliance-based approach may add on limited elements of system safety functionality, e.g., the conduct of hazard analyses that take into consideration human performance limitations.

Today, most regulators that have introduced an SMS are focusing on an operator's adherence to its documented processes. Some regulators and operators may conflate process-based SMS with a Quality Management System (QMS). In some cases, as stated in Kelly (2017), "SMS reinforce and promote a traditional mindset that equates compliance with "reliability", and reliability with safety. There is a danger that compliance-based SMS becomes institutionalized. The primacy of processes causes rigidity, and constrains the growth of mechanisms to understand the dynamic context in which hazards and system safety deficiencies exist and need to be managed." To further support this argument, the Transportation Safety Board of Canada (TSB) has found that regulatory surveillance activities focused almost entirely on SMS processes have not always been effective at identifying weaknesses in these processes and unsafe operating practices, which then have persisted and sometimes contributed to accidents (TSB, 2015, TSB, 2016a).

Ideally, as their experience and expertise grow, both regulators and transport operators will aspire to implement an integrated, performance-based and risk-based SMS where "processes are recognised to be the means, not the ends of system-wide, proactive safety management." (Kelly, 2017) This offers a significant advantage in that "safety management is explicitly integrated with other resource-driven decision-making by the service provider". Unfortunately, few operators are there yet, and many may still prefer a prescriptive regulatory approach to which they can comply and then turn their attention back to "doing business". The roundtable discussion could not identify a threshold in terms of company maturity, size or complexity above which an operator would prefer either a performance-based approach, such as SMS, or a classical prescriptive regulatory regime.

While discussing the role of the regulator in an SMS environment, roundtable participants noted that it was getting more difficult for regulators to do their job. They are asked to do more with less, reduce red tape and bureaucracy, follow a corporate model on targeting and auditing and engage with industry at a very high level. As safety management systems are introduced, regulators are learning along with the regulated entity. Progress is taking place in an organic fashion.

**Challenges of regulating safety management systems**

SMS has so far been introduced primarily as an add-on to an otherwise prescriptive regulatory framework, and is intended to complement not supersede existing regulations. There is an on-going and persistent public expectation that "… commercial operators are safe because regulators impose comprehensive regulations and standards, and conduct audits and inspections." (Kelly, 2017)

However, in some countries, the adoption of an SMS has been viewed as a form of de-regulation, where the regulator is thought to have abdicated its responsibility as the 'guardian of public safety', leaving the operators to their own devices. This perception is particularly likely to arise in the immediate aftermath of a high profile accident when various stakeholders criticise the regulator for not having done more to prevent the accident or when the SMS is strongly criticised by the same experts the public trusts to keep them safe. The public does not necessarily understand or accept that, ultimately, truly effective safety management must be achieved in the hands of the operator and would rather safety be the responsibility of the government regulator.

Whatever the rationale for adopting an SMS, the transition has presented a very significant challenge for regulators that fundamentally changes their relationship with the industry sectors they oversee and changes the duties that safety inspectors are required to perform. To coin a phrase, "SMS changes everything" – including the regulatory framework applied to transport operators, the ways in which regulators oversee operators, the skill sets required by regulatory inspectors, the tools and processes they use, how and what safety data is shared and even enforcement policies and practices. And all stakeholders need to be prepared for the reality that this journey can take many years. During roundtable discussions, one participant suggested that implementing SMS requires strong project management skills which may be beyond the capabilities of small and medium enterprises. It also requires strong senior management support which would need to see it as a tool to improve performance and not a nuisance that interferes with operations.

For regulators, successfully transitioning from a prescriptive regulatory regime to a performance-based regulatory regime, possibly with some prescriptive regulation as well can be a considerable challenge for a number of reasons, including:

- political and economic pressures;
- lack of SMS and risk-management experience and analytical skill-set in the inspectorate;
- resistance to change both within the regulatory agency and the industry;
- applicability of an SMS to small transport operators;
- difficulty in standardising application across a large (regionalised) regulatory agency;
- an inherent tension in the relationship between the regulator and the operators it oversees;
- a certain risk aversion on the part of the regulators themselves to political and media scrutiny; and
- in areas where accident rates are already very low, concern that there may be limited potential gains from an SMS but significant risk if it is improperly implemented and creates new safety risks.

Traditional oversight activities have typically been based on a checklist approach by inspectors who sample operational and technical activities and documents to verify for compliance with prescriptive regulations. As operators have transitioned to an SMS, regulatory oversight activities have focused more attention on verifying SMS processes. Kelly (2017) states that "SMS evaluations must accurately measure

a company's ability to proactively manage hazards and safety-risks in a truly dynamic, complex environment." However, the emphasis has often been on whether or not a documented process exists and is followed, rather than if it is effective. A foundational principle underlying SMS is that it is up to the company, not the regulator, to determine whether or not a given process is working as intended. This is also likely a reflection of the challenge regulators face in finding tools to actually validate whether or not a safety management process is effective, and possibly an attempt to limit the regulator's liability in the event of an accident attributed in part to a deficient process that the regulator had approved.

Many regulatory inspectors and managers were hired for their operational or technical expertise and may not have the experience, training or skills to function effectively in an SMS environment. They may also express a greater professional interest in hands-on field inspections rather than reviewing processes that mitigate risk. Furthermore, the transition from a prescriptive-based surveillance system, to a hybrid one where traditional inspections for compliance must co-exist with evolving SMS oversight processes can exert a significant strain on limited regulatory resources.

To cope with this, and in keeping with the principles of SMS, regulators have often adopted a risk-based approach to regulatory oversight in which they use a variety of data sources and intelligence gathering activities to identify the risk profile of individual operators. They then focus their limited surveillance activities on higher-risk sectors or operators using a combination of periodic or cyclical, planned audits and data-driven, unplanned inspections.

However, there is a lack of a common metric for determining what is an acceptable level of risk. Various definitions – e.g., "as low as reasonably practicable", "as low as reasonably achievable" have been adopted. Yet, it still begs the question - acceptable to whom: the regulator, the operator, shareholders, the public, the worker, the accident victims or their next of kin? Clearly there is a high degree of subjectivity and the answer probably lies at the intersection of social acceptability and financial sustainability.

This lack of common metrics for determining an acceptable level of risk brings us to the question of what kind of data on hazards and risks would be useful and meaningful for this purpose. Incident and accident data is one source. However, given the small number of serious incidents and accidents in most transport sectors, aside perhaps from road transport, this data is inadequate and often too late to be of use to either the regulator or the operator. This issue is discussed in greater detail later in this paper as well as in Lofquist (2017). Other data sources include the results of regulatory audits and inspections, both planned and unplanned, and data from confidential, safety reporting programmes.

Openness and transparency are key. The extent to which operators are prepared to share internal safety-related data with regulators is very much dependent on the level of trust between the parties, and the degree to which this information is protected from public disclosure or inappropriate use. Many operators fear regulatory repercussions, public embarrassment or even possible litigation if they acknowledge safety deficiencies in their operations. Even without those fears, both regulators and operators sometimes complain that they are "data-rich, but information-poor". A significant topic of discussion at the roundtable meeting was how regulators ensure they have access to the critical information needed on which to make risk-based decisions about how to deploy their limited surveillance resources. To do so, participants thought, would require important exchanges of data between the regulated entity and the regulator as well as a relation of trust between them so that the regulator could trust in the data it received and the regulated entity could trust that the data it sent

would not be used against it. Roundtable participants also warned against the regulator being submerged with data to the point where it becomes a hindrance rather than a tool

A further question that can be asked is how much information does the travelling public have the right to know? Some may suggest that *all* information should be made available to the public, however, their ability to interpret highly technical and specialized information objectively is limited and conclusions drawn may be exacerbated by an emotional response to events, heightened by social and mainstream media analysis.

Under EU Regulation No.376/2014, individuals are assured confidentiality for reporting safety concerns, however, the application of just culture principles within the organisation and by the regulator could be seen as a largely philosophical exercise once the information is in the public domain and subject to scrutiny by not only the media but the judicial system. There is a risk of loss of reputation and significant financial strain on a company as well as legal action and in response, operators may be motivated to generate less information for fear of how it may be interpreted, which could lead to less effective risk mitigation. Thus, there is a need to strike a proper balance between confidential and publicly-available information in order to not compromise safety in the pursuit of full transparency, recognising that in many cases, confidentiality is essential for a safety system to work properly.

One other potential source of data involves use of on-board voice and video recordings. In many jurisdictions, such recordings are protected by law, and may only be used by safety investigation agencies to investigate the events leading to an accident or incident. In Canada, there is currently an initiative underway to require the installation of voice and video recorders in locomotive cabs (not currently required by regulation) and to allow use of these recordings by regulators and by railway operators for safety analysis in the context of a proactive, non-punitive SMS. This has generated much discussion among stakeholders and many concerns about the privacy rights of workers and the potential for misuse of these recordings, e.g., for discipline, even for inconsequential deviations from standard operating procedures and rules.

Mixed views were articulated during the roundtable discussion. Some felt the use of such recordings for anything other than accident investigations would not, and should not, be allowed in their jurisdictions. Punitive use could lead to deliberate tampering with the recording system. Others questioned a regulator's and an operator's capacity to make meaningful use of so much randomly collected data outside of an accident or incident investigation, and whether the return on investment was worth it. The challenge will be to balance the privacy rights of workers with the rights and responsibility of regulators and operators to know what is going on in their operations. Having an independent recourse mechanism for workers when there is inappropriate use of such recordings was suggested by a roundtable participant and that seemed to garner broad support amongst participants; the modalities of such a mechanism were not discussed.

Finally, verifying operator compliance with prescriptive regulations is arguably less challenging than determining if its SMS is working as intended. Kelly (2017) states that "SMS evaluations must accurately measure a company's capability to proactively manage hazards and safety-risks in a truly dynamic, complex environment. The factors that influence safety-risk management are ever-changing. … A successful evaluation tool must be capable first of all of measuring performance, then identifying the (often simultaneous) circumstances that may be influencing the changed or changing performance." The most commonly used tool is a safety management system audit and these do not necessarily measure

SMS functionality well. Evaluation tools are still considered experimental by many regulators, whose inspectors lack experience using such tools.

In a prescriptive regulatory framework, there are a number of enforcement tools that regulators can call upon to ensure compliance, which can vary from monetary fines to ultimate withdrawal of the operator's authority to operate. The introduction of an SMS has tended to foster a more collaborative relationship between regulators and operators. In such an environment, the regulator may give far more latitude and time to an operator to identify the 'root cause' of any non-conformances to its SMS or regulations and develop and implement a corrective action plan to return itself to compliance, with appropriate regulatory oversight during this process. However, regulators must be careful in such circumstances. An operator with a weak SMS may not be in the best position to analyse the sources of its own shortcomings and develop and implement appropriate and timely corrective actions before an adverse outcome occurs. This is one reason why the TSB (2016) recommended that: "[Transport Canada] enhance its oversight policies, procedures and training to ensure the frequency and focus of surveillance, as well as post-surveillance oversight activities, including enforcement, are commensurate with the capability of the operator to effectively manage risk."

**Challenges faced by transport operators**

*"We keep adding layers but not removing those that aren't working. More process can hinder an SMS"* - Roundtable participant

Transport companies face numerous challenges in implementing an SMS. These may vary as a function of the mode of transport, the size of the company, and the type of industry and regulatory framework within which they operate. But some challenges are common, notably:

- the degree to which senior management is committed to safety and buys-in to the value added versus the significant investment of resources required to implement an SMS;
- the gap between the company's existing safety systems, processes and practices and the regulatory requirements for an SMS;
- the availability of internal safety management expertise, particularly experts in human and organisational factors;
- the resistance to change of lower-level managers and front-line workers; and
- the degree of trust that already exists within a company, which can significantly impact data sharing e.g., the success of internal safety reporting programmes.

Senior leadership commitment is crucial to success. This must be continuously demonstrated through active, visible engagement of the leadership team coupled with an associated commitment of resources (money, people, tools and time) to support SMS implementation and on-going activities. As processes are developed or changed, employees will only believe in and use them if they have been involved in their development and witness that senior management acts on the outputs (e.g., addresses safety issues raised through internal reporting programmes). While it may be necessary to engage the help of some outside expertise, companies need to resist the urge to buy off-the-shelf systems that may not be useable in their context and tend to disempower employee engagement.

During the roundtable discussions, some participants suggested that this is particularly true of small operators who may not have the resources to develop a bespoke system yet have their own particularities that may not be accounted for in an off-the-shelf solution. The question of small operators was raised during the roundtable discussion and there was some consensus around the fact that, when not required by regulation, an SMS may not be the right approach for a small scale operation with a relatively low degree of complexity. Nevertheless, having a small operator successfully implement a legally mandated SMS is certainly very feasible.

The root cause of challenges in implementing an SMS can often be found in the cultural features of an organisation. Lappalainen (2017) explains how safety culture is often viewed as a subset of organisational culture "that is unconscious, invisible and characterized by shared underlying values and attitudes towards safety." Many struggle to define and measure safety culture, preferring to refer to 'safety climate' as a temporal manifestation of safety culture. However, there is a widespread sense that an SMS can only be fully effective when embedded in an organisation that has a healthy safety culture. But which comes before – does safety culture enable the SMS, or does the SMS facilitate a stronger safety culture? During the roundtable discussion, some participants argued that safety culture is nothing more than an intellectual construct and can be the result of how an SMS is implemented, but not its cause, while others saw safety culture as a prerequisite to SMS implementation. We will come back later in this paper to the question of safety culture.

Conflicting priorities, time pressures, ineffective communications and worker adaptations[4] in order to get the job done can lead to increased risky behaviour which causes the operation to drift towards the boundaries of acceptable safety performance. This is important for companies to know. A healthy safety culture is usually associated with a greater tendency to share information. However, as Lappalainen (2017) highlights, numerous studies on organisations with an SMS have found that "incidents are not reported completely, there are shortages in employee participation, and the rules and procedures are not followed in daily operations as required in safety management systems."

In Lappalainen (2017), a number of reasons are provided, articulated around the struggle between rule compliance and being practical, to explain why procedures may not be followed. When these procedures are incompatible with operations, impractical or when the supporting documentation is poorly drafted, staff may decide to ignore them, which can contribute to serious accidents. To remedy this, operational staff should be fully engaged in the documentation process and act as a stalwart against well-intentioned but impractical procedures.

Reporting incidents and mishaps is a very important part of any SMS as it helps to identify safety hazards and lays the groundwork to improvements in operating procedures to prevent future mishaps. It is not always easy for employees to report incidents. They will be more inclined to report them if they know that they will not be blamed, as long as there was no ill intent, and that actions will be taken to address the issues they raise. Lappalainen (2017) explains that poor or inappropriate feedback from reports submitted instils mistrust towards the reporting system and helps maintain a blame culture. To develop a just culture, employees must feel that their reporting is valued and either see concrete corrective actions as a result of their reporting or receive an explanation as to why no action was taken. Building this trust between employees and management is essential if management's commitment to safety is to be taken seriously by employees.

A good example cited in Lappalainen (2017) of an industry-wide voluntary incident reporting system in aviation is IATA's Safety Trend Evaluation and Data Exchange System (STEADES) where trust has been

built through adherence to non-punitive action, confidentiality, ease of reporting, promotion of findings and acknowledging the importance of reporting across the industry. There is ongoing discussion about the potential value of reporting on positive human factors and successful performance (rather than incidents) which could serve as a positive motivator for improved safety reporting and help operators better understand how safety is created.

**Challenges faced by specific industries**

The nature of the industry itself has played a significant role in how SMS has evolved. The aviation and maritime sectors of transport seem to have evolved the furthest in terms of introducing advanced, international safety management system frameworks, thanks largely to the efforts of ICAO and IMO respectively. The railway industry has also moved forward with implementing an SMS, though its specific framework is largely based on the degree of cross-border integration, which is driven by geography (e.g., North America, the U.K. and Europe). In the U.S., commuter transit is emerging as the newest frontier for safety management systems. SMS is least developed in the road sector (buses and commercial truck transport) except on a voluntary basis by some progressive companies.

As previously mentioned, the maritime industry was an early adopter of the SMS (in the 1990s), in the form of the ISM Code under the International Convention for Safety of Life at Sea (SOLAS). However, the ISM Code has recently been criticised in that it does not give satisfactory information on how to implement an SMS in a company and does not provide enough support for consistent interpretations. Some believe the ISM Code is in need of major revisions but there does not appear to be much interest except in the major states of the IMO. Furthermore, there are some difficulties in implementing an SMS given the nature of the international shipping industry. Lappalainen (2017) mentions that "…the current multi-level maritime safety regime has been criticized as being ineffective in ensuring that every ship complies with the international maritime regulations. … The current safety regime allows sub-standard shipping because some flag states (Flags of Convenience; FOC) permit foreign ships to be registered in their open registers which are more permissive regarding, for example, safety regulation and manning requirements."

Other issues which can impede effective implementation of an SMS in the shipping industry include:

- flag states have different regulations and practices;
- port state control inspections are inconsistent and not always effective;
- multinational crews contribute to communication problems and different cultural assumptions;
- regulatory overload; and
- geographical distance between ships, ship management companies and regulators which reduces oversight.

"Flagging ships out to FOC countries, using manning agencies for hiring personnel and outsourcing ship management are growing trends in the shipping business. … It is a topical question how a single company can, for example, promote safety culture in a fragmented and globalized business environment." "The geographical distance between the ship owner and the ships forms a concrete barrier in developing a strong safety culture based on the shipping company's accepted goals and values." Nor is this unique to

the shipping industry. In aviation, many large airlines use leased aircraft, hire foreign pilots, and contract out training and maintenance activities to sub-contractors in other parts of the world. One strategy to cope with this is to provide culture management training to enhance crew team cohesion, improve communications and improve safety.

Another promising marine industry initiative has been undertaken by the Container Ship Safety Forum (CSSF). The CSSF provides information about improvements in safety management systems, develops common safety standards and key performance indicators, collaborates on benchmarking, and provides a network of peers to exchange best practices.

Similarly, IATA has developed a system to evaluate major airlines' safety management practices through the IATA Operational Safety Audit (IOSA) and share audit findings among registered peers. According to IATA (2017), the total accident rate for IOSA airlines between 2011 and 2015 was 3.3 times lower than the rate for non-IOSA operators. However, the causal link between IOSA membership and accident rates is not clear. IOSA is mandatory for all IATA members. In addition, 145 non-IATA airlines have also voluntarily chosen to participate. However, there may be a selection bias at play here because IATA members and non-IATA members who voluntarily take part in IOSA may have inherently safer operations than those who choose not to take part. Nevertheless, an industry-driven safety audit can be a very useful tool to help airlines compare their safety performance against a global standard while respecting their national regulatory requirements.

Road transport seems to be the most challenging mode in which to implement an SMS. Non-commercial users of the road system, such as private car drivers, cyclists and pedestrians have little or no notion of SMS. For commercial operators, there are no mandatory requirements for the implementation of an SMS, although some States like Finland and Australia are encouraging voluntary adoption. When companies do implement an SMS, it may be prompted by occupational health and safety requirements and tends to be based on QMS standards. There is a large number of road operators, and the industry is highly competitive; but the operators tend to be small and may not have the resources or expertise to implement an SMS. There has also been an increased reliance on sub-contracted drivers in the trucking industry, which further exacerbates the challenges of inculcating a strong safety culture and an SMS in that transport mode.

Meanwhile, in Sweden and the Netherlands efforts are being made to develop an SMS for the entire road sector, which would encompass all road users. However, as will be discussed later on in this paper, this modal-centric SMS may turn out to be a very different entity than an operator-centric SMS. Finally, the International Organization for Standardization (ISO) has developed a road traffic safety management standard, ISO39001 previously described in the road transport section.

Clearly these initiatives and others show an important commitment to improving road safety and are aligned with the UN Decade of Action for Road Safety.

A number of factors can impede the implementation of an SMS, no matter the mode of transport. The lack of international standards and oversight, for example, means that the SMS in a given sector may develop at different speed and in a different way in one region of the world compared to another. Industry fragmentation can lead to smaller companies which may find it more difficult to implement a full SMS. Competition between companies and between modes forces operators to keep costs at a minimum, which could make the implementation of an SMS more challenging, especially when none is

prescribed by law. Finally, the prevailing societal and industrial culture may be incompatible with some precepts of an SMS, such as a just culture.

**Lessons learned from accident investigations**

Accident investigations offer an opportunity to investigate an operator's risk management practices and why risk control measures may have failed. It also affords an opportunity for the operator to identify and correct deficiencies in its safety management system.

When safety occurrences happen, and they may despite the best designed SMS, it changes investigation practices intended to improve safety outcomes – by reducing the reliance on lessons learned *after an accident or incident* investigation – and increasing the focus on how to build safety processes into day-to-day operations that are designed to prevent accidents.

It is important that investigators collect data from a variety of sources, such as formal documented policies and procedures, audit and evaluation reports, interviews with witnesses and company executives. It is also important to consider the SMS as part of the wider organisational factors that may be relevant to the occurrence. While post-accident surveys may be informative, they can also be subject to hindsight bias and the after-effects of the accident itself potentially compromising their ability to measure the organisation's safety climate.

French and Steel (2017) references a 2009 review of Canadian TSB occurrence investigations between 2001 and 2008 and identifies a number of safety management factors that played a role in these accidents and incidents, including:

- no formal risk analysis conducted;
- risk analysis conducted but hazard not identified;
- hazards identified but residual risk underestimated;
- risk control procedures not in place, or in place but not followed;
- issues related to equipment design and/or maintenance practices;
- inadequate tracking or follow-up of safety deficiencies;
- insufficient personnel for the task at hand, heavy workload, inadequate supervision;
- insufficient training or lack of qualifications for the task to be performed;
- conditions conducive to physical or mental fatigue;
- ineffective sharing of information before, during or after the event including verbal communications, record-keeping or other documentation; and/or
- gaps created by organisational transitions affecting roles, responsibilities, workload and procedures.

These can be grouped broadly under four headings. First, some occurrences were the result of drift from prescribed processes or adapting prescribed processes in order to 'get the job done'. This would suggest that operational staff found the prescribed procedures lacking and would prevent obtaining the operational results given the time and resources available to do so. The drift away from how things should be done introduces elements of risk into the system that the SMS may not have taken into account. This reinforces the importance to have employee buy-in in drafting procedures to make sure they are fully applicable in an operational context.

The second point refers to conflicting goals, where there is a deviation from the prescribed process as a conflict arises between production and safety. The third point related to incidents not being reported which then provided incomplete data to safety analysts, making them believe that the system was safer than it actually was. This raises a topic discussed at the roundtable that was how to determine 'what we don't know'.

The last point related to the non-identification of hazards and poor risk assessment. This can be caused by a number of factors, including a lack of requisite imagination, lack of mindfulness, not recognising weak signals, making incorrect assumptions, underestimating risks, a lack of organisational resilience and a lack of learning from previous occurrences.

It is very important for investigators to "…strive to uncover the contextual drivers that influence decision-making, goal conflicts, local adaptations and 'non-compliance' with formally documented rules, procedures and safe practices to facilitate organisational learning and effective follow-up after an occurrence." In particular, significant gaps between policies, procedures and practices; a focus on production at the expense of safety; or a tendency to look for someone to blame when things go wrong (i.e. focusing on the individual rather than the system) may be indicators of a weak safety culture.

In summary, investigators need to ask six key questions when examining an organisation's SMS:

1. What were the relevant control measures defined in the SMS? How were they documented, understood and applied?

2. To what extent were the hazards and risks understood?

3. What mechanisms were in place to monitor and review the efficacy of the SMS?

4. How did the organisation learn from previous experience, and then use that experience to improve its safety arrangements?

5. How did the prevalent attitudes and behaviours within the organisation contribute to the accident/incident?

6. How much did the regulator know and to what extent did the regulator intervene?

Finally, it is also important to remember that as stated in French and Steel (2017), a deficiency in one area of an organisation's safety management system does not mean that the entire SMS is defective and therefore an SMS can be improved in one area while maintained in others.

# SMS in a non-transport context: The offshore oil and gas case study

The concept of SMS, as we've seen, can transfer quite well from one mode of transport to another, even if the concrete application can contain some elements specific to a given mode. Many of these concepts in fact apply to a far broader range of industries, where managing hazards and risks are a common occurrence. In this section, we will briefly discuss how SMS is applied in the offshore oil and gas extraction industry to show the many parallels that exist in the underlying SMS concepts between that sector and the transport industry, despite how different these industries actually are.

The Deepwater Horizon drilling rig accident that occurred in the Gulf of Mexico in 2010 was a highly publicized major disaster due to an oil well blowout and fire that killed 11 workers and resulted in devastating damage to coastal waters from an uncontained oil spill. The causes of the Deepwater Horizon were clearly attributed to organizational failures and human error. (DHSG 2011, National Committee 2011). Follow up analysis examined the underlying human factors issues and recommended application of human factors methodologies, as well as general improvements to the overall safety management process that included implementation of a safety management system (Ciavarelli 2016, and Wassel 2012).

Following this disaster, there was a significant restructuring of the agencies responsible for providing regulatory oversight for offshore oil and gas operations. The former regulatory agency, the Minerals Management Services (MMS) was dissolved, and replaced by a tripartite organizational structure that included the Office of Natural Resources Revenue (ONNR), the Bureau of Ocean Energy Management (BOEM), and the Bureau of Safety and Environmental Enforcement (BSEE).

The BSEE was specifically chartered to oversee offshore worker safety and environmental stewardship and was given statutory authority to implement rules and processes required to improve the safety management of offshore Oil and Gas operations.

BSEE began immediately to mandate a requirement for all operators to implement a Safety and Environmental Management System (SEMS). The core components of the SEMS were intended to manage safety by considering environmental hazards and impacts of operations during design, construction, operation, inspection, and maintenance of all new and existing offshore facilities. (BSEE Reforms, https://www.bsee.gov/who-we-are/history/reforms).

The BSEE SEMS was envisioned as a performance based safety management process, rather than a prescriptive one that relies on external regulatory operational inspection process.

SEMS is a safety management system (SMS) aimed at shifting from a completely prescriptive regulatory approach to one that is proactive, risk based, and goal oriented in an attempt to improve safety and reduce the likelihood that events similar to the Macondo Well (Gulf of Mexico) incident will not reoccur. (National Academy of Sciences, 2012, p.1)

Subsequent development of SEMS, referred to as SEMS II, implemented a "stop work authority" that allows any worker to request stopping work if he/she observes an unsafe condition. And any employee

requesting a work stoppage was to be protected from management reprisal. SEMS II also included prescriptive language that encouraged employees to play a more active role in identifying hazards, managing risk, and participating in safety reporting. The key components of the SEMS are shown below, as stated in the BSEE Fact Sheet available online at: https://www.bsee.gov/sites/bsee.gov/files/fact-sheet/safety/sems-ii-fact-sheet.pdf

- Developing and implementing a stop work authority that creates procedures and authorizes any and all offshore industry personnel who witness an imminent risk or dangerous activity to stop work.

- Developing and implementing an ultimate work authority that requires offshore industry operators to clearly define who has the ultimate work authority on a facility for operational safety and decision-making at any given time.

- Requiring an employee participation plan that provides an environment that promotes participation by offshore industry employees as well as their management to eliminate or mitigate safety hazards.

- Establishing guidelines for reporting unsafe working conditions that enable offshore industry personnel to report possible violations of safety, environmental regulations requirements, and threats of danger directly to BSEE.

- Establishing additional requirements for conducting a job safety analysis.

- Requiring that the team lead for an audit be independent and represent an accredited audit service provider.

- General provisions: for implementation, planning and management review and approval of the SEMS program.

- Safety and environmental information: safety and environmental information needed for any facility, e.g. design data; facility process such as flow diagrams; mechanical components such as piping and instrument diagrams; etc.

- Hazards analysis: a facility-level risk assessment.

- Management of change: program for addressing any facility or operational changes including management changes, shift changes, contractor changes, etc.

- Operating procedures: evaluation of operations and written procedures.

- Safe work practices: manuals, standards, rules of conduct, etc.

- Training: safe work practices, technical training – includes contractors.

- Mechanical integrity: preventive maintenance programs, quality control.

- Pre-startup review: review of all systems.

- Emergency response and control: emergency evacuation plans, oil spill contingency plans, etc.; in place and validated by drills.

- Investigation of Incidents: procedures for investigating incidents, corrective action and follow-up.

- Audits: requiring an initial audit within the first two years of implementation and additional audits in three year intervals.

- Records and documentation: documentation required that describes all elements of the SEMS program.

More detailed Information regarding the history, objectives, policy and SEMS regulatory policy can be obtained from the BSEE website at: https://www.bsee.gov/resources-and-tools/compliance/safety-and-environmental-management-systems-sems

Many of the elements above clearly resonate with principles found in a transport-related SMS, such as stop work authority, safety authority, safety training, employee engagement, incident investigation, safe work practices pre-start-up reviews, audits and records keeping. Of course the procedures themselves may be significantly different between the offshore drilling industry and any given mode of transport, but their intent is quite similar. Similar case studies in other high-risk industries, such as health care or nuclear energy would likely yield the same results. This drives the point that SMS is driven by a core of principles such as the ones previously enumerated and that there is likely much to be learn on SMS by one sector from others.

## Measuring the success of SMS: The Safety-I or Safety-II approach?

*"If an accident is your indicator, then it's an indicator of poor luck"*
-Roundtable participant explaining ironically that an unsafe behaviour does not usually lead to an accident but does increase the risk of one.

An important question in respect to safety management systems is verifying that they actually work and create benefits to the individual company and the society at large. The answer to that question depends of course on what the initial objectives of implementing an SMS were. If we look at shipping companies, airlines or railways in certain jurisdictions, introducing an SMS is a question of regulatory compliance. Experience shows that in many organisations, efforts are often only made to meet the minimum level of compliance needed to pass surveys and audits required by the regulator. A question that therefore can be raised is what quality these safety management systems have, if only created in a framework of a regulatory compliance culture.

The more important aspect relates to the core components of the SMS. In maritime transport, for example, core parts of the International Safety Management (ISM) Code focus on accidents and require investigations into all major occurrences on board. This is also true in other modes of transport, although accident investigations are not as intimately related to their SMS as in maritime transport. As a result, companies are forced to set up internal procedures and systems to develop competencies in accident investigation and follow-up. The concept of looking into accident and other occurrence data in order to improve system safety is called a Safety-I perspective. The idea is very much to learn from past accidents

in order to avoid similar challenges in future. The main question therefore should be recast as: is a SMS effective from a Safety-I perspective?

If an SMS is introduced with a Safety-I perspective, it may help companies prioritise safety in their organisational culture by raising safety awareness throughout the company. However, would this relatively small benefit outweigh the limits of an SMS with a primary focus on accidents and their avoidance? An important factor in this respect would be the quality needed in accident investigation that would allow for appropriate lessons to be learned to the benefit of the overall system improvement. There is a risk, however, that individual companies will make insufficient efforts to build up the necessary expertise when their objective is to meet the minimum standards needed in order to pass the government required surveys and audits?

In this respect a couple of limiting factors come to mind when considering the compliance perspective. Can one global set of standards for safety management systems in all countries be established that helps to achieve an effective no blame safety approach? Another important question in relation to this point is how prescriptive such standards have to be or not to be in order to achieve a global no blame safety approach. This will have quite an influence on the way individual companies set up their SMS. Will they try to find the best solution for their own individual needs in relation to their operational environments or will they just try to meet the more or less detailed requirements of the standards to be considered when establishing an SMS? The compliance perspective is also influenced by the individuals who survey and audit individual companies and their SMS. How is this done and when? To use once more an example from maritime transport – audits on ships are usually done when the ship is in a port and a lot of other, commercially more important operations are carried out. How accurate is the snapshot picture that such an audit can produce in such a situation?

A more fundamental question in relation to SMS that focuses on accident investigation conducted internally by an operator, as opposed to an independent accident investigation agency as a learning tool to improve system performance, is the question of how reliable accident investigation reports are for system improvement. In commercial operations there is always the issue of liability and damage compensation, which is of special importance in an accident situation. How transparent and open can individual transport companies be with accident investigation results for use as a learning tool without jeopardising their insurance cover or challenging their position in possible law suits following an accident? These are some arguments as to why a focus on accident data may not be the best possible basis for an SMS to function.

There are other factors that may also limit the potential of an accident data focus in SMS. How relevant are accident data for the assessment of the overall system performance? In maritime risk assessments the probability of groundings in a certain area is often considered as 3 out of 10,000 ship movements in that area. This is a very conservative assumption and statistics seem to suggest that there is a very high safety margin built into that assumption. However, it means that a lot of efforts are made in order to explain why 3 out of 10,000 movements could go wrong, while no efforts are made to explain why the other 9,997 ship movements in that area mastered all challenges successfully.

Another argument against an accident data focused SMS is related to the complexity of system design of modern socio-technical systems. Charles Perrow introduced the idea of “normal” accidents in the 1980s as a result of tightly coupled and complex systems. If one accepts this point of view, complex systems offer an equally complex spectrum of possible failure modes which is impossible to consider in standard risk assessment approaches.

In this respect the difference between "work done" and "work imagined" needs to be considered. When an SMS is designed, key functions and operations are identified and possible failure modes discussed. As a result of this assessment, very specific measures are suggested to avoid that failure modes may lead to adverse consequences. However, accident investigations often reveal evidence showing that routine processes in socio-technical systems were performed in different ways other than envisaged by the system designers. The operators at the 'sharp' end may for various reasons not be in able to follow the instructions prescribed by higher levels of an organisation. This could be a result of inadequate internal communication or a missing awareness for the needs of individual operators in an organisation.

One issue that should be mentioned in respect to an accident data focused SMS in a complex system are unanticipated effects of change in a system. If system improvement is initiated after serious occurrences, success is often not automatically achieved. With an accident focus in mind, any modifications to a system are often only reviewed in terms of how well they would protect the system in case of a similar occurrence. However, there may be ripple effects in complex systems and it may turn out that the new safety measure may not only result in system improvements, but may also create new challenges for the system. A typical example in the maritime sector was the introduction of the radar technology after World War II. It was hoped that this technology would reduce the risk of collisions during periods of restricted visibility. That was to a certain extent the case. At the same time, the whole process of navigation during restricted visibility changed in an unanticipated way. Many navigators did not reduce speed anymore during times of restricted visibility and accepted closer passage distances to other ships. If the navigational intentions of the other ship were misinterpreted or collision avoidance regulations not strictly followed, the safety margin was often not sufficient anymore to avoid a collision. As such, a new type of accident had emerged, which was called 'radar assisted' collisions. Radar technology introduction is far from the only new technology to raise such safety issues. This underlines once more that an accident data focused SMS faces a number of limitations in respect to the original intention.

There is an alternative approach known for a number of years now as a Safety-II approach. The main feature of this approach is to concentrate on understanding what enables good performance in a system. Accidents are rare events and often occur in extreme situations. They are in any case often not representative of routine functionality in a system. As such, the learning potential of examining individual accidents for system improvement may be limited.

Roundtable participants noted that many of the near miss reporting systems have failed because the necessary no blame culture had not taken root. It was therefore suggested that near miss reporting be replaced with reporting on examples of good performance. The inner barriers that may prevent individual operators from making reports criticising performance shouldn't impede reporting examples of good performance.

This leads to another concept of system performance for which the term 'resilience' has been coined. Resilience engineering in this respect is concerned with the ability of a system to absorb sudden changes or disturbances to its performance and to return to its original state while maintaining its functionality all the time. It is understood in this respect that systems are complex and often consist of many sub-systems. To understand the elements that enable system performance under various conditions in complex socio-technical systems is a key function in this context. Furthermore, it has to be possible to find some indication about the status of the performance enabling factors. The Resilience Analysis Grid (Hollnagel, 2011) is one of the suggested tools that allow for a determination of the resilience status of such a socio-technical system. This tool uses a series of question to measure how well a system is able to respond, monitor, learn and anticipate an event. The answers the questions help to determine the

potential for resilient performance. This is probably going hand in hand with industry developments. In the maritime sector so called Shipping Key Performance Indicators (KPIs) have been developed following a similar intention to easily identify trends in the development of the performance status of a maritime transport system.

In earlier parts of this section the argument was made that an accident data focused SMS will not be able to show the full potential they can have for the performance of a system. However, it is probably time to also admit that this part, although very prominent in SMS standards, is important, but by far not the only topic that is addressed in these standards. The accident focus is prominent in SMS standards because they were established by regulators following major accidents. But the scope of an SMS goes far beyond the review and analysis of accident and other hazardous occurrence data. The issue that should therefore be discussed is the question of why the accident focus is still so dominant in current safety management systems. In a historical context it is clear that when the standards were written, it was hoped that the accident focus would help to learn lessons from incidents and accidents and improve the arrangements in the transport sector. From a regulatory perspective the accident focus cannot be disputed. Accident investigation is an obligation to governments and required in a number of international treaties for the transport sector. Following an accident, the regulator has to review what follow-up such an accident requires in terms of regulations and resources needed in the implementation and enforcement. At the same time, not all business functions of the industry can and should be regulated.

When performance becomes a major driver in further developing an SMS, the accident data focus may become less and less relevant as we turn our focus to what went right (Safety-II) and not only limit our analysis to what went wrong (Safety-I). One roundtable participant mentioned that when his organisation changed the reporting system to collect data both on what went right and what went wrong, the number of reports quadrupled and a number of positive actions that prevented accidents came to light.

The ultimate goal of any SMS is to prevent the next adverse event from happening. As systems are continually evolving, operators need to focus their SMS on areas of vulnerability, on the impacts of changes, on issues that are precursors to accidents and on ensuring that the organisation is moving in the right direction.

## Culture and SMS

"Safety culture is a construct […] an enabler to achieve safety but is not an end in itself" – Roundtable participant

Defining what is meant by culture has been described as "among the most complex and most debated questions of the social sciences" (Antonsen, 2009). Whilst it is broadly conceived to encompass "everything that is not nature", how culture is defined and perceived is dependent upon methods used and inferences made (Antonsen, 2009; LeVine, 1984).

Informally described as "doing the right thing even when no one is watching" (Sumwalt, 2007 cited in Lappalainen, 2017), the term safety culture has its origin in the International Nuclear Safety Advisory Group report into the Chernobyl accident in 1986. The International Atomic Energy Agency (1992) stated that "the accident can be said to have flowed from deficient safety culture" and indicated that the

design, operating and regulatory organisations were as culpable as the front line operators. This report paved the way for how future accidents across all modes were investigated, such as the Herald of Free Enterprise (1987) and Piper Alpha (1988).

Safety culture, as defined by Reason (1997) rests on five components, namely:

1. Informed culture -The organisation generates significant data on incidents and accidents, which is complemented by safety audits and surveys on safety environment;

2. Reporting culture – Employees are encouraged to report their errors or near misses, and take part in surveys on safety culture;

3. Just culture – The establishment of a trust relationship between employees and employer where reporting mistakes and incidents is encouraged and employees know they will be treated fairly if they make any unintentional mistake[5];

4. Flexible culture -The organisation shows that it is able to adapt it practices when warranted;

5. Learning culture - The organisation learns from incident reports, safety audits and internally-reported issues, resulting in improved safety.

In addition to these characteristics, an organisation's safety culture is tightly bound to the societal culture in which it operates and exogenous factors such as regulators, legislations, equity investors and market conditions. However, a strong safety culture does not make an organisation immune from accidents and there are cases where an organisation where an organisation has a strong safety culture but still has accidents.

The delineation between these various elements has given rise to a desire for measurement and quantification although as French and Steel (2017) points out, different industries may have different ideas about what constitutes 'good' in relation to safety culture and therefore there may be divergence in what is thought to be a positive or negative indicator. National, organisational and professional history, values and beliefs will obviously come into play in shaping what is seen as the 'right' way for an organisation to behave.

Maurino (2017) outlines how culture can influence the values, beliefs and behaviours people share with the other members of various social groups. It binds people together as members of a group, and provides clues and cues as to how to behave in both usual and unusual situations. In so doing, it sets the 'rule of the game' and provides both the framework for interpersonal interactions and a context in which things happen. In essence, it is the sum total of the way people conduct their affairs in a particular social milieu.

As organisations constitute the context in which SMS are conceived, built and operated, the culture of the organisation is of interest but again there is little agreement with regard to what constitutes an organisational culture: Frost et al (1991) shows that there are many differences in theoretical, epistemological and methodological perspectives dependent upon whether culture is seen as something an organisation has, something that can be measured, mediated or moderated, or whether the organisation is a culture similar to a nation or tribe (Antonsen, 2009).

With regards to the management of safety, Maurino (2017) points out that understanding the concept of culture is only important in regard to it being "an important determinant of organizational performance". This, he states, is subject to three levels of culture:

National – the national characteristics and values systems;

Organisational - the characteristics and value systems of particular organisations, the collective behaviours of one company as compared to another; and

Professional – the characteristics and value systems of particular professional groups such as pilots, or engineers.

These he suggests are linked and will influence amongst other things how information is collected and shared, how workplace practices develop, how organisations react to operational errors. "The way we do things around here". (Schein, 2010)

Lappalainen (2017) draws widely on the literature outlining how three traditions or paradigms are used to describe the concept of organisational culture:

- The functionalist – built into the organisation as a subsystem to advance the development of organisational goals and values (McAuley et al 2007, Guldenmund, 2010). Culture is seen as being on a continuum and therefore measurable as positive or negative and something that management has an element of control or influence over.

- The interpretive – organisational culture is a system of shared symbols and meanings used to interpret collective identity, beliefs and behaviours (Smirchich, 1983); and

- The postmodernist or constructivist (McAuley et al 2007, Guldenmund, 2014) – this challenges previous views and suggests that unity and homogenisation of individuals within an organisation can been achieved and will create efficiency, loyalty, reliability and enhanced safety.

Lofquist (2017) asserts that the role of culture will vary across the transport sectors covered in this paper and that "culture is created through the daily interactions within a group of actors interfacing with their immediate environment". Over time, people continue the actions that work or are expedient and cease those that are of little value, forming the basis of assumptions about how to interpret information, react and behave. This adds to Maurino's (2017) three step cultural breakdown establishing the influence of history, language, religion, education and accepted norms of behaviour on national culture. On an organisational level, he states that history, leadership, and how the company competes within the industry will influence culture and proposes that this is extended to the industry level (akin to Maurino's professional) shaped by guiding rules and regulations, infrastructure design, history and educational requirements.

Given the global context in which the air, rail, maritime and road industries operate, the significance of multinational crews with regards to safety has been shown. Kelly (2017) discusses issues with communication, particularly in maritime where multicultural and multinational crews account for four fifths of the world merchant fleet.

Studies in the airline industry have shown that differences in thinking and reasoning styles can lead to barriers to understanding and collaboration (Strauch, 2010) and that it cannot be assumed that generic models will be understood in the same way even between professionals within the same industry (Reader et al, 2015). During roundtable discussions, participants raised the issue of multinational crews, especially on ships but also on aircraft and how it can be challenging to compose with a multitude of societal cultures in trying to implement a single, company-wide, safety culture. One roundtable participant mentioned that 75% of crew on EU flagged maritime vessels come from outside the EU and that a typical cruise ship would have a crew complement of 500 coming from up to 50 countries. In this context it is very challenging to implement an SMS and even more so a common safety culture.

Safety research has changed its sphere of attention over time. Maurino (2017) comprehensively describes the move from a system safety perspective based on design and engineering principles in the 1960s, through a human-centric Human Factors focus in the 1970s and 1980s, to an integrated approach including learning from business management. The result of this integration he suggests has been safety management, with SMS as the means of implementation in industry. The paper states that "the point of significance of organisational culture to the management of safety is that it is the most powerful, single shaping factor for safety reporting practices by front-line personnel". Reporting programmes have long been promoted to determine errors made in the operational context. Maurino argues that this has given rise to concerns about protecting safety information, and protecting those who report errors from retribution. This has led to a flurry of new concepts such as 'blame-free culture', 'just culture' and the most ubiquitous of all, 'safety culture'.

Safety culture has proven to be a popular if problematic concept, described variously in many of the papers prepared for this roundtable with each author agreeing that that there is no single universally accepted definition. French and Steel (2017) quote Reason (1997): "few phrases are so widely used but so hard to define."

Lappalainen (2017) illustrates how the concept of safety culture became central to the concept of the organisational accident. It cites Reiman et al's (2012) six dimensions of a 'good' safety culture:

- Safety is a genuine value, taken into account in decision making and daily operations;
- Safety is understood as a systemic and complex phenomenon;
- Hazards and requirements of the core operations are thoroughly understood;
- The organisation is conscious about uncertainties and alert towards possible risks;
- Responsibility is taken for the safe functioning of the entire system;
- Operations are organised in a manageable way, activities are properly performed and the system is manageable.

It continues by illustrating how these positive features are embodied in the ISM Code in the maritime industry and concludes that "there is no single truth about what kind of safety culture would be the best."

The stance adopted in Maurino (2017) departs from the rest of this book's authors as he ascribes a 'folk label' to what he sees as an abstract concept, such labels holding "potential for misperceptions and misunderstandings, and ultimately for aberrant endeavours". It distances itself from the constructs of safety culture and just culture, and advocates for the development of operational contexts that encourage active and effective safety reporting. It asserts that the labels "portray shortcuts that describe very specific, Anglo-Saxon values and beliefs representing what the building blocks of practices regarding fairness in safety management processes should consist of." This suggests that the practices are by their nature biased and judgemental and far from universally applicable. Finally, it argues that reporting, not just of errors but in a more generic sense, is an activity that should be "promoted, nurtured and defended". How this is achieved should be left to the individual organisations as they will need to find a means that works best for their particular structure and ways of working rather than the imposition of a universal solution.

Roundtable discussions upheld and clearly illustrated the variety of philosophies suggested by the literature. Use of concepts and labels such as safety culture suggest something that can be described and is therefore tangible and quantifiable in an organisation. Identification in this way can lead to the illusion of control. The divergence in epistemological stances means that the definition, identification, measurement and management of safety culture polarises views and calls into question the legitimacy of continuing to use safety culture as anything other than an abstract concept.

There seemed to be consensus amongst the experts assembled that safety culture is notably difficult to define and there is little agreement among safety professionals about how to measure and how to evaluate the state of an organisation's safety culture, as discussed in French and Steel (2017). Considering safety culture as an integral part of accident investigation is challenging, making the point that the use of metrics to assess safety culture, following an accident is necessarily biased when we attempt to use safety culture metrics in the shadow of a serious accident.

Deckker and Breakey (2016) make a clear distinction between mistakes, at-risk behaviours and reckless behaviours6. There is an evolving degree of wilfulness and disregard in those three categories which would be recognised by a just culture. A just culture program takes into account the varying degree of culpability and encourages transparent and honest reporting. A just culture will seek to understand and prevent future mistakes, will try to understand why employees feel the need to adopt at-risk behaviours and would not tolerate reckless behaviour. They believe that employees who believe their working environment has a just culture will have a higher morale and will be better at problem-solving. They also believe that it creates incentives for transparency and communication within the system.

Different measurement methodologies exist between and within the various modes of transport. French and Steel (2017) outlines a few of the most popular ones in use in the rail and aviation industry such as the ORR's Rail Management Maturity model (2011) and Westrum's (2004) typology of organisational cultures but they also concede that there "is a difficulty in creating a comprehensive safety culture indicator". As we discussed earlier in this paper, most social scientists 'lean away' from direct quantification of safety culture given the limited validity and reliability of the tools in use and yet safety surveys remain a popular product in the field of consulting if not in academia.

Despite the different views on what constitutes a safety culture, or whether it does in fact exist in anything more than a conceptual form, there is greater acknowledgement of the term 'safety climate'. Climate is seen as being a much more transient state with more visible characteristics which Antonsen (2009) suggests are more amenable to change. Cox and Flin (1998) assert that whilst culture is perceived

as an organisation's personality, climate is more akin to an organisation's mood. In French and Steel (2017), we remark, however, that the two quite distinct concepts are (unhelpfully) conflated and the terms used interchangeably. Safety climate is thought to be a surface feature that reflects culture and represents measurable employee attitudes and documented opinions regarding management's commitment to safe operations, implementation of safety policies and the perceived effectiveness of safety processes (Mearns and Flin, 1999, Ciavarelli, 2008, Zohar 2010).

This is discussed in part in Lappalainen (2017) which highlights the importance of employee participation in the implementing of an SMS. Empowerment and delegation has been shown to improve motivation towards safety amongst staff. Levels of risk identification and ownership of safety issues are boosted but there is a caveat. Lappalainen cites findings from Almklov et al (2014) where "safety management systems based on a generic safety management regime may lead to disempowerment of employees". It is essential that conflicting cultural approaches and local ways of working are taken into consideration if the introduction and implementation of safety management systems are to be effective.

Lappalainen (2017) also references studies that show that differences in the professional culture, between railway maintenance works and maritime personnel, will influence how readily generic safety management principles are adopted. This cultural bias, stemming from history, education and working practices, has been shown to hamper implementation of an SMS in cases where the SMS has not been tailored to fit the needs of the particular group. Engagement with staff in the design of the SMS would go some way to encouraging a commitment to the process.

Lappalainen (2017) echoes Maurino (2017) in identifying reporting as an integral component of an effective SMS and supports the view that reporting systems should not simply be used for reactive error reports but should "be changed from negative effects to positive human factors" (Teperi et al, 2015). This is based on a shift in paradigm (the Safety-I/Safety-II proposition by Hollnagel, 2014 and discussed earlier) where human behaviour is seen as contributing to successful performance and that the "positive role of human activity in coping with unexpected events" is captured to ensure continued system resilience.

Discussion amongst the roundtable participants made it clear that polarised views will inevitably continue to exist with regards to the concept of safety culture. Unfortunately, given the strongly held philosophical perspectives that influence how the concept is perceived in the context of the implementation of safety management systems, it is unlikely that consensus will be achieved either within or between academia and the various transport modes. There was, however, acknowledgement that the way an organisation is structured, resourced and led can and does have a direct impact on performance. Perhaps moving away from conceptual labels as intuitively comforting as they may be and simply, as Maurino (2017) puts it, focusing on the practices that lead to the outcomes organisations wish to achieve, the transport modes can move beyond debating what is good or bad, what is pathological or generative and utilise the principles of safety management systems in the manner in which they were first envisaged where a performing SMS "seamlessly integrate(s) safety management processes and institutional arrangements". Finally, some participants questioned if the need for employees to report an incident through a confidential system rather than openly through an SMS does not raise some question on how healthy the safety culture or climate really is.

## A sectorial SMS: Is it possible?

The discussion on safety management systems in this paper has so far been company-centric, or even vessel-centric. Independent of the mode of transport, the system is designed to inform an organisation's management of safety hazards and risks and to comply with safety-related regulations, when applicable. Since it appears to be effective to a large extent at an organisational level, can the concepts of SMS be scaled up to a sectorial or modal level? Or scaled-up further to a transport system level mega-SMS?

To properly answer the question, requires proper understanding of the framework under which an SMS operates. An SMS is a management system and we can view the transport system as a network of operators, some with safety management systems, others without, sometimes interacting with each other while other times acting completely independently from one another. For example, in maritime transport, different ships, each with their own SMS may need to operate in close proximity within the limits of a port which may also have in place something analogous to an SMS. In such instances, there may be some value in managing the various interfaces between the different operators, without actually having an overarching maritime SMS.

An SMS is probably most developed conceptually in air and maritime transport simply because both have international standards, be it Annex 19 or the ISM Code. In either case, there is no such thing as an SMS of the air or an SMS of the sea, but rather an airline's SMS or a ship's SMS. That being said, in rail transport, the safety management systems of different companies often have to interact when sharing tracks and the same can be said of those of different airlines, an airport and an air navigation service provider when operating in the same airspace or ground area. Thus we end up with different companies and entity types, each with its own SMS, needing to interface and work together without having an actual SMS in place for the entire network. This is particularly true in the rail sector, where the operator and the infrastructure manager may be two different companies with competing interests but may have some joint responsibilities when it comes to an incident such as a derailment.

A different approach is one proposed by the Dutch Ministry of Infrastructure and the Environment with their road safety management programme (Rijkswaterstaat, 2017). This programme starts with a leadership commitment to a proactive safety culture at the highest levels of the Ministry. It is supported by a safety policy statement which rests on three pillars, namely a safe infrastructure, safe vehicles and safe user behaviour, particularly in road work zones. The policy outcomes are assigned safety performance indicators for which targets are set and then the performance measured against. The road safety management programme also includes an organisational and legislative framework and a management review. Finally, construction and maintenance of road infrastructure includes a quality assurance aspect, an assessment and prioritization process to measures to mitigate risk and a determination of safety measures to be deployed.

The Dutch safety management programme enjoys many commonalities with the more conventional SMS that we have been discussing so far. One major difference though is that it is applied to the State rather than an individual company. In that sense, if we were to make a parallel with aviation or maritime transport, it seems to resemble more closely a state safety programme (SSP) in aviation or a Search and Rescue Plan in maritime transport rather than an actual SMS.

In aviation, SSPs are a requirement of Annex 19 of the Chicago Convention (ICAO, 2013). It states that each member must develop an SSP in order to achieve an acceptable level of safety performance. SSPs are built on four pillars, namely State safety policy and objective, State safety risk management, State

safety assurance and State safety promotion. As their names indicate, these pillars are responsibilities of the State rather than those of the operator.

In maritime transport, there are State obligations under Chapter V of the International Convention for the Safety of Life at Sea (1974) related to a variety of safety-related activities, including meteorological services, ice patrols, hydrographic services, vessel traffic services and search and rescue operations. Furthermore, the International Convention on Maritime Search and Rescue (1975) requires States to develop search and rescue plans and report those to the IMO. Finally, the International Convention on Oil Pollution Preparedness, Response and Co-operation (1990) adopted in the wake of the Exxon Valdez accident requires States to develop national contingency plans against oil pollution.

While the words may be a bit different, there is actually a very high correlation between the Dutch Road Safety Management Programme and aviation SSPs; the correlation is weaker when compared to maritime transport which is more mode-specific in how it addresses the State's role in safety. The following table shows how the various components translate from the Dutch Road Safety Programme to an aviation State Safety Plan:

Table 3: Dutch road safety programme and corresponding elements in State Safety Programme

| Dutch Road Safety Programme | State Safety Programme |
|---|---|
| Policy and safety performance indicators | State safety policy and objectives |
| Organisation, responsibilities, resources, law | State safety legislative framework<br>State safety responsibilities and accountabilities |
| Quality assurance in construction and maintenance | Agreement on the service provider's safety performance |
| Risk management | State safety risk management |
| Monitoring | State data collection, analysis and exchange |
| Investigation of accidents with fatalities | Accident and incident investigation |
| Management review | Safety data-driven targeting of oversight of areas of greater concern |
| | State safety promotion through training, communication and dissemination of information |

Source: Rijkswaterstaat, (2017), ICAO (2013).

The table shows that there is a strong correspondence between the Dutch programme and State Safety Programmes, with the exception that the latter also has a component for internal and external safety training, communication and dissemination of information that does not seem to be present in the former. This strong correlation would tend to indicate that the Dutch programme may in fact be an SSP for the road mode, which could be as relevant and useful to that mode as SSPs are to aviation in countries having implemented an SSP.

The variant of SMS being discussed here may have more in common with the concept of Safe Systems than it does with an SMS in the classical sense. This concept began in Sweden and the Netherlands in the 1980s and 1990s (ITF, 2016). It required changing the mind-set from one where road users were responsible for their behaviour and thus their safety to one where all parties involved in delivering,

managing and using the road system are responsible for ensuring users should not be killed or seriously injured as a result of a road accident, recognising that human behaviour is inherently fallible. This implied that the road traffic system itself had to be designed in such a way to 'forgive' the errors of the users rather than allow these errors to bring harm to them.

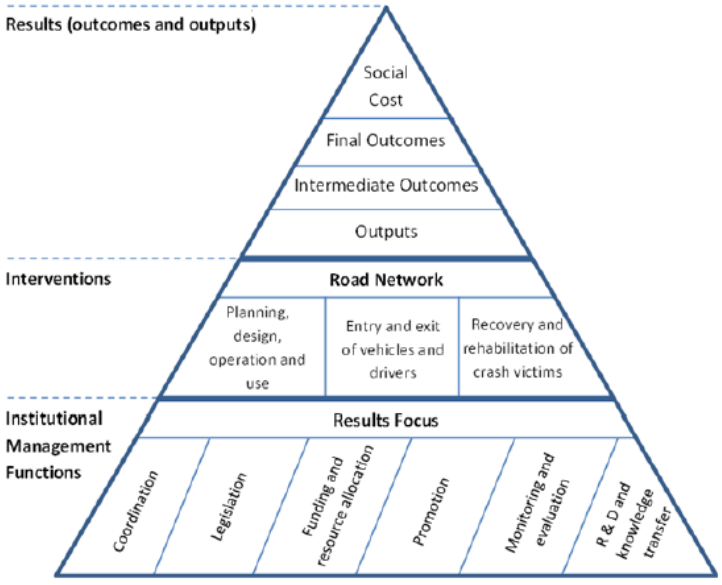
Some basic elements of SMS can be found in the Safe System approach to public road safety policy, the philosophy adopted by an increasing number of governments, including many at the leading edge of cutting road trauma (ITF 2016). The approach was adopted from occupational safety, conceiving design and management of the system in a way that takes into account the failings of humans. Building a Safe System requires mobilising broad support because it is based on shared responsibility for road safety performance. Not just road users, but all involved in planning, building, maintaining, managing or using road traffic need to endorse a responsibility for road safety performance, and act on it. A Safe System is holistic and proactive, managed so the elements of the road transport system combine and interact to guide users to act safely to prevent crashes and, when they occur, ensure that impact forces do not exceed the physical limits of the human body and result in serious injury or death. However, contrary to an SMS, which is a management tool for an operator, a Safe System approach is a policy framework for road safety authorities that impact all road stakeholders. Safe System is one possible approach to safety and focuses on an entire system, such as road transport whereas SMS is operator-centric and built around the processes and hazards which are specific to that operator.

The road system needs to be resilient to crashes through the strengthening of safety mechanisms in all parts in the system to multiply their effects and ensure that the failure of one component does not lead to the failure of the system. This led to the concept of safe system management for the entire road network.

Peden et al. (2004) underlines the need in all parts of the world to improve the safety of the traffic system and to do so, adopt a systemic approach to safety. This approach is developed around four principles: identifying the problem, formulating a strategy, setting targets and monitoring performance. This approach seeks to identify and rectify the major sources of error or design weakness that contribute to fatal and severe injury crashes, as well as to mitigate the severity and consequences of injury.

PIARC (2015) proposes the following model for a safety management system for roads:

Figure 3: The Road Safety Management System




Source: PIARC (2015)

In this model, a strong focus is placed on the institutional arrangements around road transport and on the design of the road network itself. In other modes of transport, this would be considered safety design and safety policies rather than a safety management system per se.

New Zealand has adopted a similar model of SMS to manage its road network and improve road traffic safety. The SMS is an integral part of the management of the road network and helps to identify strategies, policies, standards and procedures and audit systems for roadway authorities. The application of safety management systems throughout New Zealand was one of the key aspects of the *Road Safety to 2010* strategy.

A roadway authorities' SMS is made up of four layers, namely:

- Direction which defines a safety strategy;
- Means of deliveries which includes policies, standards and guidelines;
- Control which is the management system with a clear identification of processes and responsibilities; and,
- Audit which includes a review, monitoring and evaluation regime

ISO39001, previously explained in the Road Transport section, can apply to road agencies or transport authorities to be applied system-wide; however, to date there are no known cases of any of them being certified to that standard.

When comparing the sectorial safety management system for the road mode with organisational safety management systems in any modes or other high-risk industries, a few differences clearly stand out. One difference is that the former seems to be a system that manages safety for safety's sake whereas the latter is a management tool that helps executives manage safety as part of the overall governance of the organisation. Executives would have access to a number of management tools, such as a financial management system, a human resources management system or a revenue management system and will take decisions using inputs from all these systems. A road safety management system on the other hand is a stand-alone tool to evaluate road safety risks, measure overall road safety and helps shape safety policies and programmes.

A second difference is the target audience for the SMS. A sectorial safety management system's target audience is the authority responsible for road safety. Of course road and vehicle operators will be impacted by actions taken as a result of the SMS, such as better road design standards or public awareness campaigns, but they may not necessarily be fully aware of the entire SMS. At the organisational level, the target audience is management. Staff will have a role to play depending on their function within the organisation and regulators will exert an oversight duty on the SMS to ensure it complies with regulatory requirements but ultimately, an SMS is a tool for management.

A third difference is the level of control. In a sectorial SMS, safety authorities may not have full control over the different entities operating in the sector. For example, speed limits can be determined by law and enforced by police but individual drivers still have the choice to obey the speed limit or not. At an organisational level, management can have a more coercive impact on its staff, by, for example, putting speed limiters on vehicles or imposing a disciplinary action on those drivers that exceed the speed limit. This differentiated level of control also implies a differentiated level of accountability and responsibility. A safety authority can set targets for safety performance indicators and could be held accountable in front of elected officials or society at large if those are not met, but would not be held to account for every single accident. On the other hand, at the organisational level, accountable executives would be held to much higher scrutiny for every single accident in which their organisation is involved and could even, in certain jurisdictions, face civil or criminal prosecution.

A fourth difference is the role of the regulator. Kelly (2017) discusses at length the role of the regulator within an SMS framework, something also discussed earlier in this paper. In a sectorial SMS, it is far from clear that there are any impacts to regulators. For example, in the case of an SMS for roads, there does not seem to be any difference in how the behaviour of the regulator would change vis-à-vis any of the regulated entities, be it drivers, vehicles or road authorities. It is even less clear that what would ensue from the adoption of a sectorial SMS would be a shift from prescriptive to descriptive regulation, as we have witnessed when SMS are applied at a corporate level.

A final difference relates to safety culture. At the sectorial level, since many of the actions are taken at the safety policy and road design level, it may be easier to argue that these should be done with the highest safety standards in mind. At the organisational level, staff are keenly aware that reporting a safety issue can cause immediate operational disturbances for the organisation, engender significant costs and may place their employment in peril. Strong safety and just cultures in that context help convey to employees that reporting safety issue is their duty and the right thing to do. This may be easier to convey with the ISO39001 standard or a conventional company-centric SMS than with a broad, sectorial safety policy as most vehicles on the road are operated by their owner and the only person they would report a safety issue is to themselves.

To come back then to the initial question, is a sectorial SMS possible? We are left with the question of how to define an SMS, something discussed further in Maurino (2017). If the SMS is a management tool used by senior executives along with other management tools in evaluating a situation and take appropriate decisions, then the answer is most likely no. However, if we also allow an SMS to be a system to manage safety, then a sectorial SMS can help policy makers better monitor safety within the system, set and track safety performance targets and determine the best policies and actions to improve safety. This variant of an SMS closely resembles SSPs in aviation or national safety plans in other modes of transport. Aligning the national macro approach to safety management with the organisation-based micro approach can be a powerful way to develop an integral vision for safety within a particular mode in which a network of safety management systems interact as part of one holistic system. However, it would be wise to choose another name for a sectorial system to manage safety in order to avoid creating confusion with the organisation-centric SMS.

The conclusion reached above may not hold over time. As automation and the Internet of Things become increasingly prevalent in our daily lives, this differentiation between an organisational SMS and a systemic one could become significantly less relevant. In a future world where road vehicles are all automated, connected to each other and connected to the roadway, we may come to see vehicles, (automated) drivers and infrastructure as different parts of one organism, in which case a sectorial SMS could be very feasible, covering the entire organism as if it were a single company. This organism could function like an ant colony, with each individual component interacting with the whole organism and no one actually owning the entire organism.

## Divergence on SMS

During the roundtable, areas of debate focused largely on the unspoken assumptions behind the current practice. Safety management can be seen as a collection of best practices based on a number of assumptions that are taken for granted, hence rarely discussed. Examples include the traditional dictum of 'safety first', the belief that increasing protection will increase safety, and the notion that most accidents are caused by human error or lack of compliance. These, and other, assumptions determine individual attitudes, corporate policies and regulatory practices and therefore deserve to be questioned, if not continuously then at least every now and then. Thus the roundtable provided an opportunity to revisit these basic tenets of SMS.

### The meaning of the term 'safety'

One issue is that practically all the presentations and discussions repeatedly used the word 'safety' without defining what it meant. In dealing with safety, it is taken for granted that the concept is meaningful to all involved and also that everyone has the same interpretation of what it means. While the former is a reasonable assumption to make, the latter is not.

This issue can be seen in relation to Weick's (1999) definition of safety as a "dynamic non-event", meaning the absence rather than the presence of adverse outcomes and more than the avoidance of preventable errors, occurrences or risks. The question then becomes how one can manage the absence of something – and indeed how one can measure the absence of something in the first place. Thus, Weick argues, safety emerges from the interactions of all the components in the system and does not reside with one component in particular, implying safety must be viewed under a holistic, system-wide lens.

**What is 'managed' by Safety Management?**

The notion of an SMS implies that safety is something that can be managed. This leads to the question of whether safety is something that happens, an activity or a process, or whether it is the result of something that has happened, an outcome or a consequence. If safety is defined – as it usually is – in terms of (adverse) outcomes or the 'freedom' from such, it is evident that one cannot manage the outcomes without considering the processes and activities that lead to the outcomes. But if the focus is on the processes that lead to adverse outcomes, then it makes little sense to see those processes as representing safety. On the contrary, it should rightly be the processes that do not lead to adverse outcomes – the Weick non-events – that represent safety. So a focus on both is indicated. This also answers the question of what we should learn from in order to be able to improve safety management? Clearly not (only) the processes that resulted in the incidents and accidents.

**Can there be a standard for safety management?**

A third issue is whether there can be a standard way of managing safety that serves as a reference so that safety (still undefined) can be ensured by compliance to this standard. The notion of compliance must here be considered in two ways. First, in the sense that the people at the 'sharp end' have to comply with the rules and procedures that govern work to ensure safety. And second that the management of safety itself must comply with the standards for safety management. In the first case the experience from every domain is that work cannot be prescribed in detail, hence that compliance is not a viable solution. There may possibly be a few exceptions to that, but they are not found in the transport industries. The same argument can be made for safety management as an activity in itself. Even within a single domain – aviation or maritime, for instance – there will be such a variety of operators and business conditions that standards become impossible.

**What determines what people do?**

A fourth issue is whether organisational culture, or safety culture, is important for the management of safety. This can also be seen as the question of what determines what people do. One position is that individual and collective human performance is a function of the organisational context, expressed either as the organisational culture or a safety culture. Another position is that the organisational culture – and the safety culture – is a function of individual and collective performance. ("Safety culture is the way we do things around here.") In practice, both positions are probably correct. At the very least it seems unreasonable to deny that organisational culture is an important determiner of human performance.

**Measure versus prediction**

A fifth issue deals with the challenge of predicting events. The experience from safety management across industries has clearly demonstrated that it is entirely possible to measure or count how many undesired events have occurred. But the same experience has also shown that it is not possible to predict them. Yet the management (of anything) is not possible unless there is some way of predicting what will happen. Without prediction, management must remain purely reactive, which is not viable in the long run. The discussions by the panel seemed to agree that we need to measure safety so that we know whether we are moving in the wrong direction – towards undesired events. But it would make as much sense, and possibly even more, to measure on-going processes to ensure that we are moving in the right direction, i.e., that things go well. That should also be easier to do. In other words, we should focus on the actual and the potentially positive rather than on the factual and the potentially negative. It is first of all simpler to do. It is secondly easier to understand, since it does not rely on hypothetical

reasoning. And it thirdly supports profitability and productivity, hence represents an investment rather than a cost. And finally, of course, if something goes right it cannot go wrong at the same time. Which means that trying to manage things so they work well actually achieves the purposes of safety management, but without being hampered by all the contentious issues. This is indeed the essence of resilience engineering and Safety-II discussed at length previously. However, this should not be confused with instances where everything was done correctly and still yielded negative results. These "right yet wrong" circumstances are best identified proactively but sometimes come to light only as the result of an accident investigation.

**Automation**

A sixth issue is the subject of increasing automation across transport domains was discussed. In her seminal paper about the Ironies of Automation, Bainbridge (1983) argued that designer errors can be a major source of operating problems that are left to the operators to handle. Clearly, advances in technology leading to such applications as autonomous vehicles do pose operational adjustments and new risks. Aviation has been an early adopter of high levels of automation in aircraft cockpits, but has not had a spotless record. There are notable accidents in aviation for which automation played a significant role leading to pilot performance errors (Ciavarelli 2016, Rosenkrans 2014). Increased automation could introduce new challenges in designing a safety management system but could also help various SMS work together through real-time exchanges of information. Thus we need to understand how to leverage the full power of automated systems, while recognising their limits and how human factors can ensure that future autonomous systems can be as safe if not more so than today. With the coming of age of connected and automated vehicles, we need to prepare the SMS on the road as automation comes into play.

## The future of the SMS

The answer to what the future of SMS may be depends on what an SMS is assumed to do. If the sole or main purpose is to provide information to management, then there will clearly always be a need of information. The question, however, is what the information should be about. Even if the management functions are restricted to the management of safety, rather than the management of the performance and productivity of the transportation system, the information will need to go beyond information about what has happened in the past. As Samuel Coleridge pointed out "… the light which experience gives us is a lantern on the stern which shines only on the waves behind us". Neither safety management, nor any other kind of management, can afford to be reactive only, to look at "the waves behind us". The information that an SMS must provide must therefore include what is likely to happen in the future – not only what may possibly go wrong as in risk management, but also what should be done to ensure continued acceptable performance. Using Weick's terminology, there is a need for information which can be used to ensure that the "dynamic non-events" – meaning the acceptable outcomes – do actually happen. In that interpretation SMS clearly have a future as ways to gather relevant information. In the long run this information can, however, not be limited to safety issues only but must also comprise other information needed for the overall management of the transportation system.

An SMS may be more than a system to provide information and rather be the execution and implementation of the safety programme. Or, to use the definition adopted by this panel, "a systematic approach to managing safety that includes the necessary organisational structure, management accountabilities, safety policies and processes, a corporate tool that improves the decision making

process by incorporating safety in the discussion and turns safety into a business function". Corporate management can, however, not be effective if safety is considered in isolation, separate from issues such as productivity, quality, customer satisfaction, punctuality, etc. Indeed, in a world where systems of all kinds become more and more interconnected, system management must be extended in at least three different dimensions: a vertical extension to cover the entire system, from hands-on technology to organisational strategies, an horizontal extension to cover the larger parts of the lifecycle, from design to maintenance and possibly even decommissioning, and an extension that includes upstream and downstream processes further away.

Just as the World Health Organization argues that health is "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity", then safety must be seen as a state of effective functioning on all dimensions pertinent to the system's purpose and not merely the absence of risks, failures, and accidents. To achieve this will obviously require that the system is managed in terms of the overall performance rather than by looking at specific issues in isolation. Given that interpretation, the SMS clearly also has a future but only if it takes a critical look at present practices and assess them in terms of future challenges, as ways to gather relevant information. In the long run this information cannot be limited to safety issues only but must also comprise other information needed for the overall management of the transportation system. It is the unenviable dilemma of safety management systems that they inadvertently create the problems of the future by trying to solve the challenges of the present with the mindset – models, theories and methods – of the past.

# Conclusions and recommendations

Transport is a more complex industry than the sum of its parts. David D. Woods, a professor at Ohio State University and expert in resilience engineering, describes it as a tangled network of independent units, which includes human factors, where all elements are interconnected. There are a variety of human roles at play in transportation that need to be coordinated in order to deliver transportation services safely. Safety is one part of performance, along with quality assurance, reliability management and financial management and we must be cognisant how all these elements are interrelated and how decisions in one area impact all others.

Having discussed at length the various aspects of safety management systems during the roundtable, a few key points emerged. There is a need to align our understanding of what an SMS actually is. The SMS brings safety to the level of other corporate management systems. It is an organisational tool that helps to manage safety in the same way that a financial system helps manage finances. We clearly should distinguish between what an SMS should do, which is provide management with an information system on safety as well as mechanism and tools to proactively identify, measure and mange hazards and what a safety programme does which is to implement measures to increase safety. However, SMS and safety programs are not mutually exclusive and can co-exist, as is the case in aviation where the SMS of individual airlines, airports and air navigation service providers coexist with a State Safety Program.

The implementation of an SMS is no easy task. For operators, it requires substantial investment in money and time and a commitment by senior management to safety. As for regulators, they need to make significant changes to the way they regulate the industry and need to feel comfortable and competent in this new role and relationship with industry. They see their role evolving from that of monitoring compliance to becoming a partner in the operator's journey to better identify hazards and the risks they create and then put in place measures to mitigate them. This new relationship requires data sharing between regulators and operators. It is key to a successful implementation of the SMS and will likely only occur if safety-critical data is protected in a way that appropriately balances the rights/responsibilities of various stakeholders.

There are different well-established ways to measure risk and reduce it. An alternative to looking only at hazards, risks, and failures is resilience engineering. Resilience engineering combines being reactive and proactive and emphasises the ability to cope with complexity as well as to respond to adverse events. We traditionally see safety as the absence of something bad happening, known as Safety-I. Resilience engineering instead sees safety as the presence of something, namely the ability to sustain required operations in expected and unexpected conditions alike, also known as Safety-II, with a focus on processes as well as outcomes.

Growing complexity in the transportation system has enabled the industry to carry an ever-increasing number of passengers and volumes of freight at an ever-decreasing real cost. Growing complexity has also introduced new hazards to the transportation system and thus requires proper predictive risk analysis and mitigation that should be done as part of an SMS.

**Key points and recommendations**

- SMS is a strategic management tool that, as one outcome, can help senior executives better understand the safety consequences of decisions they take. Taken with other management systems, it helps them have a holistic view of their operations. It should be considered to be separate but complementary to organisational safety programmes.

- 'Good' safety management systems comprise key components drawn from a variety of safety approaches: systems safety; socio-technical perspectives; human factors methodologies. The SMS should be holistic as well as reactive and proactive, continuously improving based on emergent thinking. The validity and reliability of the SMS is contingent on real time evidence from multiple data sources.

- An SMS requires a shift away from a compliance-based regulatory approach to a performance-based one. In order to do this effectively, both operators and regulators will need a different competence and skill set. At present this level of competence varies between operators, industries and regulators and will need to be harmonised towards best practice if safety management systems are to be implemented and assessed consistently and adequately.

- There is no "one size fits all" solution either within or across the transport sectors. The operating environment, regulatory framework and historical context all influence the approach taken, where the focus is placed and the definitions used. No one approach is found to be superior to another. This does, however, create difficulties in regards to like for like comparison.

- There was agreement that the success of a safety management system is in part predicated upon the maturity of an organisation's safety culture. However, there is no single definition as to what constitutes a safety culture nor whether it is tangible and measurable or simply an abstract concept or mental construct. The transport sector should work towards a shared understanding of terms and models to ensure consistency and clarity, and in particular, develop a shared framework, model and definitions for safety culture that could be effectively applied in and co-exist with very different societal cultures around the world.

- To fully benefit from an SMS, there must be a just culture within a company where staff trust that reporting mistakes, omissions or incorrect decisions will not be met by disciplinary actions but where there will be no tolerance for gross negligence or unlawful acts.

- Reporting of incidents and accidents, free from fear of inappropriate organisational response was seen as a key indicator of a culture that supports safety. This raised the question as to the legitimacy of a system largely built around reactive data-driven investigation processes. As such, the SMS should focus on both Safety-I and Safety-II, focusing on process as well as outcomes, and ensure that resilience and adaptability are engineered into operational and management systems.

- SMS depends on the ability to collect data and use it in predictive analysis to foresee issues and manage them. However, the collection of this data may raise employee privacy issues. Thus, the rights of employees need to be balanced against the right of operators and regulators to know what is going on in a broader context of trying to identify hazards and mitigate risks to improve safety for the benefit of all. It therefore becomes crucial that such data only be used for accident prevention purposes and that employees have access to impartial and independent recourse should the data be used inappropriately by operators or inspectors.

- For safety-related documentation to be used by staff, it must be practical from an operational perspective. For this reason, operational staff should be fully engaged in the drafting of safety documentation to produce a document that is both practical and positively contributes to making operations safe.

- Voluntary programmes such as IATA's IOSA programme should be encouraged to help industry go beyond basic regulatory compliance to proactively evaluate safety and mitigate risks to achieve the highest levels of safety as feasibly possible.

- Programmes such as the Safe System for public road safety and State Safety Programmes for aviation are good examples of how public policies to improve safety in a particular mode can be applied. They can help public authorities create systems that promote safety without actually being an SMS and could be used as a basis for national approaches to safety management within the transport sector.

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# Notes

1 A broader view of air transport, including general aviation and commercial aircraft other than Western-built jets would depict a somewhat less safe industry. However, for the purposes of this analysis, we will limit ourselves to major commercial operations, responsible for the overwhelming number of passenger-km and tonne-km flown in the world.

2 Annex 19 and the Chicago Convention in its entirety only apply to international aviation and thus only international general aviation is mentioned. However, States could also apply a SMS to domestic general aviation in a way that is commensurate with the size and complexity of the operation.

3 In Canada only railways that cross a provincial or international boundary, or local railways while operating on federal railway tracks, are federally regulated.

4 Deviations from rules and standard operating procedures.

5 We should distinguish here the intentional from the unintentional mistake. Wilfully disobeying a law or regulation without a justifiable reason to do so (avoiding an accident for example) would still be met with discipline, even within a just culture.

6 At-risk behaviours include shortcuts, workarounds and routine violations of procedures or policies

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# Safety Management Systems
## Summary and Conclusions

Safety Management Systems (SMS) helps managers better monitor and understand the safety performance of their organisation.  ncreasingly prevalent in the past two decades, SMS provide a rigorous framework for analysing hazards and controlling risks.

This report reviews the history and the workings of SMS and addresses the role of the regulator in an SMS environment. It discusses how to overcome obstacles to SMS implementation, introduces resilience engineering as a way to measure the effectiveness of SMS and finally examines how accident investigations can help address deficiencies in the SMS.  Many of the concepts and notions brought forward in this report apply equally to all modes of transport as well as any industry that operate with inherent hazards that can lead to safety risks.

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