A REVIEW OF AN NATIONAL SAFETY AUTHORITY'S SUPERVISION ACTIVITIES & AUDIT OUTCOMES TO ENHANCE ITS MONITORING OF RAILWAY ORGANISATION SAFETY MANAGEMENT SYSTEMS.

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Abstract

The National Safety Authority (NSA) plays an important role in safety oversight of railway organisations (RO's) operating within their European Union (EU) Member State. The NSA is tasked with assessing and supervising RO Safety Management System's (SMS's), ensuring compliance with standards and legislative requirements. Depending on the size of the NSA, it can be a challenge to implement all the legislative requirements due to constraints in resources and competence. This review concentrated on a data analysis of NSA supervision activities and audit outcomes to enhance the NSA in monitoring RO SMS's. The purpose of this study is to provide evidence to support the NSA supervision planning process changing from a compliance-based approach to being a risk-based approach. This research examined broadly accepted approaches to measure or indicate if an SMS is effective and reviewed current practices and studies linking SMS with safety culture. Key recommendations for the NSA would be, to implement the European Railway Agency (ERA) Management Maturity Model (MMM) tool and the safety perception survey approach for evaluating SMS effectiveness and safety culture. The analysis of NSA data and literature reviewed, found a correlation that competence management and risk management were the two most problematic areas of the SMS. The implications of these findings for the NSA are further discussed.

Keywords: Safety Management System, SMS effectiveness, Maturity Model, Safety Culture.

1. INTRODUCTION

In each EU Member State, the NSA is the responsible body for ensuring that railway organisations have in place an appropriate SMS which they are implementing in accordance with duly approved documentation. The NSA and the SMS principle were established when the Railway Safety Directive (RSD) 2004/49/EC (European legislation) was transposed into corresponding national legislation by each EU Member State. In Ireland, the RSD was implemented through the Railway Safety Act (2005), which established the Commission for Railway Regulation (CRR) as the NSA.

The NSA's role is to provide safety oversight of RO SMS's to ensure they are managing the risks of their activities. An RO must initially have an SMS authorised or certified by

the NSA conformity assessment team, depending on if they are an Infrastructure Manager or Railway Undertaking respectively, in order to operate. Following this, all RO SMS's are supervised by the NSA through auditing and inspection activities. The NSA Supervision section audit each RO's SMS against these CSM Regulations, which then led to the NSA producing audit outcomes. If required, the NSA Inspectors have enforcement powers for railway safety to ensure legislative compliance. The author is employed by a small-sized NSA, which has limited resources to manage its priorities. This limitation has led to there being no formal methodology developed to analyse the findings of previous SMS audits. The NSA is required by mandatory EU railway safety legislation to analyse its audit outcomes and to develop a risk-based planning approach. This recently introduced legislation will impact the planning priorities and new competencies required for the NSA staff. Providing the resources internally to deliver these new activities will be a significant challenge for the NSA.

The EU legislation in the form of the recast Railway Safety Directive (RSD) 2016 (recently transposed into national Irish legislation Statutory Instrument (S.I.) 476 of 2020) and CSM Regulations 2018/761, 2018/762, 2018/763, & 2018/780, were introduced for NSA conformity assessment and supervision teams to implement. This has introduced the following additional mandatory requirements for the NSA, to evaluate the SMS for effectiveness and to develop a risk based supervision.

1.1 OBJECTIVES

The aim of this study is to provide recommendations to enhance the NSA planning process for monitoring a RO's SMS. This led to the following two objectives: Firstly, to provide an overview of the impact on NSA supervision activities with the introduction of new Common Safety Methods (CSM) regulations/legislation. This included identifying a broadly accepted approach to measure/indicate if an SMS is effective and, to review current practices and studies linking SMS with SC.

Secondly, to undertake a data analysis of the NSA audit outcomes from previous SMS supervision audit reports of several railway organisations. A thorough review of the NSA Supervision audit outcomes over the period of 2012 to 2019 inclusive, was undertaken by the author to classify each outcome against the CSM SMS criteria. To quote from George Santayana, "Those who cannot remember the past are condemned to repeat it", in other words, we need to look back to improve going forward. The potential of this research is to make recommendations for the NSA, to better enhance the NSA monitoring of a RO's SMS.

2. IMPLICATIONS OF NEW LEGISLATION

A key impact of the new legislation on a small sized NSA, is how to manage these additional mandatory legislative requirements on top of its current mandatory supervisory activities. The new legislation will require the NSA to develop new staff competencies, requiring additional work planning as resources are currently limited. The NSA will need to develop a new risk-based planning approach to supervision and include new NSA decision-making criteria. The NSA will need to produce updated guidelines for the national rail sector of the changes in the supervision approach before being implemented.

In 2018 the EUAR (European Union Agency for Railways) – hereafter referred to as ERA, developed an ERA Management Maturity Model (MMM) tool. ERA indicates the tool can be used to satisfy a new CSM Regulation requirement for NSA supervision for evaluating SMS effectiveness. It is most likely any NSA with limited resources will adopt

ERA's MMM tool. Additionally, Safety culture (SC) is another new CSM requirement that RO's will have to demonstrate implementation of. ERA has produced guidance for SC and MMM which the NSA may simply have to adopt as its guidelines. In summary the implications for these new CSM Regulations will take time for the NSA to have the appropriate competence to assess all these new requirements. On a positive note, the NSA will be supported by ERA should they adopt any of their recommended processes.

3. LITERATURE REVIEW

Some substantially differing views were found when researching the approaches used to evaluate the effectiveness of an SMS. This may have been due to their interpretations used for the terms 'effectiveness' and 'performance', but the Cambridge dictionary definitions are as follows: Effectiveness - the degree to which something is effective; Effective - producing the intended results, or (of a person) skilled or able to do something well; Performance - how well a person, machine, etc. does a piece of work or an activity. As you can see there is a close alignment of the definitions for the terms 'effectiveness' and 'performance', which could potentially be viewed as interchangeable, depending on the context. With the above in mind, the author researched published literature on the approaches used to measure/indicate if an SMS is effective.

3.1 Approaches for measuring the effectiveness of an SMS

Li and Guldenmund [1] discuss system performance, which it says is about assessing the effectiveness of the SMS, and this needs a clear list of safety indicators to be developed. [1] continues that SMS effectiveness is evaluated by a compliance audit and a performance evaluation. Compliance auditing is considered the straightforward part which is auditing against the SMS procedures. Performance evaluation was noted by [1] as the challenging part, as it is essential to develop key indicators to monitor, which the paper further states can be very difficult to establish and implement.

In 2020 ERA began a project of setting up a working group to develop legislation in the area of evaluating the performance of the SMS. This project will eventually lead to a new CSM regulation with performance indicator requirements. EUAR [2] has produced guidance documents in response to the latest EU legislation, for the NSA supervision section and how to use the ERA Management Maturity Model (MMM). These are guidance for safety certification and supervision, Supervision guide [2] and guidance for safety certification and supervision, Management Maturity Model [3]. The Supervision guidance [2] will aid the NSA to implement the new CSM Regulation supervision requirements. There is a requirement to evaluate the effectiveness of a RO's SMS, which ERA indicates can be done using [3]. While ERA indicates the use of their MMM tool is voluntary for NSAs to select, the task itself is mandatory for NSAs to undertake. Whatever approach is adopted by NSAs, it will take time for the NSA Supervision staff to be trained and competent with [3]. No published research could be found on the return of experience about implementing the ERA MMM tool.

While [3] is relatively new, it should be acknowledged the Office for Rail and Road (ORR) i.e., NSA for the United Kingdom (UK), did produce their specific Risk Management Maturity Model (RM3) which originated in 2011. RM3 does indicate it includes assessing both the effectiveness of the SMS and the organisational culture of a RO. The ORR RM3 has now matured over time with use, and the third version was produced in 2019. It is likely RM3 was included in the general review of maturity models by ERA before producing [3] in 2018, as the ORR would have been represented in the ERA working group who devised the model.

Apart from maturity models, Chen [4] describes another method to measure the safety management process using safety performance indicators (SPIs). [4] indicates that this method works as they recommend the safety authority should change over to their quantitative safety performance monitoring and measurement process. In Carder et al. [5] they developed a methodology for safety measurement using a standardised perception survey, for checking the effectiveness of an SMS. The work lasting several years involved surveying 6,000 staff who worked for a large chemical company with 50 factories. The survey was based on a variant of the Minnesota safety perception survey credited to Bailey and Peterson (1989). Taking a holistic view of the methodology used, there clearly seems a potential in applying this approach to the railway sector in the absence of a generally accepted and standardised approach. Further exploration of this approach would be needed and is beyond the scope of this study.

Thomas [6] researched the efficacy or effectiveness of an SMS for a High-Reliability Organisation (HRO) on behalf of the Australian Transport Safety Bureau (ATSB). The question posed by the study was to identify which parts of the SMS enhance safety. [6] research found only 37 articles published related to the topic which was then reviewed. [6] indicated there was no literature on the rail sector identifying which components of the SMS are driving safety performance. [6] stated, 'Evaluating the effectiveness of SMS in managing low-probability but high consequence events such as a major transport accident is extremely difficult'. [6] concluded that this research cannot adequately answer the question of what parts of the SMS are effective for HRO. On a more positive note, [6] stated, 'The systematic review did, however, highlight that recent studies have demonstrated that well-implemented SMS, especially those where the organisation invests effort into the SMS, are associated with enhanced safety performance'. Overall, this research indicates a lack of published papers found in the area of effectiveness of an SMS, which coincidentally was commented on by Stolzer et al. [7].

For the aviation industry Stolzer et al. [7] describe how they developed a tool to measure the SMS effectiveness. [7] research determined that they could not find any specific tool to measure the FAA approach to SMS effectiveness, which formed the basis of developing their tool. [7] stated, 'From a practical perspective, this research provides a platform organizations can use to determine whether the SMS they have in place is effective and working properly'. This statement indicates the tool developed by [7] can be used to measure SMS effectiveness. [7] expands that the tool went live and is now a requirement by Federal Aviation Authority (FAA) for any aviation organisation to measure its SMS for effectiveness. [7] tool has been adopted by the Safety Management International Collaboration Group (SM ICG) [8] who have produced an SMS Evaluation Tool Guidance for the aviation industry, based on the 12 elements of the International Civil Aviation Organisation (ICAO) SMS Framework. One observation from the paper by [7] was found in a reference to Cambon et al. [9]. [9] described there are three different ways you could measure the effectiveness of an SMS, a results-based approach, a compliance-based approach and a process-based approach. The study by [9] is discussed further on, but incidentally does not recommend any of these three approaches. The possible three methods described by [9] are interesting when comparing them to [1]. In [1] they said that to assess the effectiveness of an SMS you need to carry out both a compliance audit and a performance evaluation. This just indicates the widely varying views with the meaning of SMS effectiveness, and thus the difficulty in evaluating the effectiveness of an SMS.

Continuing with the aviation sector, the European Aviation Safety Agency (EASA) [10] describes, how safety performance indicators (SPIs) are used to measure the effectiveness of the SMS. Supporting the SPIs is a regular collection and analysis of data from sources such as surveys, occurrences, operational performance, inspections and monitoring etc. This paper also describes the additional issues faced when changing from compliance-based oversight (CBO) to risk-based oversight (RBO). The NSA should be aware that these similar issues could arise when it decides to change over to RBO.

Initially the aviation authorities were implementing CBO for the aviation organisations required to hold an SMS. Currently the aviation sector SMS has matured and has moved on to RBO or performance-based regulation (PBR). EASA [11] has produced a 'Practices for risk-based oversight' guidance for the aviation sector. It would seem reasonable then for the railway sector to move in a similar direction of SMS maturity when appropriate.

SMS effectiveness can also be interpreted as to how the SMS is performing. Cambon et al. [9] suggested a tool to measure the SMS performance of the structural or descriptive part and the operational parts. The overall concept is that there are two components needed i.e. structural and operational, to measure SMS effectiveness, which does seem to equate with other author's views.

Separately, on a similar theme of evaluating how the SMS is performing, Fox [12] also stated performance indicators (PI) are needed for an effective SMS. The basis of this opinion was not clearly indicated in the study by [12]. However, this viewpoint does align with what other authors have said i.e. [7] and [1], that for SMS effectiveness you need to include a performance evaluation component with the compliance part. A performance evaluation methodology could entail using a maturity model, performance indicators or a survey.

3.2 Linking SMS with Safety Culture

An SMS will be influenced by the type of culture within an organisation that must implement it. Rolina [13] representing ERA, delivered a conference paper at the International Railway Safety Council (IRSC) 2018 which described the Safety Culture Model (SCM) proposed for European Railways. The new CSM Regulation requires a safety culture strategy to be provided by a RO to show how behavioural issues are identified and mitigated in the SMS. The NSA most likely will adopt the ERA guidance to assess safety culture of an RO's SMS.

Sherry [14] produced a conference paper concerning the key components in the measurement of safety culture and safety leadership, for the International Railway Safety Conference (IRSC) in 2018. An observation of the inputs was that only state department staff who had no managerial responsibilities were involved. It was interesting then 'Management commitment' was found overwhelmingly i.e. 50% to be the most important component of safety culture. [14] indicates further work will be undertaken to develop a leadership assessment linked with a safety culture assessment.

In Farrington-Darby et al. [15], a survey approach of the safety culture of a UK railway maintenance company was conducted. This survey approach was successfully applied to evaluate SMS effectiveness as described in [5]. [15] used independent safety culture experts to undertake this type of work rather than use internally trained personnel which does seem appropriate, as it will be an infrequent activity. Overall, this paper gave a very good insight into how the task of surveying safety culture could be undertaken.

Goncalves et al. [16] carried out a critical review of maturity models and safety culture. Prominent findings highlighted by [16] were, maturity model results may not be repeatable over time and results of the study could not provide any solid conclusions about their reliability, validity or robustness in using them. [16] also found that using maturity models for safety culture assessments can have a lot of drawbacks in achieving consistent results.

Piers et al. [17] developed a safety culture framework for aviation safety within the EU. A scoring system approach was designed for the characteristics and indicators of safety culture maturity. While details of the scoring system were not provided, the positive to take away is the example checklist could easily be adapted for any transport sector.

In Blais et al. [18] they produced and validated a safety culture measurement tool using a safety culture perception survey. The purpose of the tool was to enhance the safety culture of ROs with a SMS operating under the Canadian Department of Transport (Transport Canada). It was recommended by [18] the enhanced safety culture perception survey tool is not used alone, as you may get a false sense of reliability, and it should be used in combination with further interviews and workshops.

French and Steel [19] reviewed SMSs and safety culture from the point of view of accident investigation. They explored themes like, what were the key elements of the SMS and how to address safety culture. In regard to safety culture, they described it that it surrounds the SMS, but it is difficult for accident investigators to assess. [19] continued that evidence of multiple non-compliances with the SMS may be an indicator of a problem with the underlying safety culture of an RO.

3.3 CSM criteria related to the cause of an accident

The author identified the following papers that linked the causes of accidents to elements of the SMS criteria. This research was performed to see if there were any similar themes found in the published literature that may correlate with the results of this NSA audit outcomes data analysis. The following three published studies reviewed railway investigation reports and identified the elements/factors of the SMS that were most commonly related to the causes of the accidents. The elements/factors of the SMS identified in the papers were then assigned the closest element of the CSM SMS criteria as follows:

- Wu et al. [20] A – Risk assessment, O - Safety-related information management, N - Competence management.

- French and Steel [19] A – Risk assessment, N - Competence management, M - Change management.

- Fox [12] A – Risk management, N - Competence management.

In summary, the studies indicate that the most problematic areas of the SMS were risk management and competence management.

4. METHODOLOGY

The main body of work undertaken centred on the objective of reviewing the NSA supervision audit outcomes data to satisfy the new CSM Regulation requirement. Reviewing supervision outcomes data will provide one input into the NSA supervision strategy and plan. This study focused on finding weaknesses in the SMS of which a non-

compliance (NC) audit outcome is one indicator. It is also possible from the definition of an action-required (AR) audit outcome, a weakness in the SMS was also being identified by an auditor for an isolated error. So, it is for this reason AR outcomes have been included in this data review. The current audit outcome descriptions developed by the NSA are as follows: Non-Compliance (NC) - an area of non-compliance with a railway organisation's internal standard, or applicable external standard, or legislation. Action Required (AR) - an area where potential exists for a non-compliance to occur unless remedial action is taken or improvement is made, an isolated error that requires correction, or some other action arising from the audit.

While the definitions for an audit outcome could be possibly improved, judgement is always required by the auditor on how they are applied to a finding. All audit outcomes would be reviewed by a second auditor ensuring they are specific, measurable, achievable, realistic and timely (SMART), before being issued. There are other NSA audit outcome classifications such as a good practice, scope for improvement, audit trail, but as these do not highlight a weakness with the SMS, so they were excluded from this study.

The NSA audit reports included in this data analysis, were finalised reports issued in the period from 2012 to 2019 inclusive. These audits were performed by various auditors i.e. internal NSA staff and external audit contractors with various ranges of competence working for the NSA. The quantity of audit outcomes that the author had to review was 505 outcomes.

Each outcome had to be reviewed against the CSM SMS criteria A to W, found in CSM Regulations ([22] [23]). Reviewing every outcome involved examining the audit report to initially to identify which SMS standard the NC or AR outcome was related to. Following this the SMS standard had to be cross checked as to which CSM criterion the RO's SMS standard originally satisfied during the NSA conformity assessment process. Then it had to be determined what was the most applicable CSM criterion sub clause to be assigned for that outcome. The CSM criteria A to W, is sub divided into 87 clauses, e.g. A - Risk management, has six sub clauses A1 to A6, C has 4 etc. so there is an element of judgement and experience is required for this task. The output of this review produced results for each RO's overall compliance with their SMS. A comparison of the six ROs results was also undertaken to identify which CSM criteria were recurring. The results will then indicate the most problematic CSM criterion for ROs complying with their SMS.

Each RO that was part of this review has different characteristics i.e. passenger or freight operations or both, vehicle or track maintenance or both, size of organisation, quantity of staff employed, financial resources and contractual arrangements. The CSM regulations simply provide a list of mandatory requirements that must be achieved by every RO, for their SMS to be accepted by the NSA. It must therefore be appreciated as each RO has different characteristics which affect their risk profile, this then determines the quantity of audits planned annually for each RO by the NSA.

5. ANALYSIS AND RESULTS

Initially each RO outcome data was processed and analysed separately. When this was complete the results of all the ROs were amalgamated to find the CSM criteria that were the most problematic or viewed as being the weakest components of the ROs SMS. Figure 1 shows for each RO, the NC and AR outcome quantities assigned to each CSM criterion by the author. For example, in RO1 CSM criteria B to E are shown as zero. Reasons for this could be, either CSM criteria B to E were audited and no outcomes were prescribed which is considered a positive for that RO, or simply CSM criteria B to E were not

audited. In this case CSM criteria B to E were not audited. It was not possible to include the reasoning why CSM criteria were not audited, as this was not feasible in the time required for this study.
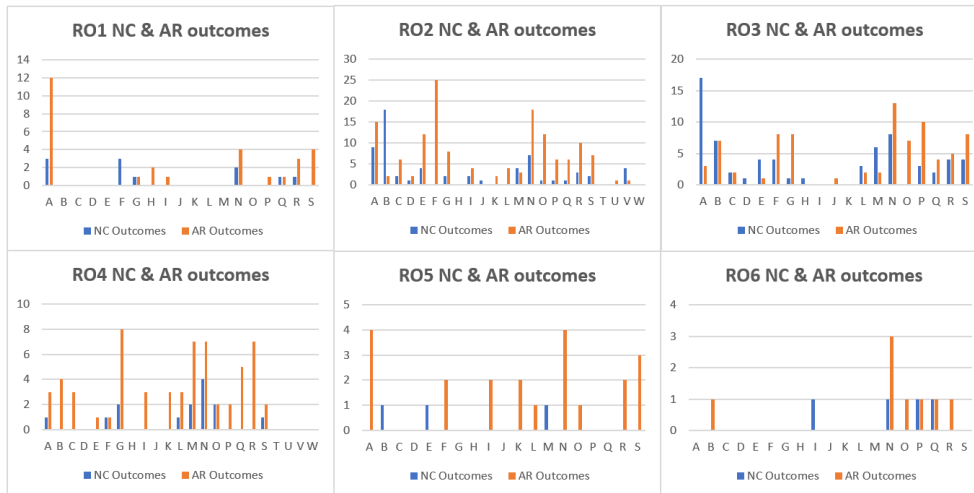

Figure 1: NC & AR outcome quantities assigned to each CSM criterion per RO

Figure 2 shows the poorly-performing CSM criteria found in this data analysis by the author which were: N - Competence management, A - Risk management, B - Maintenance management risks, F - Distribution of responsibilities, R - Emergency management, G - Management control, S - Internal audit of SMS, O - Information provision – Internal. Based on this information found, this research proposes the NSA could take a holistic view of its current supervision plan and apply a risk-based approach. For example, the NSA could choose to ensure the poorly performing CSM criteria found above in Figure 2, are as a minimum being audited repeatedly over a periodic basis for every RO.
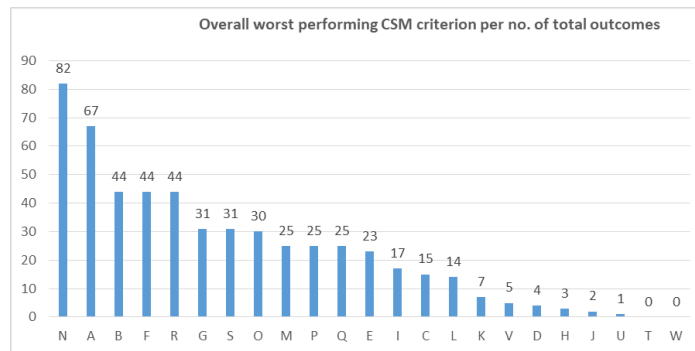

Figure 2: Overall poorly performing CSM criterion per no. of total outcomes

Reflecting on the results above, it should be noted that a high quantity of audit outcomes against a particular CSM criterion is an indicator that there are issues with compliance with this area of the SMS. A possible reason that a CSM criterion has a low quantity of audit outcomes is that it may be easier to comply with this requirement, thus it has fewer outcomes. Other reasons regarding why a CSM criterion had a low quantity of audit outcomes, could be due to a lack of NSA resources, no available competent auditors or other NSA activities were being prioritised.

6. CONCLUSION

The NSA will have to review these new legislative areas in the context of the additional workload arising from the new CSM regulations covering SMS effectiveness and SC, and a risk-based planning approach will be required. The NSA should also examine [14] to be prepared for similar issues that may arise when changing to an RBO. The NSA should provide additional training and procedures to staff, and guidelines for the railway sector for evaluating the SMS effectiveness of an RO, using [3] and for, assessment and supervision of SC in a RO's SMS using [2].

Using the methodology and results of this data analysis, the NSA should prepare a new strategy and plan to address the new CSM regulation for NSA supervision. It is additionally recommended that the NSA considers in its strategy the new mandatory requirements for human and organisational factors (HOF), which must be part of the RO's SMS. It should be noted it was not feasible in the time available for this study for HOF requirements to be considered. The NSA with limited resources should consider adopting [2] as the new NSA guidelines, as this includes guidance on HOF and SC.

The NSA should begin implementing [3] as this will meet the new CSM regulation requirements for NSA supervision to check an SMS for effectiveness. It was noted from [5] a safety perception survey was also used to check for SMS effectiveness which the NSA could consider as an option. There did however seem to be a consensus from the literature review that SMS effectiveness requires two parts to be included, a compliance component and a performance component. A safety perception survey should be developed and implemented by the NSA to assess the SC of RO. The NSA should ensure the poorly performing CSM criteria found above in Figure 2, are as a minimum being audited repeatedly over a periodic basis for every RO.

The rail sector and wider audience should also be aware of the correlation found in this analysis of NSA data and the published papers in section 3.3 above, indicating that the most problematic areas of the SMS were risk management and competence management.

Acknowledgments

References

[1] Li Y., Guldenmund F.W., 'Safety management systems: A broad overview of the literature', Safety Science, Volume 103, March 2018, Pages 94-123, 2018. [Accessed 5 April 2020]

[2] European Agency for Railways (EUAR). Guidance for safety certification and supervision, Supervision guide. 2018.

[3] European Agency for Railways (EUAR). Guidance for safety certification and supervision, Management Maturity Model. Final issue, published June 2018. [Online]. [Accessed 20 Jan 2020]. Available from: https://www.era.europa.eu/activities/common-safety-methods_en

[4] Chen W., Li, J., 'Safety performance monitoring and measurement of civil aviation unit'. Journal of Air Transport Management, 57, 228–233, 2016. doi:10.1016/j.jairtraman.2016.08.015

[5] Carder B., Ragan P.W., 'A survey-based system for safety measurement and improvement', Journal of Safety Research 34 (2003) pg. 157-165, National safety Council and Elsevier Science Ltd., 2002.

[6] Thomas M.J.W., 'A Systematic Review of the Effectiveness of Safety Management Systems Australian Transport Safety Bureau' TRANSPORT SAFETY REPORT Cross-modal Research Investigation XR-2011-002 Final, 2012.

[7] Stolzer, A. J., Friend, M. A., Truong, D., Tuccio, W. A., & Aguiar, M., 'Measuring and evaluating safety management system effectiveness using Data Envelopment Analysis'. Safety Science, 104, 55–69. doi:10.1016/j.ssci.2017.12.037, 2018.

[8] Safety Management International Collaboration Group (SM ICG), SMS Evaluation Tool Guidance, Version 2, April 2019, 2012. [Online]. [Accessed 10 December 2020].

[9] Cambon J., Guarnieri F., Groeneweg J., 'Towards a new tool for measuring Safety Management Systems performance'. 2nd Symposium on Resilience Engineering, Nov 2006, Juan-les-Pins, France. 10 p. ffhal-00637874f.

[10] European Aviation Safety Agency (EASA), 'A Harmonised European Approach to a Performance-Based Environment (PBE)', EASA, 25 Aug 2014. [Online]. [Accessed 26 March 2021].

[11] European Aviation Safety Agency (EASA), 'Practices for risk-based oversight', EASA, Edition 1, 22 November 2016 [Online]. [Accessed 26 March 2021]. https://www.skybrary.aero/bookshelf/books/3699.pdf

[12] Fox K., 'Thesis: How has the implementation of Safety Management Systems (SMS) in the transportation industry impacted on risk management and decision making', Lund University in Sweden, published 15 June 2009. [online], [Accessed 5 Feb 2020]

[13] Rolina G., Accou B. (2018) Evaluate to Learn and Improve: A Safety Culture Model for European Railways, International Railway Safety Council, Dublin, 21-26 October 2018, [Online], [Accessed 15 April 2020]. https://international-railway-safety-council.com/wp-content/uploads/2019/03/P05-Paper-Rolina-Accou-2018-IRSC.pdf

[14] Sherry P. (2018) Key components in the measurement of safety culture and safety leadership, University of Denver, IRSC conference paper, October 2018, [Online], [Accessed 20 May 2020]. https://international-railway-safety-council.com/tag/dublin/

[15] Farrington-Darby, T., Pickup, L., & Wilson, J. R., 'Safety culture in railway maintenance'. Safety Science, 43(1), 39–60, 2005. doi:10.1016/j.ssci.2004.09.003

[16] Goncalves Filho, A. P., & Waterson, P., 'Maturity models and safety culture: A critical review'. Safety Science, 105, 192–211, 2018. doi:10.1016/j.ssci.2018.02.017

[17] Piers M., Montijn C., Balk A., Dutch National Aerospace Laboratory (NLR) Safety Management System and Safety Culture Working Group (SMS WG), 6 March 2009

[18] Blais D., Duda R., 'Development of a safety culture measurement and improvement tool for the Canadian Railway industry', Canadian Department of Transport (Transport Canada), International Railway safety Conference (IRSC), Berlin, 12-17 October 2014

[19] French S., Steel T., 'The Investigation of Safety Management Systems and Safety Culture', International Transport Forum, Discussion Paper 2017-20, 23-24 March 2017, Paris

[20] Wu S., Geo X., Luo Y., A New Model of Safety Management System for Railway Operation, First International Conference on Rail Transportation, Chengdu, China, 10th-12th July 2017

[21] Commission Regulation (EC) No 1158/2010 (2010) of 9 December 2010 on a common safety method for assessing conformity with the requirements for obtaining railway safety certificates Text with EEA relevance. 9 Dec 2010. [Online]. [Accessed 10 Feb 2020]. Available from: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32010R1158

[22] Commission Regulation (EC) No 1169/2010 (2010) of 10 December 2010 on a common safety method for assessing conformity with the requirements for obtaining a railway safety authorisation Text with EEA relevance, 10 Dec 2010. [Online]. [Accessed 10 Feb 2020]. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32010R1169