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Corinne Bieder

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# 1 Safety science: a situated science

2 An exploration through the lens of Safety Management Systems

3

4 Corinne Bieder

5 ENAC (Ecole Nationale de l'Aviation Civile), University of Toulouse, France. Email: corinne.bieder@enac.fr

6

## 7 *Abstract*

8 A number of key concepts have punctuated the development of Safety science. Reflecting on what  
9 the next ones could be is a tricky exercise. How come certain safety concepts or theories or  
10 dispositive in the sense of Foucault emerge and become 'dominating concepts' or turning points in  
11 safety science? The paper considers a case from the past, namely that of Safety Management System  
12 (SMS), as a proxy to shed light on this question. The origins of SMS are explored to unravel what lies  
13 behind its emergence and development. The research is based on a literature review and open-  
14 ended interviews of 15 people who played a personal part in safety science or practices development  
15 before and/or when SMS started to emerge. Overall, the sample of interviewees represents a range  
16 of safety stakeholders (academia, industry, regulatory bodies, consulting companies) and high-risk  
17 industries to provide a diversity of perspectives on the emergence of SMS. The analysis of this  
18 material highlights several aspects that contributed to converge towards an approach like the SMS,  
19 beyond the identified limitations of safety science at that time. First, the intellectual context in which  
20 SMS emerged, was that of major developments on organizational and managerial dimensions of  
21 safety. Second, most safety stakeholders had motivations beyond safety enhancement to move  
22 towards a new approach. Last, the overall environment, way beyond safety and high-risk industries,  
23 facilitated the convergence towards an approach like the SMS. Eventually, this research  
24 demonstrates that safety is a situated science, situated not only in time, but also in a much wider  
25 economic, industrial, political, societal context. Putting safety into such perspective opens new  
26 avenues for reflecting about the future of safety science considering current trends not only in safety  
27 but also way beyond.

## 28 *Keywords*

29 Safety Science; Safety Management System (SMS); Societal context; Enabling context

30

## 31 Introduction

32 Reflecting about the future of safety science is a tricky exercise. Although one can have a  
33 performative approach to the description of a possible future, it partly denies the existence of  
34 uncertainties, at least the temporal uncertainty (Rowe, 1993). In the case of safety science, the  
35 diversity of views and developments adds on to the challenge intrinsically related to that of  
36 anticipation, when it comes to reflecting about its future. Indeed, without entering the debates  
37 around the scientific validity of safety science, largely addressed in the special issue of *Safety Science*  
38 of August 2014 and in the “founding fathers’ retrospection” (Stoop et al., 2017), safety science  
39 cannot be considered a unified science where there is an overall or even some kind of wide  
40 consensus on concepts, theories, models or tools (Ge et al., 2019).

41 From a historical perspective, several major turning points triggering new eras of safety science  
42 development were identified. Dekker (2019), for example, highlights eleven turning points since the  
43 beginning of the last century, each characterized by a dominating trend or concept. Just to mention  
44 the past three decades, the author identifies, “Swiss cheese” and “safety management” as  
45 dominating concepts in the 1990s, “safety culture” in the 2000s and “resilience engineering” in the  
46 2010s. However, even if new ideas, approaches or theories were indeed advanced at some point in  
47 time, in practice, research is still ongoing on most of the founding concepts and theories that  
48 emerged decades ago, such as High Reliability Organization that appeared in the late 1980s or  
49 “system safety” in the 1950s/60s. A variety of safety science schools of thought and practices keep  
50 existing and developing in parallel. In addition, depending on the industry, and /or the applicable  
51 regulatory requirements and regimes, different directions are explored to enhance safety before  
52 some of them become widely adopted with time and recognized as generic safety science  
53 developments.

54 A number of needs and challenges are identified today by safety scientists or practitioners, in  
55 relation to either the evolution of high-risk activities or the intrinsic characteristics of safety science  
56 (Le Coze, 2019a). For example, complexity is currently identified as insufficiently addressed by safety  
57 science be it that of technology, organizations or institutions for example (Stoop et al., 2017; Le Coze,  
58 2019b; Schulman, 2020). In relation to complexity as well, but primarily operational complexity and  
59 its contingencies, another major challenge widely acknowledged is how to cope with the unexpected  
60 or being “prepared” to be unprepared (La Porte, 2020; Weick & Sutcliffe, 2016; Grote, 2015). With  
61 the increase of security threats and the demonstrated coupling of safety and security, this question  
62 becomes an even more burning issue and opens as well to a number of possible future developments  
63 (Bieder & Pettersen, 2020). On the technological side, digitalization and the development of artificial  
64 intelligence is another area that poses new safety questions and issues (Almklov & Antonsen, 2019).

65 Beyond the evolution of high-risk activities and the way they are performed, challenges intrinsic to  
66 the current state of safety science are also pointed out by some authors. Schulman for example,  
67 underlines the need to be more constructive and collectively cumulative as safety scientists  
68 (Schulman, 2020). The challenges of getting different disciplines to collaborate with one another in a  
69 highly transdisciplinary domain such as safety was also discussed by Le Coze (2019b).

70 This landscape of possible avenues to explore identified within the safety science community may  
71 provide interesting insights as to future areas of research, but is it sufficient to anticipate possible  
72 future major steps in safety science? How come certain safety concepts or theories or dispositive in  
73 the sense of Foucault emerge and become 'dominating concepts' or turning points in safety science  
74 as named by Dekker (2019)? Very little knowledge is available regarding this genesis and spreading of  
75 new safety approaches. Yet, understanding why and how a new idea emerges at a certain point in  
76 time and develops, to a point where it starts spreading widely, could help reflecting about the future  
77 of safety science.

78 The work presented in this paper focuses on the emergence of one safety approach characterized as  
79 a turning point by Dekker (2019), namely, Safety Management Systems (SMSs). SMS can be used as a  
80 proxy for a broader reflection on safety science because: a/ it is commonly used in many high-risk  
81 industries today (it is even often a regulatory requirement in highly regulated activities) and is still  
82 considered a promising way forward safety wise. As an example, following the preliminary report on  
83 the investigation of the two Boeing 737 MAX, the Federal Aviation Administration recommended to  
84 reinforce the SMS for aircraft manufacturers<sup>1</sup>. In that respect, the SMS provides some insights about  
85 the safety science situation today even though safety science includes many other safety concepts,  
86 theories and approaches, some of which are commonly used as well today, often in parallel with the  
87 SMS when the latter is implemented; b/ it is an example 'sufficiently' from the past to have reached  
88 the status of a 'dominating concept' in safety science considering the numerous traces of its reach  
89 and penetration in many areas, especially the industry, regulation or academia. As such, it can  
90 support a reflection about the future of safety science and the possible 'dominating concepts' or  
91 turning points to come. At the same time, the advent of the SMS is 'recent enough' to allow for a  
92 comprehensive investigation of its origins, including through the views of those who contributed to  
93 or witnessed its genesis.

94 A Safety Management System is an approach to systematically manage safety. Although detailed  
95 characteristics may vary from one high-risk domain to another, overall, all SMSs share the following  
96 features (already present in Kysor's papers in 1973): a/a definition of the organizational structure  
97 that needs to be put in place to manage safety, including objectives, policies and accountabilities; b/

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<sup>1</sup> <https://www.reuters.com/article/boeing-737max/faa-to-mandate-new-safety-management-tools-for-airplane-manufacturers-idUSL1N2D11CX>

98 analysis of operational risks; c/ a definition of a safety assurance process (including the definition and  
99 implementation of risk control measures) to keep the risks at an acceptable level; d/ a risk  
100 communication process.

101 This paper aims to add knowledge to the emergence of new safety approaches by investigating that  
102 of Safety Management Systems (SMSs), first discussed in the 1970s and progressively adopted as a  
103 new safety frontier in the 80s and 90s. In particular, the research sheds light on what motivated a  
104 change of safety approach at that time, as well as what contributed to the convergence towards an  
105 approach like the SMS. The results are then discussed in the light of today's context to draw some  
106 lines of reflection about the future of safety science reaching beyond its current identified limitations  
107 and needs.

108

### 109 [Literature review](#)

110 The history of safety science has been largely explored in the literature ((Swuste et al., 2016, 2018;  
111 Dekker, 2019; Le Coze, 2019a). Different time frames and steps or turning points have been  
112 considered with small variations from one author to the other. However, very little is explored  
113 regarding how the new concepts, theories or dispositives appeared. Bourrier (2011) provides insights  
114 on the genesis of the High-Reliability Organization theory through an ethnographic approach. The  
115 author explores several dimensions: the founding fathers' and mother's profiles, the group's ways of  
116 working and the intellectual context at that time (especially the paradox faced by the group when  
117 comparing its field observations with what the recently published Normal Accident Theory (Perrow,  
118 1984) would lead to expect). Nevertheless, such endeavors to understand what contributes to the  
119 emergence of a new vision are extremely rare. SMS is no exception to that. Although the number of  
120 publications on SMS has been growing dramatically over the past decades<sup>2</sup>, most of them focus on  
121 the definition of SMS, its characteristics, its implementation in a variety of domains, its evaluation.  
122 Nevertheless, some insights are provided by Li and Guldemund (2019) from their extensive literature  
123 review on the commencement of SMSs. They characterize the latter as the merging between an  
124 insurance approach focused on risk management and an industrial approach focused on accident  
125 prevention and the development of safety defenses. However, very little is said about what  
126 contributed to this merging. The main argument advanced is the improvement of technology  
127 inducing more complicated safety defences, thus requiring management systems to "implement,  
128 maintain and update these" (Li and Guldemund, 2019, p.97).

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<sup>2</sup> From 3 papers in the 1970s, the number went up to 228 in the 1990s and kept increasing exponentially with a total number close to 3000 publications as of mid-2019 (Source: Scopus using the keyword "Safety Management System").

129 More generally, the emergence of new concepts, theories or approaches is not a widely explored  
130 area in safety science. From a broader perspective, Kuhn (1962) in his essay on the structure of  
131 scientific revolution identifies as a driver for new paradigms the existence of anomalies or violation  
132 of expectations, that is, facts that cannot be explained using existing theories or concepts. However,  
133 besides the limitations of existing scientific developments as drivers for new paradigms, Kuhn also  
134 acknowledges that the “conditions outside the sciences may influence the range of alternatives  
135 available to the man who seeks to end a crisis by proposing one or another revolutionary reform »  
136 (Kuhn, 1962, p. x). One important aspect in these outside conditions is the world of ideas available to  
137 the scientists. According to the author, shifts in visions do not result exclusively from the genius of  
138 individuals, be them called Aristotle or Galileo, but also from the world in which they were  
139 immersed, especially, the intellectual environment and the knowledge available at the time. Without  
140 being as far reaching as scientific revolutions, Jasanoff (2004) highlights that science is intertwined  
141 with societal evolution. “Science and society are *co-produced*, each underwriting the other’s  
142 existence” (Jasanoff, 2004, p.17). Therefore, exploring the societal context makes sense to  
143 understand the genesis of scientific developments.  
144 Closer to safety, other authors have pointed out the influence of the context on the development of  
145 safety vision and approaches. Merritt & Maurino (2004) illustrate the role of cultural aspects but also  
146 that of the resources available to perform research, not only the financial or technological ones, but  
147 also the ongoing access to news ideas and theories (p. 176). The influence of the political context is  
148 also emphasized, especially in relation to the emergence of the safety culture concept following the  
149 Chernobyl accident (Dekker, 2019). More recently, when reflecting about the future of safety  
150 science, Dekker (2020) makes a link between recent safety developments and neoliberalism,  
151 highlighting the impact of the overall political, economic and social context on safety and its  
152 evolution. In short, it seems that scientific developments may be influenced by a broader context  
153 that reaches beyond the identified limitations and needs of the science itself.  
154

## 155 Methods

156 To try and understand the origins and generalization of safety management systems (SMS), a  
157 research was conducted based on a literature review and interviews of stakeholders who  
158 participated in the emergence and spreading of SMS. As underlined by Descamps (2005), interviews  
159 allow for reaching beyond the official, declared objectives and strategies of organizations. Besides,  
160 although written sources present a rather linear and rational story, interviews give access to “the  
161 complex interactions between the structure, the strategy, the actors and external environment  
162 permanently changing” (Chandler, 1989, cited by Descamps, 2005, pp.578-579).

163 In total, 17 persons were interviewed between July 2018 and July 2019. They were chosen for the  
164 personal part they played in safety science or practices development before and/or when SMS  
165 started to emerge either in their own domain or more globally. Overall, the sample of interviewees  
166 represents a range of safety management stakeholders, high-risk industries and countries to provide  
167 a diversity of perspectives on the emergence of SMS. 4 interviewees were from regulatory bodies, 3  
168 from high-risk industrial companies, 3 from academia, 2 from consulting companies on safety  
169 management and 3 had hybrid profiles including two or more of these experiences either  
170 sequentially or simultaneously. The interviewees came from 7 different countries from Europe and

171 America. 7 out of the 15 were already involved in safety in the 70s, 6 started in the 80s, and 2 in the  
172 early 90s.

173 The interviews were open-ended interviews, lasting between one and three hours. They were  
174 conducted in English for non-native French speakers and in French for the others. The interviews  
175 were not recorded but extensive notes were made in real-time and were afterwards validated by the  
176 interviewee.

177 A qualitative content analysis method was used to process the interview data since this historical  
178 investigation didn't rely on *a priori* assumptions or theory (Descamps, 2005). Considering the limited  
179 size of the sample, the analysis was still manageable without software assistance and was performed  
180 manually. The analysis of these data led to characterize: a/ the intellectual context and background  
181 in relation to safety when the idea of SMS started to appear; b/ the actors who played a part as well  
182 as their motivations to move towards a new safety approach; c/ key aspects of the overall context  
183 that facilitated the convergence towards an approach like the SMS.

## 184 Results

### 185 The intellectual context and background related to safety around the 70s

186 The SMS is not a revolutionary concept or dispositive that spontaneously appeared. Its emergence is  
187 closely linked to the evolution of safety thinking. A number of ideas and practices in relation to safety  
188 already existed in the 70s and even earlier, and the intellectual context was dynamic with number of  
189 developments to better understand and address safety. Some of these developments were led by  
190 the industry, insurance or consultancy business, others were more scientific, led by academics.  
191 However, the boundaries are not always easy to draw for some key actors had a multi-fold activity.

192 The first publication mentioned in Scopus in relation to Safety Management System dates back from  
193 1973 and appears in the *National Safety News*, a US National Safety Council publication. H.D. Kysor,  
194 the author, is not an academic with a safety related background but rather an aeronautical  
195 consultant. In his two papers on SMS, *Part I: the design of a system* (Kysor, 1973a), and *Part II: SMS*  
196 *organization* (Kysor, 1973b) one can find most of the ideas that can be found today in SMS  
197 requirements.

198 Within industry, the idea of safety management was introduced in the 1920s by Louis De Blois, safety  
199 manager of Dupont, according to a kind of risk concept that he invented, based on the two principles  
200 that "hazard is energy and management is responsible" (Academic 2, diverse industries, June 14,  
201 2019).

202 Coming from a different perspective, that of insurance, the contribution to accidents of workers'  
203 social environment (underlying human unsafe acts) was identified in the industry as early as in the

204 30s by Herbert Heinrich in the US. The analysis of the root causes of thousands of accidents  
205 (workplace accidents) in the steel industry led him to develop the dominos' model and to derive  
206 recommendations in terms of managerial practices. In the 70s, in the US as well, Frank Bird Jr.,  
207 further developed and refined Heinrich's dominos' model, especially through the description of  
208 managerial factors likely to lead to a human unsafe act (Bird, 1974). He then turned this model into  
209 an audit tool to help managers self-check they were doing what was needed (or described to be  
210 needed) to prevent accidents and associated losses. This audit model, called the International Safety  
211 Rating System (ISRS), consisted of a practical tool, namely a series of questions that managers could  
212 use to check whether they were covering all the aspects of management contributing to safety (or  
213 modeled as such). According to one of the interviewees, "the ISRS had no scientific foundations. It  
214 was just the codification of industrial practice" (Academic 1, diverse industries, September 11 & 20,  
215 2018). Yet, its development was derived from the incident causation model he developed based on  
216 the analysis of more than 1.7 million accident reports.

217 On the academic side, the interest in safety developed in the 70s and 80s to a point where dedicated  
218 multi-disciplinary research departments and specific courses were set up for example at Delft  
219 University in 1978 (Stoop et al., 2017). Along the same lines, the journal *Safety Science* was first  
220 issued in 1976. Although safety approaches had so far mainly focused on technology and human  
221 factors (understood essentially as first line operators' errors), Barry Turner, a sociologist, published in  
222 1978 *Man-made disasters*, a book theorizing the organizational vulnerability to accidents. In his  
223 book, Turner (1978) highlighted the existence of a long period of incubation before the occurrence of  
224 an accident, during which the organization remains blind to all signs contradicting existing beliefs and  
225 norms. This was the first account of an organizational contribution to accidents.

226

## 227 [Motivations for a new approach](#)

228 Although enhancing safety is an obvious reason to improve the way safety is managed, other aspects  
229 and motivations come into play in the emergence of an approach like the SMS. This section explores  
230 the motivations, including beyond safety itself, of the main safety management stakeholders for  
231 moving towards a new approach.

## 232 [Academics: the limitations of an individual focus](#)

233 Among the main drivers for scientific developments in safety science at that time was a series of  
234 accidents (e.g. Flixborough in 1974, Bhopal in 1984, Challenger in 1986, Chernobyl in 1986). Indeed,  
235 the dominant accident models and safety thinking of that time, focused on technical and human  
236 factors aspects, couldn't provide sound explanations of these disasters. The research environment  
237 on safety evolved and can be characterized by several waves of developments emphasizing the role

238 played by organizations on safety. Several organizational angles were proposed to describe and  
239 explain either accidents, or alternatively, how safety can be ensured. Social scientists adopting a  
240 more qualitative and 'situated' approach based on field research work started to pay more attention  
241 to organizations as contributors to safety or to accidents (La Porte, 1994; Vaughan, 1997; Perrow,  
242 1984; Reason, 1990). Two distinct academic profiles can be identified, with different contributions:  
243 psychologists such as Andrew Hale, Bernhard Wilpert or James Reason, extending their scope from  
244 individual behaviors to organizations following major accidents becoming hard to explain on the sole  
245 basis of individual behaviors; sociologists or political scientists, with two types of contributions. First,  
246 the analysis of how high-risk organizations drifted and/or failed (Turner was a pioneer in this area).  
247 For example, organizational mechanisms whereby deviance become normalized were described by  
248 Diane Vaughan in 1996. Second, an analysis of how high-risk organizations successfully managed to  
249 sustain a high-reliability performance like for example La Porte, Schulman and the whole Berkeley  
250 school of thought on HROs in the late 80s, proposing the High-Reliability Organizations theory (La  
251 Porte, 1996). The introduction of a more managerial-like approach in academic research,  
252 emphasizing the key role played by management in ensuring working conditions preventing unsafe  
253 acts can be associated with the development of the Swiss Cheese model by James Reason in the late  
254 80s, and published his book on Human Error (Reason, 1990).

#### 255 [Insurance companies: better calibrating premiums](#)

256 Beyond any ethical consideration, one of the stakes, especially for insurance companies, was the cost  
257 of accidents. Therefore, safety management became a wider concern in the 70s for these companies,  
258 especially in the US. Indeed, the main challenge was to calculate insurance premiums depending on  
259 what industrials had in place to 'manage' safety in a societal context where companies needed to  
260 subscribe a private insurance for there was no public insurance system in some states in the US at  
261 that time. In such context, the insights drawn by Frank Bird Jr., originally an engineer and then a  
262 safety manager in the steel industry in the US, led an insurance company to recruit him in 1968.  
263 "What he had developed served as a structure to determine the level of risk of a company, thus its  
264 insurance premium. Frank Bird tried to put criteria to determine this premium" (Consultant/industry  
265 2, diverse industries, 21 December 2018).

#### 266 [Industrials: trauma, ethics and performance](#)

267 On the industrial side, historically, part of the motivation for Dupont to enhance safety management  
268 in the 1920s was the fact that "the factory of [the company] blew up regularly" (Academic 2, diverse  
269 industries, June 14, 2019). Accidents were still part of the factors that led companies, essentially in  
270 the mining, oil & gas, chemical, food processing industries to turn to Franck Bird Jr's consulting  
271 company in the 80s and 90s. As mentioned by one of the former employees of this company:

272 “Their [the companies we were working for] initial motivation was often triggered by a trauma,  
273 either internal or close to the company or experienced by one of the organization’s leader in his  
274 previous company. The change to adopt the ISRS<sup>3</sup> was not spontaneous, it was rather an  
275 electroshock” (Consultant/industry 2, diverse industries, December 21, 2018).

276  
277 However, other motivations were mentioned by the interviewees regarding the decision to develop  
278 or adopt different approaches to further enhance safety in the 90s, including ethical reasons, beyond  
279 the reduction of the costs associated with accidents.

280 As stated by one of the interviewees: “Management systems were already discussed at that time  
281 internally. Chemistry was a leader in terms of safety and safety management. HSE<sup>4</sup> as well as social  
282 aspects were explicitly part of the values promoted by the company. It was agreed at the top level of  
283 the company that people were working at [name of the company] to make a living, not to lose their  
284 lives. It wasn’t just words.” (Industrial 2, chemistry, January 25, 2019)

285 In the 90s, other industries in different countries as well funded their own research and development  
286 to further enhance their approaches to manage safety. It was the case of Shell in the oil & gas  
287 industry wanting to develop their own methods to identify organizational contributors to safety and  
288 performance more generally. Enhancing safety management was seen as a way to improve their  
289 overall performance by some companies’ and formed part of their motivations to move towards a  
290 new approach. In the case of the adoption of the ISRS, “safety was just a pretext. It consisted in  
291 expecting from each manager to bring its contribution to the good functioning of the company and  
292 to take his share of responsibility” (Consultant/industry 2, diverse industries, December 21, 2018).

293 In the nuclear industry where the main approach to safety was certification, EDF in France, as well as  
294 the NRC (Nuclear Regulatory Commission) in the US, developed new HRA (Human Reliability Analysis)  
295 methods to integrate ‘on-line’ safety management aspects and operating experience. Performing  
296 these more sophisticated analyses would not only respond to the mandatory certification  
297 requirements, but also, beyond the certification exercise, allow drawing useful insights to enhance  
298 safety (Bieder et al., 1998; Cooper et al., 1996). In France, the trigger was a change in technology  
299 with the introduction of computerized control rooms and the need to certify these new N4 reactor  
300 types with these novel control rooms. These HRA developments were focused on enhancing safety  
301 by design of a socio-technical system rather than by supporting managers in addressing safety.

### 302 [Regulators: overcoming the pitfalls of command and control](#)

303 Different motivations were also identified on the part of regulatory agencies, not all similar nor  
304 synchronized in time. Coming from different regulatory regimes, several countries played an

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<sup>3</sup> The ISRS (International Safety Rating System) was a tool to support managers in managing safety developed by F. Bird Jr. and sold to industrials when he decided to set up his own consulting company after him years spent in an insurance company.

<sup>4</sup> Health Safety & Environment

305 influential role in the development of a new approach to safety management, such as Norway  
306 (especially the oil & gas industry there), the Netherlands or the UK.

307 The reconsideration of the 'command and control' model of regulation is dated back to the end of  
308 the 60s. It translated into some influential reports such as the Robens Committee one in the UK  
309 published in 1972 and criticizing the traditional regulation model, mainly a top-down one, or the  
310 introduction of the "humanization of work" concept in the Netherlands inspired from the Norwegian  
311 Work Environment Act published in 1977 (Aalders & Wilthagen, 1997).

312 The Norwegian Petroleum Directorate (NPD), established in the 70s to regulate and oversee the  
313 emerging oil & gas activity, soon initiated reflections on the regulatory regime to be adopted in their  
314 particular context where (Lindøe and Olsen, 2009):

- 315 - the Norwegian Work Environment Act of 1977, "the world's possibly most stringent labour  
316 legislation" (*ibid*, p.432) was in place;
- 317 - the offshore industry was densely unionized "with extensive collective bargaining rights and  
318 a comprehensive network of safety representatives" (*ibid*, p.432);
- 319 - two major accidents occurred (the blow-out on the 'Bravo' platform in 1977, the capsizing of  
320 the 'Alexander Kielland' platform in 1980) showing the limitations of the regulatory regime in  
321 place.

322 The NPD pushed for moving from a reward and punishment to a mutual understanding and  
323 cooperation approach to safety regulation (Lindøe and Olsen, 2009; Hovden, 2002; Hovden &  
324 Tinmannsvik, 1990).

325 This reflection initially gave rise to an Internal Control approach that was then extended to all  
326 industries to overcome a double bind resources issue. The first issue is a qualitative one related to  
327 the increase in complexity and automation in industry, making it hard for a regulatory agency to keep  
328 up with. The second issue is a quantitative one since resources were becoming too limited to  
329 continue traditional monitoring (Hovden & Tinmannsvik, 1990).

330  
331 In the UK, beyond the Robens report, the motivation for regulators to change approaches (initially in  
332 process industry) also came from doubts expressed by the civil society about the efficiency of  
333 regulators with a series of accidents occurring in the 70s and 80s, but more generally about public  
334 services as further detailed in the following section. In this context, beyond the enhancement of  
335 safety, regulators had two major challenges, namely, protect their liability and demonstrate their  
336 efficacy (Power, 2004). In rail, a similar need to change approaches was identified in the 90s  
337 following a decade of mediatized accidents. "There were also a lot of rail accidents, or the media  
338 were more focused on accidents whereas they were silent in the past". (Academic 2, diverse  
339 industries, June 14, 2019). "There was a decision made by the secretary of state not to put a warning  
340 system on trains before this series of accidents. They had made a quick calculation on the back on  
341 the envelope and came to the conclusion that it was not worth it. The "Yellow book" which was their  
342 basis to perform risk assessment in the 90s had led to calculations 'proving' that it was safe enough  
343 as such. But then this series of accidents happened. This risk assessment approach based on  
344 calculations was not working so well in rail" (Mixed experience 1, diverse industries, January 21,  
345 2019).

346 In aviation in Europe, regulation was essentially based on certification. The need for moving towards  
347 new approaches came even later, just before the turn of the 21<sup>st</sup> century, with the corporatization of  
348 Air Navigation Service Providers in some countries like the UK for example in 1996. “The privatization  
349 or corporatization of public services was a strong incentive to rule the economic and safety aspects  
350 independently from one another. Economic aspect to make sure that the increase of profits wouldn’t  
351 be done to the detriment of clients. Safety aspect to make sure that safety wouldn’t be sacrificed to  
352 the benefit of other business indicators” (Regulator 3, aviation, February 20, 2019). Regarding how to  
353 rule the safety aspects, the main push came from the UK. “The UK CAA Safety Regulation Group had  
354 a vision of how the regulator should intervene, considering that they had an issue to remain  
355 competent on technology and that they didn’t want to take the responsibility of a detailed  
356 prescriptive and oversight approach. They were willing to focus the approval on the safety  
357 management system rather than on operational aspects. They had had bad experiences.” (Regulator  
358 4, aviation, February 25, 2019) “The UK was perceived as dominant. The chairman of the SRC<sup>5</sup> came  
359 from the UK. The head of the SRU<sup>6</sup> came from the UK. The other countries didn’t have the  
360 experience. They were not doing such thing in their countries.” Aviation relied on the railway  
361 experience in the UK that went through the privatization experience earlier which led to learn the  
362 hard way. “How this interface would work didn’t come from aviation in the UK. It came from the  
363 experience in the railway industry after it was privatized in a context of a liberal political system and  
364 more generally a certain vision of the world. The UK experienced a number of rail accidents which led  
365 to the clarification of control functions, especially for safety” (Regulator 4, aviation, February 25,  
366 2019). However, despite the early developments of safety management, the real push towards a  
367 change in regulatory approach happened following the Milan Linate and Überlingen accidents,  
368 respectively in 2001 and 2002, revealing that there were “organizational and oversight  
369 shortcomings.” (Industrial 3, aviation, February 12, 2019).

370

### 371 [Civil society: a growing suspicion](#)

372 An interesting angle to understand the societal push towards a new approach to safety management  
373 is provided by the ‘risk society’ theoretical perspective developed and addressed by Giddens (1990)  
374 and Beck (1992). In this perspective, risk is seen as amplified by the post-modern era where risks are  
375 spreading and amplifying due to industrialization, globalization and urbanization, created and  
376 accelerated by human activities.

377 In the 80s, as described by Beck (1992), the consciousness of self-produced or manufactured risks  
378 was increasing, creating enhanced public anxieties fueled by media. Likewise, the public defiance  
379 towards the governmental institutions and experts’ opaqueness was growing at that time (Giddens,  
380 1990; Beck, 1992; Hutter, 1997; Power, 2004). Indeed, the public started to realize that experts were  
381 disagreeing and that governments were failing to act, not to mention a certain suspicion towards  
382 science that also contributed to modernization, thus to the development of risks. Both the public and  
383 the media were less willing to accept advice from experts or to rely on regulatory models that they

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<sup>5</sup> Safety Regulation Commission

<sup>6</sup> Safety Regulation Unit

384 suspected were lacking knowledge about a growing number of risks. The public expected decisions  
385 and demanded the right for considering decision-makers accountable (Power, 2004, p.14).

### 386 [An enabling overall context](#)

387 If most safety stakeholders had diverse motivations to move towards new safety management  
388 approaches, it is worth wondering why Safety Management Systems turned out to be “the” most  
389 relevant approach crystalizing the variety of interests at stake. Exploring the overall context beyond  
390 safety itself in the late 70s and 80s when SMS started to largely emerge and be adopted provides  
391 some insights.

### 392 [An injunction for transparent and efficient control](#)

393 A big wave of deregulation occurred in the 80s, driven by a concern with over-regulation of business  
394 and uncontrolled costs of regulation which still left serious doubts about the efficiency of the  
395 regulatory practices in place. The 70s and 80s were indeed decades of a number of major accidents  
396 such as Flixborough (1974), Piper Alpha (1988), Herald of Free Enterprise (1987). The concern with  
397 regulation and its efficiency was in fact much broader than safety. It led in the 80s to the advent of  
398 the New Public Management in the UK.

399 The growing public injunction for transparency, control and accountability of public services was  
400 identified as a driving force for the explosion of audits in the UK in the 80s, combined with the  
401 evolution of the regulatory strategy towards a ‘control of control’ or oversight of internal control  
402 strategy, not only in the domain of safety (Power, 2000). More generally, the move towards the ‘risk  
403 management of everything’ is a way to define a structure of (apparent) control and accountability  
404 that provides the reassurance called for by the public including regarding the governance of the  
405 unknown (Power, 2004).

406 As characterized by Hood (1995), “the basis of NPM<sup>7</sup> lay in reversing the two cardinal doctrines of  
407 PPA<sup>8</sup>; that is, lessening or removing differences between the public and the private sector and  
408 shifting the emphasis from process accountability towards a greater element of accountability in  
409 terms of results.” (p.94). Progressively, the NPM model spread across the OECD<sup>9</sup> countries even  
410 though there were some variations in the way and pace at which the model was implemented (Hood,  
411 1995). A similar wave was observed in other European countries and the US starting in the 80s,  
412 emphasizing the cost issue (Hutter, 1997). Regulators were forced to legitimate their own activities  
413 by demonstrating they were operating both efficiently and effectively, that is without wasting  
414 resources and by proving that their activities were making a difference. They adopted a private  
415 sector style of management and risk-based approaches allowing for benchmarking public sector

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<sup>7</sup> New Public Management

<sup>8</sup> Progressive Public Administration

<sup>9</sup> Organization for Economic Cooperation and Development

416 activities against private sector activities. These approaches not only incorporated a cost-benefit  
417 approach, but they also had the apparent benefit of being ‘objective’ and transparent and perceived  
418 as efficient to support resources allocation, tested and trusted by the business community (Hutter,  
419 1997).

420 However, this apparent transparency reaches beyond the sole objective of legitimating regulators  
421 activities. It also constitutes an alibi, a ‘demonstration’ that everything was done to prevent failure.  
422 As such, it is a form of preventive accountability to avoid being blamed in case of failure (Power,  
423 2007).

424 This societal context in the 80s/90s is not just valid in the UK as a consequence of ‘Thatcherism’, but  
425 is rather related to the “organization of trust in modern societies and institutionalization of checking  
426 mechanisms”. (Power, (the audit society preface to the paperback edition in 1999, p. xvi)).

427 In this context, the generalization of internal control leads to a new balance between resources and  
428 responsibility, more specifically to an evolution from detailed prescriptive laws and regulations  
429 specifying the preventative measures to be implemented to more formal and calculative approaches,  
430 that can be audited based on a generic structure to make them reasonably one-size-fits-all tools for  
431 assessing a wide range of companies (Hale, 2003). The arguments put forward to support this move  
432 were a combination of a systematic and verifiable way to work with safety, a management system  
433 for safety, some leeway for each company to find their own solutions to safety & work environment,  
434 a way to place responsibility to individuals, including managers and directors, and also a way for  
435 fostering a dynamic approach and up-to-date solutions to safety problems (Hovden & Tinmannsvik,  
436 1990). By making internal control or self-regulation a regulatory requirement, authorities foster the  
437 generalization and further development by companies of internal control in a kind of ultimately self-  
438 reinforcing mechanism (Power, 2007).

#### 439 [The Quality Management wave](#)

440 Although “TQM’s origins can be traced to 1949, when the Union of Japanese Scientists and  
441 Engineers formed a committee of scholars, engineers, and government officials devoted to  
442 improving Japanese productivity, and enhancing their post-war quality of life” (Powell, 1995,  
443 p.16), it was introduced in the US in the 70s (when Japanese products penetrate the US market  
444 and as well as a result of the impact of Deming, Juran and other authors’ writing) and in the UK  
445 in the early 80s with the objective to enhance product quality, hence ultimately productivity  
446 (Martinez-Lorente et al., 1998). This quality management wave translated into the publication of  
447 the ISO 9000 norm in 1987 and the voluntary compliance with this standard having no  
448 authoritative power reflecting the evolution of the whole society towards increased  
449 bureaucratization and blurred boundaries between ‘public’ and ‘private’ (Hibou, 2012). Quality

450 Management Systems started to be part of the organizational landscape. Although ISO standards  
451 initially focused on quality, groups were set up in the 80s and 90s to extend the quality  
452 management approach to environment and then safety.

453 The development of standards (under the lobbying of certification companies) led to a shift of focus  
454 and understanding by some high-risk companies that saw in the standards not the minimum but  
455 what needs to be done (i.e. something like the maximum), an external recognition or sign of safety  
456 consciousness and a cheaper option than other in-depth analysis approaches. Therefore, a number of  
457 industries that had adopted the ISRS initially developed at a time where there were no ISO norms,  
458 mistook it for a management system and welcomed more standardized approaches. “Some  
459 companies came to the ISRS although all they wanted was the score. They would get the scores but  
460 not the actual outcome (...) The ISRS was also a matter of external acknowledgement/recognition.  
461 Companies would display their certificate in a visible location on the wall. Getting an ISO certificate  
462 was easier” (Consultant/industry 2, diverse industries, December 20, 2018).

463 This standardization was also a good opportunity for certification companies and emerging  
464 consulting companies making of the compliance with standards a juicy business and cutting costs  
465 paving the way to a “low cost safety management” (Almklov, 2018).

#### 466 [A practical approach endorsed by safety science after the fact](#)

467 The role of management and organizations in safety was analyzed and highlighted within the safety  
468 science community leading to a number of theories as described earlier. The academic topic of  
469 research was safety management. Interestingly, the theories coming from social scientists were  
470 descriptive and didn’t rely on a hierarchical control model, thereby failed to meet industrials’  
471 expectations. As stated by one of the industrial interviewees: “The ISRS was attractive for [name of  
472 the company] people for they had a scientific background and wanted a framed approach. There was  
473 a control loop (each item was graded: operational, need to improve or non-operational) and it was  
474 prescriptive” (Industrial 2, chemistry, 25 January 2019). Eventually, the SMS, as it emerged as a way  
475 to account for the role of management in safety, doesn’t originate from scientific developments. The  
476 SMS developed despite the absence of scientific evidence (Hovden & Tinnmansvik, 1990) significantly  
477 driven by forces outside the safety science arena and was then tentatively addressed in this arena.  
478 Put in one of the Academic interviewees’ words, “when SMS became an item, Academics wondered  
479 how to do that” (Academic 2, diverse industries, June 14, 2019). Turning to SMS for academics was a  
480 way to push scientific ideas on the role of management on safety but also a way to get funding. “The  
481 industrials would listen to academic SMS people who moved where the money was” (Academic 1,  
482 diverse industries, 11 & 20 September 2018).

#### 483 [Discussion](#)

484 Although the SMS is considered a turning point in safety science (Dekker, 2019), its emergence  
485 reflects and crystalizes the needs, trends and expectations of a global industrial, economic, political

486 and societal context, far beyond the thinking on safety of the 70s and 80s. The research reported  
487 here highlights the plurality of dimensions that come into play in the motivations of the different  
488 safety stakeholders to move towards a new approach. The main drivers are of very different natures.  
489 They include more specifically: technological progress and its related effects such as the challenges  
490 to keep up to speed with the pace of it, especially for regulators; the limitations of existing safety  
491 concepts and theories to explain real events; the concern of industrials to improve their overall  
492 performance in an increasingly competitive context. Besides these aspects calling for a new safety  
493 management approach, the overall context fostered the convergence towards an approach based on  
494 risk management and control. More specifically, among the key shaping factors were: the  
495 generalization of total quality and quality management systems (originally to improve companies'  
496 performance) ; the societal crisis of trust in public institutions and experts, but also in technology for  
497 they increased the will to manage and control everything both internally and externally, using private  
498 companies' approaches and tools (Power, 2004).

499 Of course, the research presented in this paper is limited to the genesis of the SMS, that is of one  
500 safety 'dominating concept' in the history of safety science. The results would need to be  
501 complemented through the investigation of other examples to come up with a more consolidated  
502 framework to think and understand the emergence of safety science 'turning points'. Nevertheless,  
503 the research outcomes lead to consider safety as a situated science; situated not only in time with a  
504 certain state of knowledge and technology, but also in a broad multi-dimensional context,  
505 characterized by certain world views, attitudes towards uncertainty, visions of trust and modes of  
506 interactions. The results unravel especially the influence of societal expectations and pressures with  
507 respect to technology and institutions as well as of industrial practices on the shaping of a widely  
508 accepted solution. This broad framework of the development of safety science 'dominating concept'  
509 invites to contemplate some of today's major trends that could constitute some of the conditions  
510 enabling the emergence of future safety science turning points.

511 Technology naturally comes to mind with the increased digitalization and development of  
512 technologies such as artificial intelligence and machine learning that pave the way for new  
513 'operators' with unprecedented and evolving capabilities and new forms of 'autonomy'. Autonomous  
514 vehicles, drones, robots are already starting to raise a number of safety issues including in relation to  
515 regulation and governance (Macrae, 2019; Andrews, 2017). However, the impact of digitalization  
516 reaches far beyond safety itself, transforming social interactions, the foundation of trust or even  
517 making new sources of data (if not information) available and new processing possible, with a variety  
518 of effects in many domains.

519 Another current trend could contribute to shaping the future of safety science is the observed  
520 evolution of governance mechanisms whereby the civil society at different levels pushes to make

521 behaviors evolve whether or not it involves institutional reactions. These phenomena, of which ‘flight  
522 shaming’ is an illustration, challenge still widespread models considering that government is the only  
523 actor managing and organizing societal and political solutions. More generally, “the shift to  
524 governance is best understood as response to new challenges, such as globalization, increased  
525 international cooperation (such as the European Union), societal changes, including the increased  
526 engagement of citizens and the rise of non-governmental organizations (NGOs), changing role of the  
527 private sector, an augmenting complexity of policy issues, and the resulting difficulty in taking  
528 decisions with confidence and legitimacy” (Renn et al., 2011, p.233), citing (Walls et al., 2005).  
529 Matyjasik & Guenoun (2019) explicitly envisage the end of the New Public Management<sup>10</sup> and the  
530 possible emergence of new modes of governance, some of which build by the way on the new  
531 capabilities offered by digitalization. The evolution of governance models at a global level may  
532 significantly impact safety and drive for new safety science concepts. Indeed, as shown earlier, the  
533 NPM played a key role in the emergence of an approach like the SMS, by calling for more  
534 transparency, control and responsibility.

535 Climate change, and the generalization of public acknowledgement of the urgency to address it, is  
536 another current trend to consider. Indeed, it may challenge the value of safety. It raises questions as  
537 to the relationship between safety and climate change. For example, will they be considered  
538 mutually reinforcing each other or competing with one another (and under what conditions) like  
539 safety and productivity have been for a long time and still are in many organizations? Other growing  
540 concerns raise similar questions as to their coupling with safety. It is the case of security for example  
541 (Bieder and Pettersen, 2020) or more recently with the Covid-19 outbreak of health.

542 Many recent disasters include a large number of natural disasters or attacks (cyber or physical) or  
543 more recently pandemics. Concerns like climate change, security or global health also induce a  
544 societal evolution that may shape future safety science concepts, namely, the attitude towards  
545 uncertainty. Whereas the society of the late 20<sup>th</sup> century was that of the risk control of everything  
546 (Power, 2004), a number of mediatized events challenge this view and reveals the limitations of risk  
547 control. It is the case of some extreme climate events like wildfires in California or Australia, or  
548 security events like 9/11, the Paris attacks in 2015 or the Germanwings accident, or more recently of  
549 the Covid-19 outbreak. These evidences that total risk control is an illusion call for the need to  
550 develop strategies to live with uncertainty more than try and pretend to reduce it totally.

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<sup>10</sup> One of the enablers of the convergence towards the SMS.

## 551 Conclusions

552 The analysis of the genesis of SMSs, one of the 'turning points' in the history of safety science,  
553 provides some insights as to the many aspects that contributed to the emergence of such a  
554 'dominating concept'. It reveals the multiplicity of motivations of the various stakeholders to change  
555 safety approaches, including beyond the enhancement of safety itself. Resource issues, global  
556 performance improvement or liability for example are dimensions that were part of the motivations.  
557 However, the convergence towards an approach inspired from industrial practices, based on the  
558 clarification of responsibilities and risk management also results from an overall enabling context.  
559 Indeed, the generalization of quality management systems and the development and spreading of  
560 New Public Management contributed to shaping a safety management approach that would be not  
561 only acceptable to all safety stakeholders, but also matching the political, economic and societal  
562 environment of that time. As such, the SMS as a new safety science dominating concept is situated.  
563 Although the detailed framework to understand the genesis of new safety science concepts would  
564 need to be consolidated, the research invites to contemplate safety as a situated science. As such, it  
565 opens new avenues for reflecting about the future of safety science considering today's world. It  
566 leads to putting safety into a wider context and perspective, considering some current technological  
567 and societal trends such as the generalization of digitalization, or the growing concerns about climate  
568 change, or the increasing acknowledgement of uncertainties and the need to live with them calling  
569 for other modes of governance. It also and maybe above all encourages to remain humble as to what  
570 can be advanced about the future of safety science.

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