Safety Science 102 (2018) 79–100

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

Review

Resilience engineering: Current status of the research and future challenges

Riccardo Patriarca[a,*], Johan Bergström[b], Giulio Di Gravio[a], Francesco Costantino[a]

[a] Department of Mechanical and Aerospace Engineering, "Sapienza" University of Rome, Via Eudossiana 18, Rome, Italy
[b] Division of Risk Management and Societal Safety, Centre for Societal Resilience, Lund University, PO Box 118, Lund, Sweden

ARTICLE INFO

Keywords:
Resilience engineering
Resilience
Factor analysis
Meta-review

ABSTRACT

This paper offers an extensive literature review on the field of Resilience Engineering (RE), encompassing 472 contributions, including journal articles, conference proceedings and book chapters. Adopting the numbers of co-citations as a metric of conceptual proximity, this paper details the application of Factor Analysis and Multi-Dimensional Scaling, as groundbreaking means to extract relevant research factors. A temporal analysis in a multi-variate two-dimensional space confirms the significance and relevance of the identified research factors. An in-depth analysis of the five research factors, labeled as *the need of RE*, *RE for modelling, defining and exploring RE*, *reflecting on RE*, *RE and improvisation*, guides the definition of future research paths and open research questions within the field and across several domains, suggesting the need for multi-disciplinary future studies.

1. Introduction

Resilience Engineering (RE) is a paradigm for safety management that focuses on systems coping with complexity and balancing productivity with safety. RE aims at providing tools to proactively manage risk, acknowledging the inherent complexity of system functioning and the correspondent need for performance variability. This perspective becomes crucial if linked to the risk-related needs of current socio-technical systems. In these systems, safety is not a constant or permanent property (Carayon et al., 2015); its presence or absence is a continuous function, i.e. emerges from, the interactive properties and activities of its constituent components. Safety is related to how system performs, generating the need to focus on whole system and the connection between agents, rather than individual agents (Bakx and Nyce, 2015). Risk and safety management for socio-technical systems shall not be reduced to tracking and analyzing roles and variables (Pava, 1986). Therefore, RE "uses the insights from research on failures in complex systems, including organizational contributors to risk, and the factors that affect human performance to provide systems engineering tools to manage risks proactively" (Woods, 2003). The concept of resilience is usually linked to terms such as robust, buoyant, elastic, and flexible. It can be intended as "[…] a feature of some systems that allows them to respond to an unanticipated disturbance that can lead to failure and then to resume normal operations quickly and with minimum decrement in their performance" (Fairbanks et al., 2014). Thus RE can be advocated as the discipline aimed at providing systems means to concretise these characteristics in response to external and internal perturbations (Hollnagel, 2006; Woods, 2006a).

This article aims to investigate the research domain of RE, by reviewing over twelve years of literature from 2004 to 2016 (and including articles published in 2017 but available online until October 2016). Starting from the confused consensus about RE argued in the first Resilience Engineering Association (REA) symposium in 2004 (Dekker, 2006), this paper aims at understanding the current state of the art of this research stream and its potential future directions. However, this is not the first literature review on the field: Righi et al. (2015) developed a systematic literature review to define the main areas and the agenda. Even if their review relies on a research protocol to reduce the subjectivity of the search, their work presents several limitations. Firstly, the inclusion and exclusion criteria, as the same authors acknowledge, incorporated the possibility for having neglected relevant studies and included a substantial portion of studies with little relevance. Furthermore, they suggested a frank critique of how they assigned papers to specific research areas, since many studies cut across several areas, thus reducing the relevance of the defined categories. Lastly, the same authors recognize the need to explore other meta-analysis techniques, (e.g.) using bibliometric indicators. Similar problems arise from another literature review on the field (Bergström et al., 2015), mainly focused on the domain of safety, which includes only papers from main journals related to resilience. The definition of main journals might be considered not completely objective since the authors define them as "the more generic journals on safety and resilience". Furthermore, the authors consider only seventy-one papers, i.e. filtering those papers where resilience was only a sub-topic. Those papers might as well contribute to the definition of the field, in a broader sense.

Starting from the inherent limitations of these two reviews, it is

* Corresponding author at: Via Eudossiana 18 - 00184, Rome, Italy.
E-mail address: riccardo.patriarca@uniroma1.it (R. Patriarca).

http://dx.doi.org/10.1016/j.ssci.2017.10.005
Received 2 December 2016; Received in revised form 27 August 2017; Accepted 10 October 2017
0925-7535/

possible to observe that a review on the wide topic of Resilience Engineering is currently lacking. Approximately twenty years after its first systematic definition (2004), this paper aims at providing a robust contribution to describe the current status and identify potential future challenges for the field.

According to these observations, we conducted the first meta-analysis on the field of RE. Our aim is to answer several research questions, including: What is the relevant literature in the field? How, and where, does the field define itself? Has there been an evolution of the field over the years? Which are the most and the less advanced research areas?

For this purpose, we adopt a groundbreaking and robust methodology, based on the bibliometric method of co-citation analysis, to ensure objectivity of the review and identify the intellectual structure of the research field. This latter has been discussed according to five relevant research domains, in terms of implications, limitations and future evolutions, adding also a time-reflective dimension to the research agenda.

2. Methodology

Understanding the intellectual structure of a research field can be a complex activity, especially in case of multiple, different and extensive amounts of contributions, where it is challenging even to restrict the literature review to a core dataset of publications. Analyzing citations as a starting point to evaluate co-citations represents a strategy to perform meta-analysis of the literature (Shafique, 2013). Co-citation analysis is a standard bibliometric method to examine relationships between articles, or even authors, in order to understand how they contribute to the development of a research field. This method relies on the assumption that if two contributions are often co-cited, the same contributions have to be linked somehow (Di Stefano et al., 2012). On this path, the more two documents are co-cited; the stronger the relationship between them, implying their belonging to a common research area, often referred as *invisible college* (Crane, 1969) in terms of authors' commonality.

The first step of our analysis consists of determining which documents are relevant in the field, i.e. related to Resilience Engineering, by a wide literature research, no restricting the search to any context.

The meta-analysis based on co-citations serves as an input to identify the intellectual research structure by Factor Analysis (FA). FA is a multi-variate technique useful for data reduction and it is compatible with the metric of co-citations, as a means to understand the not immediately visible relationships among documents (Pilkington and Meredith, 2009). For this purpose, we use the notion of *research factors* rather than invisible college, defining a research factor as a set of documents that analyze similar research interests concerning a specific field or sub-field with semantic commonalities.

However, since it is commonly acknowledged that an invisible college (and similarly a research factor) is not a one-dimensional construct, but rather a multi-faceted phenomenon, we consider it interesting to understand them and their relationships in a multi-dimensional representation. We use Multi-Dimensional Scaling (MDS), a multi-variate technique that graphically depicts the conceptual proximity between documents, based on co-citations metric (Ramos-Rodríguez and Ruíz-Navarro, 2004). Furthermore, we combine the results of FA with MDS to achieve an in-depth understanding of the research stream and interactions among research factors (Annarelli and Nonino, 2015; Costantino et al., 2016).

2.1. Searching and selecting the articles

The literature search of this study mainly used the Scopus database, which is the largest abstract and citation database of peer-reviewed literature. In order to avoid limitations in the search, we used a wide key-search analysis, searching for "resilience engineering" in the fields of title, abstract, keywords, i.e. TITLE-ABS-KEY ("resilience engineering"), including documents indexed until October 2016. We obtained 264 documents that refer to different subject areas, mainly "Engineering", "Social Sciences", "Computer Science", "Medicine", "Chemical Engineering", "Business, Management and Accounting", "Environmental Science", "Decision Sciences". As a final step, we performed a title and abstract reading in order to remove documents clearly outside the scope, duplicates, erratum and retracted articles.

2.1.1. Managing books

Since the set obtained by Scopus included in some cases both an entire book and its chapters, we performed specific analyses to evaluate their inclusion criteria. We removed those chapters of the books "Resilience Engineering: Concepts and Precepts", "Resilience Engineering in practice: A guidebook" and "Resilient Health Care", included in the original 264 documents, and the entire books. To maintain a systematic perspective and considering the relevance of these books for the analysis, we included their chapters as single documents. About the book "Governance and Control of Financial Systems: A Resilience Engineering Perspective" we decided to maintain it as a book, summarizing all the citations of the ten chapters (in total 12), which refer to RE in a single document. On the contrary, about the book "Oil and Gas, Technology and Humans: Assessing the Human Factors of Technological Change", we decided to evaluate the single chapters yet included in the original search, since not all the contributions in the books are related to RE.

We did not perform any further actions for the other book chapters included in the original 264 documents, in the following books: Human Factors in aviation", "Social Media and the Transformation of Interaction in Society", "Applications of Systems Thinking and Soft Operations Research in Managing Complexity: From Problem Framing to Problem Solving", "Pediatric and Congenital Cardiac Care: Volume 2: Quality Improvement and Patient Safety", "Numerical Methods for Reliability and Safety Assessment: Multiscale and Multiphysics Systems", "Reflections on the Fukushima Daiichi Nuclear Accident: Toward Social-Scientific Literacy and Engineering Resilience", "Risk Management in Life-Critical Systems", "Software Design and Development: Concepts, Methodologies, Tools, and Applications", "Simulator-based Human Factors Studies Across 25 Years: The History of the Halden Man-Machine Laboratory", "Robust Design Methodology for Reliability: Exploring the Effects of Variation and Uncertainty", "Designing, Engineering, and Analyzing Reliable and Efficient Software".

The choice to include book chapters in the analysis plays a relevant role for gathering emerging trends on resilience engineering, especially considering that book format is considered generally the best format to set innovative theories and approaches, thus contributing to an emergent discipline by a broad coverage of different aspects.

2.1.2. Managing proceedings

The original search included several relevant documents as proceedings (e.g. "Proceedings of the Human Factors and Ergonomics Society", "Proceedings of the European Safety and Reliability Conferences (ESREL)", proceedings of the "Probabilistic Assessment and Management (PSAM)" conferences). In addition, the Scopus database does not index the Resilience Engineering Association (REA) symposia papers, which represent significant contributions to the field of RE. We decided to include all the contributions related to the REA symposia. In particular, rather than including the proceedings, we included the relative chapters of the published books - where available - since they typically represent the same, or typically improved and more readable, peer-reviewed versions of the original conference papers. In order to maintain a systematic perspective and avoid duplicates, based on the correspondences sketched in Table 1, our analysis included all the chapters of the books "Resilience Engineering: Concepts and Precepts" (already included in the dataset, since included in Scopus, see Section 2.1.1), "Resilience Engineering Perspective Volume 1 –

Table 1
Correspondence between REA symposium proceedings and books.

REA symposium	Related published book
1st REA symposium (2004)	Resilience Engineering: Concepts and Precepts
2nd REA symposium (2006)	Resilience Engineering Perspective Volume 1 – Remaining sensitive to the possibility of failure Resilience Engineering Perspective Volume 2 – Preparation and restoration
3rd REA symposium (2008)	Resilience Engineering in practice: A guidebook
4th REA symposium (2011)	Becoming resilient
5th REA symposium (2013)	–
6th REA symposium (2015)	–

Remaining sensitive to the possibility of failure", "Resilience Engineering Perspective Volume 2 – Preparation and restoration", "Becoming resilient". About the 5th and 6th REA symposia, since no books have been published so far, the conference papers have been included.

Note that the conference proceedings included in the analysis are generally indexed in Scopus, which selects contributions based on the relevancy and quality of the conference, with priorities to reputable organizations and publishers in relevant subject fields. In addition, even if REA proceedings are indexed partially in Scopus as book chapters (as per 1st REA symposium, see Table 1), we decided to include them for the straightforward link with the topic under analysis, and considering them reputable as well. In particular, REA proceedings aim to explore how resilience can be put in practice, and which can be its full extent of implications and its potential benefits, relying on a robust cross-domain scientific community.

For the purpose of this meta-analysis, even if the conference proceedings contribute to define the research field (citing and co-citing other works), they are expected not to be included in the core dataset which define the research field, since they are usually less cited with respect to journal papers.

2.1.3. Finalizing the dataset

The searching strategy has also been refined to include relevant papers (including the word "resilience" in title, abstract, keywords) by a detailed additional search. Based on authors' experience, this hand-search strategy has been limited to journals with a primer interest in safety, e.g. "Safety Science", "Reliability Engineering and System Safety", "Cognition, Technology and Work". The choice not to include journals related to other technical areas, arise as a consequence of acknowledging that RE was born as a paradigm shift for safety management (Hollnagel, 2006; Woods, 2006a). Consequently, the size of the initial dataset increased to 472 documents, as summarized in Fig. 1.

2.2. Identifying the core dataset

In order to systematically develop the co-citation analysis, we built an entry form based on VBA scripts to acquire data directly from Scopus (for the contributions indexed in Scopus) and to delve into papers, codifying and extracting citations (for papers not indexed in Scopus).

As a first step, we developed a 472 × 472 citation matrix, listing all the documents as citing and cited papers. Then, we developed a co-citation matrix, based on the citations matrix and counting how many times two papers were cited together. Each element represented the number of co-citations of a specific couple of papers. At this step, excluding those papers that have never been co-cited together, we defined the core dataset of the analysis of 180 papers. Fig. 2 compares the initial dataset and the core dataset over time. To understand the decreasing trend for 2017 and 2016, it should be noted that the literature search stops at papers published until October 2016, and of course, the most recent papers are generally not co-cited yet. This figure also highlights that several contributions related to 2013 and 2015 have not been included in the analysis. These latter mainly refer to the 5th (2013) and 6th (2015) REA symposia (see Table 1): even if these contributions may help addressing the research field, i.e. citing and co-citing other relevant contributions, they are generally not cited (and co-cited), confirming the general scientific tendency to rely more on journal papers (see Fig. 3).

Lastly, we developed a 180 × 180 Pearson correlation matrix based on the co-citation matrix, in order to make the co-citations comparable and standardized, allowing a more robust basis for the following statistical analysis, i.e. FA and MDS (Rowlands, 1999).

3. Findings

3.1. Findings from systematic literature search

Among the initial 472 papers in the dataset, 277 (58.8%) are not cited by other papers in the dataset, while 15 (3.1%) are, even if cited, never co-cited with any other paper in the dataset. The initial dataset of 472 papers presents 1016 citations, while the core dataset of 180 papers presents 1001 citations (98.5% of the total). These data prove the relevance of the applied selection to identify the relevant literature on the field, obtaining contributions with 5.45 average citations.

The most relevant journals in the core dataset are Reliability Engineering and System Safety (20 papers, 4.3 average citations per paper), Safety Science (15 papers, 8.53 average citations per paper) and Cognition, Technology and Work (12 papers, 2.75 average citations per paper). The Resilience Engineering Association plays a crucial role in the field, considering that the core dataset includes 19 chapters of "Resilience Engineering: Concepts and Precepts", averagely the most cited ones (14.89 citations per chapter), 16 of "Resilience Engineering in Practice: A guidebook" (6.37 citations per chapter), 11 of "Resilience Engineering Perspective Volume 1 – Remaining sensitive to the possibility of failure" (5.09 citations per chapter) and 10 conference papers of the recently published 5th REA symposium (1.5 citations per chapter).

3.2. Findings from factor analysis

Starting from the 180 × 180 Pearson correlation matrix based on the co-citation matrix, we developed a Principal Components Analysis (PCA) with Varimax rotation (Kaiser, 1958) in order to extract the key factors of the core dataset. A factor is a linear combination of optimally-weighted observed variables that accounts for a maximal amount of variance in the observed variables (relying on the correlation matrix obtained by the co-citation matrix) that was not accounted for by the preceding components, and is uncorrelated with all of the preceding components (Kline, 1994). Considering our scope of extracting major research factors, Varimax represents a helpful rotation criterion, capable of rotating elements in such a way as to economically represent those with high loadings on a single factor. Even if it would have been possible to include additional factors with few contributions per factor, we considered useful to study the first five factors, which include 156 contributions, and explains 65.9% of the total variance, as shown in Table 2.

Factor loading represents the correlation between contributions and factors, i.e. the degree to which a specific document belongs to a factor. Even if there is no standard criteria for defining a threshold for significant factor loading, we consider a zero loading any value falling between ± 0.10. Some studies adopt a significance threshold of 0.40 (Annarelli and Nonino, 2015; Di Stefano et al., 2012). However, it is possible to argue that a factor loading of 0.3 is reasonable for sample size greater than 100, since it indicates that 9% of the variance is accounted for by the factor, enough to indicate that the loading is salient,

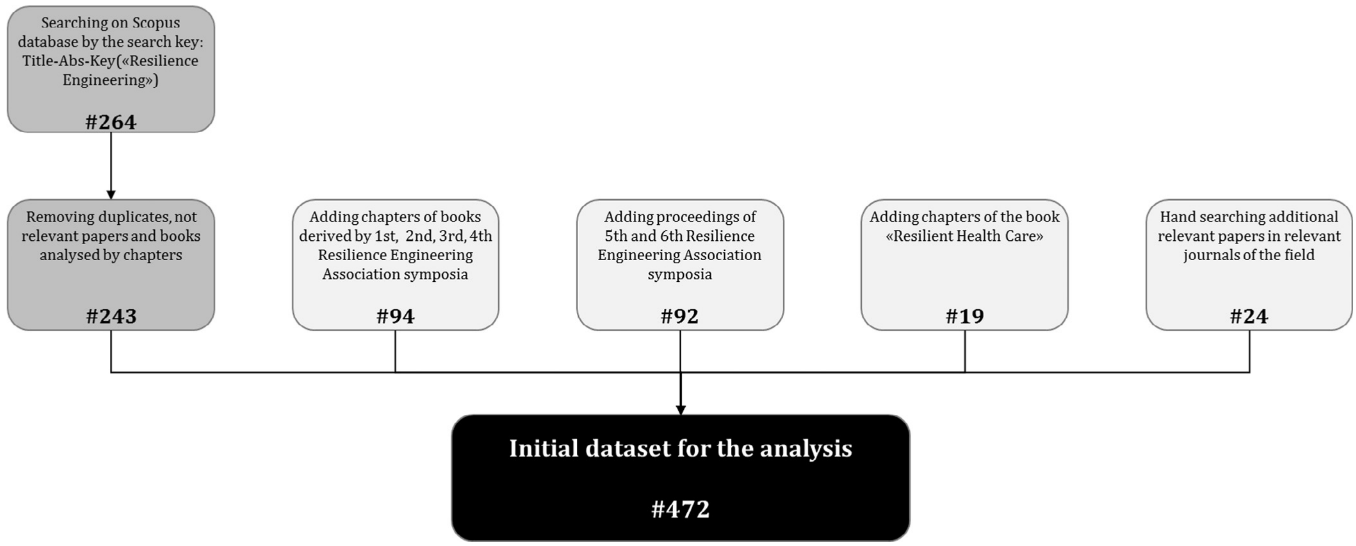

Fig. 1. Details of the searching strategy and initial dataset for the analysis.

even arguing that the threshold could be lowered in case of bigger sample (Kline, 1994). Based on these assumptions, we adopted a threshold of 0.30 and assigned the papers to the factors if scores are higher than the threshold. In case of multiple loadings, we assigned the paper to the factors after an in-depth reading of the text. Table 3 shows the loadings for each document and the relative assigned factor (compare Appendix for details of papers). We decided not to assign factors for 24 papers, since they had near-zero loading on the first five factors and adding small factors would have been of limited value for the analysis.

Starting from the list of papers and factors, two reviewers examined independently the records' title, abstract and full text in order to identify the (possible) common conceptual meaning for the papers grouped by FA. Reading the full-text was necessary to allow each reviewer including a synthetic description of the manuscript's outputs, highlighting in the text relevant keywords and sentences to ease the following group discussion. The full text reading also was useful to define the main contributions of the paper, its critical aspects and tis contribution to the field. The group discussion involved also the other two reviewers, which previously read title, abstract and keywords of each paper as well.

The process presented a strong consistency of the independent judgments from the reviewers (around 90%), and the discrepancies were solved in a point-to-point discussion, starting from the notes by the two reviewers who read the full text. This thematic construction allowed us refining the structure of the factors, re-assigning those papers with multiple loadings to different components respectively to the more proximal semantical factors. The thematic construction forced us to subsume deductively the authors' perspective, always using as a guidance the results of FA. Note that the potential subjective bias was limited by involving all the authors of this paper in the final factor classification. The outcome of this phase was a spreadsheet with the papers grouped per factor, linking them to a Mendeley database including the full text.

Finally, it has been possible to define five clusters of research within RE. As expected, the factors showed different aspects of RE, describing the field according to complementary perspectives.

Research factor 1. RE for Modelling
Research factor 2. Defining and exploring RE
Research factor 3. Reflecting on RE
Research factor 4. The need for RE
Research factor 5. RE and improvisation

The following sections (Sections 3.2.1–3.2.6) discuss the factors, detailing implications, outcomes and limitations arising from the the analysis of the contributions. The order of presentation of the research factors reflects a semantical logic deriving from the full text analysis, rather than the mathematical sequencing of variance assessment.

3.2.1. *The need of RE*

This research factor includes 17 (of 180) contributions. These

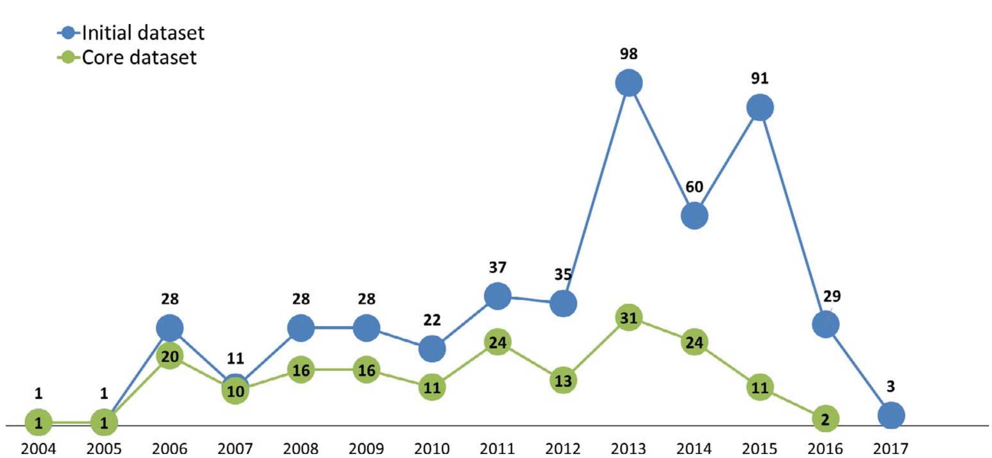

Fig. 2. Initial dataset and core dataset over years.

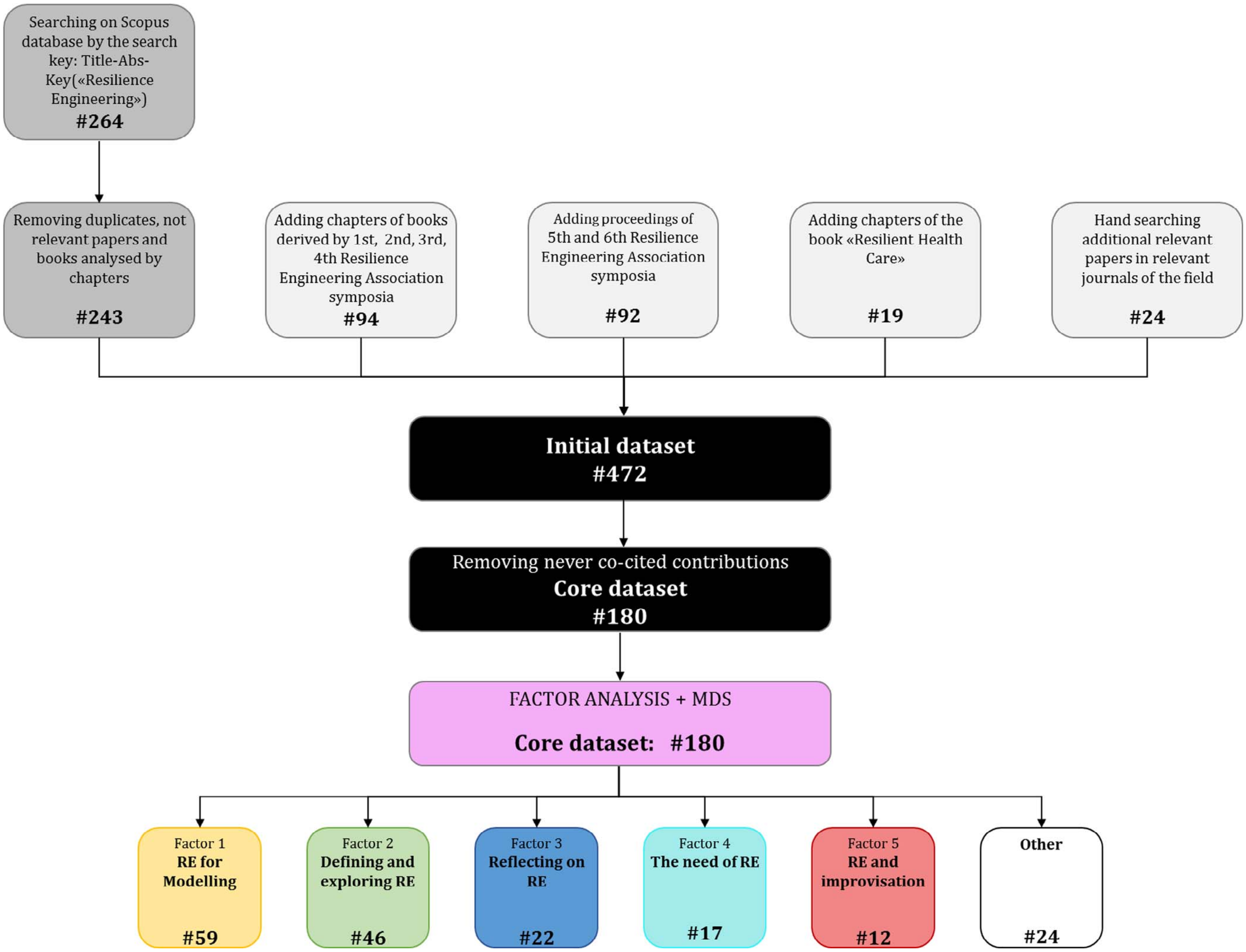

Fig. 3. Details of the relationship between papers, research factors and datasets.

Table 2
Results of the PCA for the most relevant five factors.

Factor	Value	Percent	Cumulate%	Ratio
1	44.7203	24.3	24.3	1.149
2	38.9234	45.4	45.4	2.424
3	16.0577	54.1	54.1	1.347
4	11.9188	60.6	60.6	1.222
5	9.7520	65.9	65.9	1.323

contributions discuss the need for a new perspective on risk assessment and accident analysis, in line with a system perspective. A comparison among this new concept, called RE, and other well-established theories is often present in the contributions.

The oldest contribution in this factor is the famous work of Leveson (Leveson, 2004) that discusses the need for new explanatory mechanism about the etiology of accidents. The work addresses the relevance of going beyond the blame assignment, considering instead social and organizational structures, by STAMP (System-Theoretic Accident Model and Process) as a model capable of evolving the event chain conception. Even if not syntactically related to RE, this paper stresses the importance of shifting from "cause" to the understanding system functioning by control theory. This theory has also been discussed in order to move from traditional "looking back" towards a new proactive "looking forward" perspective, based on normal work, rather than failures (Hollnagel, 2008a). The need for a new paradigm appears significant also in the context of handling uncertainty across organization, moving from static routines to organizational flexibility (Grote, 2008). This flexibility concerns the most relevant difference between reliability and resilience: something is reliable if the failure probability is acceptable low while (in contrast) something is resilient if it has the ability to recover from irregular variations, disruptions and degradation of expected working conditions (Nemeth, 2008a).

On this path, even if there could be several similarities between HRO (High Reliability Organization) theory and RE (Hopkins, 2014), there is a strong consensus on the need to make RE usable also at an industrial level, even reconciling it with HRA (Human Reliability Analysis) (Boring, 2009). RE gives instruments to allow the system to steer its activities so that it may sail close to the area where accidents will happen, but always staying out of the dangerous area (Hale and Heijer, 2006a), adapting and quickly recovering from disruptions (Erol et al., 2010). This conception has a clear implication with the nature of safety, considering the so-called fifth age of safety, i.e. the adaptive age, and its implications for the OHS (Borys et al., 2009).

Similarly, a critical review of traditional error/risk analysis, compared with the paradigm of RE, confirms the relevance of RE (Sheridan, 2008). The study especially highlights the inherent flaws of PRA (Probability Risk Assessment) related to the arbitrary definition of error and unpredictability of future events, acknowledging that the new paradigm of RE may improve organizational process with anticipating and preparing to recover from abnormal events (Epstein, 2008). An example confirm the benefits of RE in terms of resilience of middle

Table 3
Factors loadings for papers in the core.[a]

ID	F1	F2	F3	F4	F5	Factor
485	0.991					1
210	0.989					1
239	0.987					1
185	0.985					1
211	0.985					1
90	0.977					1
246	0.977					1
220	0.975					1
184	0.971					1
247	0.97					1
255	0.959					1
146	0.956					1
301	0.956					1
177	0.952					1
84	0.95					1
175	0.949					1
293	0.948					1
89	0.942					1
156	0.933					1
285	0.923					1
214	0.922					1
183	0.919					1
287	0.912					1
88	0.906					1
232	0.893					1
263	0.893					1
44	0.885					1
43	0.874					1
275	0.816			−0.351		1
243	0.815	0.375		−0.336		1
259	0.802					1
231	0.793					1
235	0.774				0.362	1
471	0.722					1
80	0.721					1
118	0.721					1
265	0.702	0.618				1
244	0.698					1
281	0.662	0.373			0.315	1
490	0.662					1
95	0.628					1
489	0.541	0.582				1
473	0.507			−0.332		1
125	0.495					1
337	0.495					1
470	0.406					1
148	0.362					1
261	0.362					1
477	0.36					1
205	0.357	0.465				1
488	0.339					1
472	0.305	0.403				1
52	0.301					1
91	0.301					1
138	−0.301					1
229	−0.316					1
106	−0.32					1
257	−0.361					1
300	−0.361					1
484	−0.361					1
290		0.948				2
326		0.897				2
295		0.894				2
336		0.892				2
483		0.89				2
49		0.882				2
278		0.882		−0.311		2
274		0.853				2
458		0.849				2
314		0.843				2
262		0.841				2
345		0.84				2
333		0.839			0.373	2
152		0.822			0.351	2

Table 3 (*continued*)

ID	F1	F2	F3	F4	F5	Factor
242		0.816				2
130		0.8				2
283		0.797		−0.326		2
342		0.795				2
136		0.786			0.414	2
291		0.785		−0.382		2
186		0.77				2
328		0.754				2
47		0.744				2
272		0.736			0.337	2
343		0.734				2
316		0.729				2
149		0.715				2
104		0.71				2
426		0.708			0.548	2
338		0.7				2
271		0.699		−0.549		2
352		0.676			0.452	2
453		0.676			0.452	2
457		0.676			0.452	2
284		0.665		−0.513		2
318	0.555	0.659				2
289		0.645		−0.564		2
335		0.642				2
358		0.641			0.468	2
273	0.604	0.627		−0.432		2
317	0.417	0.582		−0.445		2
267	0.461	0.575		−0.43		2
217		0.573				2
264		0.57			0.31	2
327		0.538				2
493	0.359	0.464				2
219		0.388			0.342	2
48			0.923			3
50			0.923			3
83			0.923			3
362			0.923			3
436			0.923			3
359			0.908			3
92			0.906			3
375			0.901			3
482			0.893			3
370			0.89			3
153	0.486		0.761			3
176	0.486		0.761			3
306		0.584	0.603	−0.302		3
372	−0.336		0.564			3
85			0.478		0.615	3
298			0.45		0.373	3
252	0.368		0.445			3
432		0.431	0.313			3
256			0.308			3
331			0.306			3
474		0.444	0.304			3
341			0.3			3
313				−0.306		4
294				−0.307		4
103				−0.308		4
228	0.308	0.648		−0.323		4
277	0.425	0.709		−0.332		4
478		0.392		−0.428	0.644	4
299		0.649		−0.429		4
251		0.383		−0.527		4
297	0.335			−0.597	0.48	4
486				−0.612	0.431	4
282	0.332	0.581		−0.661		4
268	0.441	0.485		−0.716		4
253	0.447	0.407		−0.745		4
248		0.407		−0.804		4
250		0.407		−0.804		4
296		0.34		−0.866		4
237				−0.911		4
114					0.866	5
53					0.852	5
424		0.329			0.851	5

(*continued on next page*)

Table 3 (*continued*)

ID	F1	F2	F3	F4	F5	Factor
280					0.843	5
440					0.843	5
427					0.763	5
86		0.519			0.738	5
492					0.656	5
157		0.508			0.621	5
311					0.613	5
168		0.575			0.587	5
203					0.323	5

[a] Extraction method: PCA with Varimax rotation. Variance explained: 65.9%. Reports present only factor loadings higher than 0.3 and papers loaded on the first five factors.

managers, as a critical component of organizational resilience, comparing the disaster of the Swedish warship Vasa in 1628, to the NASA Challenger failure in 1986 (Flin, 2006).

Nevertheless, in 2008 it was argued that the new methods and models based on RE were still far from the concept of "knowledge for action", but rather still focusing on "knowledge for knowledge", thus setting the agenda for translating the new modeling approaches (Le Coze and Dupré, 2008) following an operational perspective. A similar agenda is shared with other works that explore the need of RE in different contexts (e.g.) Nuclear Power Plants (Axelsson, 2006; Back et al., 2008), aviation (Chialastri and Pozzi, 2008), and healthcare (Wears et al., 2007).

3.2.2. *Defining and exploring RE*

This research factor includes 46 (of 180) contributions that deal with different theoretical and explorative studies on RE. From the need to define resilience univocally, starting from a confused consensus, the contributions listed here first define resilience only as adaptation, then considering multiple abilities, which would be later summarized as the four cornerstones. Lastly, more recent research add new perspectives to the field, suggesting alternative definitions of resilience.

The first REA symposium, held in Sweden in 2004, was the first attempt to establish a confused consensus on RE, trying to set the boundaries of the field. Four general themes were explored: limitations of current accident analysis based on causality and decomposition and potential benefits of RE at preventing accidents (Amalberti, 2006; Leveson et al., 2006); difficulties at detecting organizational drift and differences about perceived and actual resilience; acknowledgment of detecting drift into failure as a major role for RE; and lastly the need for additional markers of resilience (Dekker, 2006).

Since the beginning, RE was supposed to provide organizations with help on how to decide when to relax production pressure to reduce risk. Nevertheless this trade-off is often implicit and unrecognized, as proved by an analysis of the Norwegian aviation transport system (Tjørhom and Aase, 2011), air traffic management (Joyekurun, 2007), the 2009 Hudson River accident (Pariès, 2011a) or an analysis of the railway system (Wilson et al., 2009), even if trying to consider different levels of abstraction (Cedergren, 2013). Therefore, it is argued that there is a need for conceptual explorations of different modeling perspectives to understand the effects of these tradeoffs in operational activities (Woods et al., 2013, 2009).

For this purpose, consciousness on system's dynamics plays a crucial role to ensure resilient decision-making (Woods, 2006a), and to enhance the sort of diversity that facilitates the emergence of resilience in complex situations, as proved by examples in the obstetric practice (Dekker et al., 2013). To understand these dynamics, it would be possible to sketch resilience according to the different aspects to threat, i.e. the predictability of the threat, its potential to disrupt the system, and its origin. This analysis acknowledges that resilience is situational, based on specific capabilities to manage different typologies of threats (Westrum, 2006), generating a strong consensus about identifying different patterns in adaptive capacity (Woods and Cook, 2006).

It appears evident that resilience is not just about being able to adapt (Woods and Branlat, 2011). As described by the raw definition included in research factor 1 "The need of RE"; Resilience is critically about the appropriateness of stability or change to the requirements of the environment, in terms of planning, enabling or accommodating of change to meet current and future requirements of the operating environment (Sundström and Hollnagel, 2006). It is also about the ability to return to normal functioning when the alerting or unusual conditions are over, shifting among the so-called different states of resilience (Hollnagel and Sundström, 2006). On the same path, the "R4" notion of resilience defines Robustness, Redundancy, Resourcefulness, Rapidity as necessary characteristics at different dimensions, i.e. technical, organizational, social, and economic (Birkland and Waterman, 2009). Even margin/tolerance and flexibility/stiffness are relevant factors contributing to resilience. More specifically, it would be possible to define indicators capable of addressing resilience (transmission capacity, network stability, resource utilization, etc.), as proved by the observation of infrastructure restoration in New York City, following 11 September 2001 attack (Mendoca, 2008). Even coordination (Nyssen, 2011), cross-checking (Patterson et al., 2005) or, more generally, information exchange during the shift changeover process acquires a crucial role for providing timely response to unexpected events, reducing the occurrence of cognitive overloads and contributing to the construction of a common cognitive ground that enhances system resilience (De Carvalho et al., 2012). In terms of societal resilience, it is argued the relevance of moving from a "state of preparedness" to a "state of resilience", i.e. considering not merely the ability to intervene in the event of emergency or disaster, but the concept of anticipation, maintenance and adaptation of activities, regardless of what may happen, with several consequences on how to define the requested knowledge of the system (Hémond and Robert, 2012a,b).

However, in order to make these features operational, it is necessary to anchor resilience in some clearly describable characteristics, transcending occasional associations with local success (McDonald, 2006). In this context, the efforts of Hollnagel to define some essential characteristics of resilience represent a well-established contribution (Hollnagel, 2009). He asserts that resilience can be decomposed into four cornerstones i.e. responding (Pariès, 2011b), monitoring (Øien et al., 2010), learning, and anticipating (Woods, 2011), respectively linked to the actual, critical, potential and factual (Hollnagel, 2011a). These cornerstones appear significant also in terms of describing how people deal successfully with unexpected and unforeseen events, highlighting the difference between work-as-done and work-as-imagined (Rankin et al., 2014a) or even to promote more strategic and tactical control within daily operations (Praetorius and Hollnagel, 2014). The same cornerstones have been discussed in terms of societal resilience, defining a systematic framework to make sense of concrete cases, considering legal, institutional, organizational, and procurement aspects (Becker et al., 2014).

According to an operational perspective, the SCALES framework (Herrera et al., 2014) and the ADAPTER questionnaire (Van Der Beek and Schraagen, 2015), both based on the four cornerstones, offer useful insights as a starting point to more detailed analysis of processes and criticalities.

In accordance with the need to measure resilience (Wreathall, 2009) and its four essential characteristics, Hollnagel proposes the Resilience Analysis Grid (RAG), a questionnaire-based tool to support resilience management (Hollnagel, 2011b) which at the moment is not a widely diffused method, except from some few case studies, (e.g.) in the oil and gas industry (Apneseth et al., 2013). Following a more conceptual perspective, all the four characteristics are related to incident reporting, as proved by a comparison of healthcare and aviation reporting effectiveness (Pasquini et al., 2011). In terms of reaching an effective learning, it becomes relevant to promote means for organizations to shift the focus of event analysis from surface characteristics to deeper patterns and more abstract dimensions (Cook and Woods, 2006), even considering the fruitful possibilities for learning across different high-risk domains (Branlat and Woods, 2010; Grote, 2012).

Other classifications also move from the traditional cornerstones defining, rather than characteristics of resilience, some behaviors of resilient organizations, i.e. anticipation, noticing, planning and adapting (Lay, 2011), recognizing RE useful as an effective way for organizations to make targeted investments to improve resilience to enhance productivity (Woods, 2007). As recently summarized by Woods, it is possible to define four concepts for resilience, i.e. rebound, robustness, graceful extensibility, and adaptability (Woods, 2015), which have been recurring since the introduction of resilience as a critical system property. The idea behind this partition is the impossibility of addressing some general characteristics of resilience, which are valid for each engineering purpose, and the subsequent need to explicitly define which of the four concepts is under study, when describing, measuring or modeling resilience, and that engineering the interactions among the different partitions should be the purpose of further research.

3.2.3. RE for modeling

This research factor summarizes the efforts for developing reliable models and measurements of resilience. The 59 (of 180) contributions range from individual, process and systemic modeling to address the still open gap between the notion of RE and its applicability in real contexts.

The inherent complexity of work activities in current socio-technical systems does not allow adopting linear and simple theory, models and methods (Qureshi et al., 2007), suggesting the development of more complex structures (Madni and Jackson, 2009; Re and Macchi, 2010). RE, acknowledging the limitations of traditional barrier-based approaches, should promote the development of more advanced modeling techniques (Haavik, 2014), as proved by a wide interest in the industrial (Saurin and Carim Júnior, 2011; Zhang and Lin, 2010), even societal (Dolif et al., 2013) and military operation context (Goerger et al., 2014). Furthermore, new safety-oriented models should not only consider advances in managerial, social and political sciences but also epistemological and philosophical areas in order to take advantage of different perspectives of knowledge (Le Coze, 2013). These efforts for RE would be reasonable even on modeling the what Turner labelled the "incubation period" (Turner, 1975), i.e. the period of increasing an unrecognized risk before an accident (Dekker and Pruchnicki, 2014). Similarly, since risk is not fully predictable from failure of components, but should be considered as an emergent property of system interactions, it becomes necessary to model performance to define dynamic sensor signals, (e.g.) based on Bayesian network (Pasman et al., 2013). This approach would replace probability by uncertainty in the definition of risk (Steen and Aven, 2011), a concept proved to be extremely valuable in different high-risk organizations (Grote et al., 2009), especially in the infrastructure system (Francis and Bekera, 2014). It should then be possible to define and monitor failure and marginal boundaries, taking into account the crucial role of several competing factors, as proved in the healthcare (Dermot Williams and Smart, 2010) and transportation context (Da Mata et al., 2007; Gomes et al., 2009). This paradigm shift confirms that improving safety performance relies on the ability of an organization to reflect and dynamically modify its models of risk, pairing the inherent dynamic of everyday processes (Huber et al., 2009).

In this context, system dynamics and causal loop diagrams have been adopted to model resilience in industrial systems, with a simple case study for a storage plant of LPG (Salzano et al., 2014). On a different perspective, the Functional Resonance Analysis Method (FRAM) allows a true multidisciplinary analysis with respect to an accident, taking into account technical as well as human and organizational aspects (Belmonte et al., 2011). Other specific RE models have been developed to perform stochastic ordering of network components (Barker et al., 2013), for logistic network design (Wang and Ip, 2009) or starting from graph theory in a fictional electrified railway network (Johansson and Hassel, 2010). Other approaches also produced good outcomes, for example modeling activities by fuzzy cognitive maps (FCMs) in a petrochemical plant (Azadeh et al., 2014a) and characterizing resilience of Human-Machine Systems (HMS) by traditional surveys (Zieba et al., 2010) or a more systematic approach, such as the Benefit-Cost-Deficit (BCD) model (Kiswendsida et al., 2010).

In the efforts to model resilience, and, thus work activities, and essential aspect is the non-negligible differences between the work-as-imagined (WAI) and the work-as-done (WAD), i.e. the prescribed/procedural work and the actual work (Azadeh and Salehi, 2014). For example, WAD has been proved to be relevant in managing changes, i.e. being resilient, in operational conditions (Morel et al., 2009), in the Vessel Traffic Service (VTS) system (Praetorius et al., 2015), or in a petrochemical company through the adoption of Data Envelopment Analysis (DEA) (Azadeh et al., 2014b). Similar conclusions are derived from studies using the Critical Decision Method, a content-orientated knowledge elicitation technique, adopted to interview practitioners working in the diabetes care context (Ross et al., 2014). On this path, FRAM offers a valuable practical contribution, as emerged from the analysis of a mid-air collision between two aircraft, demonstrating how accidents can emerge from normal variability conditions of everyday work (De Carvalho, 2011).

It is valuable to consider the efforts of researchers aimed at assessing resilience systematically (Shirali et al., 2012b), even by quantitative methods (Shirali et al., 2012a). The first step of these methods should identify sources of resilience and define proper indicators (Dinh et al., 2012; Saurin and Carim Junior, 2012), which should be able to assess elements that contribute to resilience at different levels, organizing them temporarily as a hierarchy (Huber et al., 2012). As an example, Principal Component Analysis (PCA) has been applied to determine the more relevant resilience factors in a process unit (Shirali et al., 2016, 2013), among six resilience dimensions, i.e. top management commitment, just culture, learning culture, awareness and opacity, preparedness and flexibility. Alternatively, a set of domain-specific leading and lagging indicators have been discussed to monitor safety performance for helicopter offshore operations, by the adoption of FRAM (Herrera et al., 2010).

An algorithm based on Adaptive Neuro-Fuzzy Inference System (ANFIS) aims at quantifying job satisfaction in hazardous labs (signal process, chemical, material, robotic, photonic, etc.) with respect to RE factors and HSE and ergonomic concepts (Azadeh et al., 2015). Lastly, a framework for measuring resilience should be extremely valuable if capable of illustrating resilience factors and mechanisms at different levels of analysis (from the individual to operational) (Woods, 2006b), providing measures for improving the overall resilience within and across domains (Furniss et al., 2011a).

3.2.4. RE and improvisation

This research factor includes 12 (of 180) contributions discussing RE as affected by - and affecting - complexity and uncertainty, mainly in terms of improvisation and emergence of resilience, not necessarily in relationship with safe performance.

Managing resilience is tightly coupled with the management of complexity and uncertainty in sociotechnical systems (Robbins et al., 2012). Moving from safety to resilience would require assessing risks more accurately, e.g. taking into account how changes in training, procedures or technology affect system resilience (Dijkstra, 2006).

Researchers discuss the relevance of changes also in terms of the traditional four cornerstones of resilience. Defining additional functions, i.e. recovery and self-monitoring, a systemic resilience model (SyRes) is proposed to deal with four areas: event-based constraints, functional dependencies, adaptive capacity and strategy, allowing a description of dependencies between constraints, functions and strategies (Lundberg and Johansson, 2015). Similarly, Naturalistic Decision

Making (NDM) and other observational studies might help understanding regular patterns in unpredictable work flows (Nemeth et al., 2007). Further, the variety space diagram has been developed as a means to describe the effects of system variability, disturbances and constraints on work performance in different domains, including healthcare, transportation, emergency services and nuclear power (Rankin et al., 2014b). The study develops a strategies framework for practitioners and researchers to report findings, structure cases and make sense of operators' adaptations, defining the adaptation-enabling factors both for sharp-end and blunt-end operators. A different discussion emerges from the analysis of other operating environments with an unpredictable variability and huge differences between the expectations and plans (e.g. the crisis management of the Asian Tsunami of 2004 and the Israel-Lebanon crisis of 2006). In these cases, although role improvisation and adaptation are necessary to get the job done, they inherently bring negative side effects, e.g. reduced quality of work, due to lack of expertise and lack of professional networks, higher workload for the instructor, and inefficiency (Lundberg and Rankin, 2014). About work improvisation, specific strategies of training should be conducted to take on the responsibility of tasks or roles outside one's professional area, developing routines for changes in roles and tasks, improving information sharing (Rankin et al., 2013a) and communication (Longstaff et al., 2013). Nevertheless, when design training procedures, it would be necessary to critically discuss the inherent risk of deciding if an event might deserve investigation and, subsequently, generate lessons learned, in line with the principle of WYLIWYF (What-You-Look-Is-What-You-Find), see (Lundberg et al., 2009).

3.2.5. Reflecting on RE

This research factor includes 22 (of 180), generally recent, contributions. A good summary of the contributions in this factor is provided by the editorial by Nemeth and Herrera (2015) of the special issue dedicated to RE, published in 2015 in the journal Reliability Engineering and System Safety. This editorial, which is also located in this factor, introduces how the special issue is explicitly aimed at gathering works on RE and critically view progress and contributions, both in research and in practice, stimulating further critical research questions (Nemeth and Herrera, 2015).

In this sense, a discussion about one of the four cornerstone of resilience, i.e. monitoring, and the definition of its indicators (Wreathall, 2011) seems relevant. The study criticizes a sharp distinction between leading and lagging indicators and how this distinction is of little use in case of complex systems, with multiple time-scales and levels for control actions. The study also advocates researchers to make that distinction pragmatic rather than theoretical.

About learning, a critical discussion starts from the analysis of the EI-AI B747 crash of 1992 in Amsterdam and of several related accidents that pushed Boeing to redesign a new system for the engine attachment. It is argued how an accident analysis, if performed according to a RE perspective, would allow unnoticed deficiencies, able to enhance system safety (Stoop, 2011). The example can be used as a reference for proving the benefits of a resilience-oriented accident analysis. The four cornerstones have been under observation also in the context of Built Environment, i.e. the physical structures and artefacts that enable and ease specific activities. Acknowledging that only few cases allow the assumption of a stable environment, it is necessary to deal with the environment itself in the definition and assessment of the four cornerstones (Hollnagel, 2014a), updating the static initial definition of the external conditions. Other modeling perspective may express indicators able to quantify resilience, based on the state space model (Siegel and Schraagen, 2014). Nevertheless, starting from an analysis of the Emergency Department, it is observed also how the state-space model or the stress-strain model do not directly include temporal dimension (Wears et al., 2008). The contribution stresses the relevance of understanding patterns of performance degradations and system dynamic behavior during different situations in terms of timing, one of the points addressed in modeling and design of IT equipment in healthcare (Nemeth and Cook, 2007).

More recently, the benefits of RE are conceptually discussed in healthcare, starting from the unacceptable "sorry state of affairs" of patient safety and from the limited success so far (Hollnagel et al., 2013). On this conception, the definition of Resilient Health Care rises as "the ability of the system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required performance under expected and unexpected conditions" (Robson, 2013). The definition of resilience in healthcare drives a reconsideration of the concepts of safety, performance and success. It is even discussed if the growth of resilience may represent a desirable target or not (Amalberti, 2013). In healthcare, a too resilient system may generate negative effects. It might depend on resilience too much to achieve routine success, wasting resource for tractable threats. It might spend too much time and efforts in adapting to not so relevant operations. It might also employ resilience unevenly across organizational levels and thereby create a co-dependency (Wears and Vincent, 2013).

"When resilience does not work" (Komatsubara, 2008) delves into two Japanese cases (in 1999 and 2000); one of a uranium fuel manufacturing company and the other a milk company. Both cases reveal how unavoidable failures can be in a resilient system, in case of lack of the attitude of social responsibility, professionalism or other non-technical skills. The analysis stresses the relevance of balancing trade-offs between efficiency and thoroughness (ETTO) (Hollnagel, 2010), considering the centrality of safety culture. The paper address the need to consider the relation between the (safety) culture, which resilience expects, and resilience. This need emerges also from an explorative research on the rules and safety in light of different disciplines, i.e. psychology, sociology, ethnography, organizational studies, behavioral economics (Hale and Borys, 2013a), in order to encourage a systemic safety culture and endorsing new targets in safety management (Reiman and Rollenhagen, 2011). Similarly, acknowledging that the object of resilience is typically the individual and its ability to adapt and guarantee continuity, a recent critical review on the rational of resilience itself raises ethical questions about the risks of the RE agenda leading to an acceptance of danger at the sharp end (Bergström et al., 2015).

3.2.6. Other contributions

Twenty-four contributions are not mathematically assigned to any factor, according to the outcomes of the factor analysis. Some of these contributions might be assigned to the identified research factors (and thus discussed in the proper section), based on an in-depth reading of the text, even if they have low loadings. On the contrary, five contributions reflect a different aspect of RE, mainly based on supply chain and logistic resilience.

RE might have the potential to deal with the complexity of current logistic systems, coping with the limitations of traditional lean management in global supply networks. RE becomes necessary to guarantee business continuity in dynamic changes, disturbances, disruptions, threats and uncertainty of the market (Bukowski and Feliks, 2015). It has been represented as a multidimensional vector with three aspects, i.e. security, survivability and recovery. This description is the basis for developing simulation packages to measure technical resilience (Bukowski and Feliks, 2012).

According to the interpretation of complex socio-technical systems as networked systems, Information and Communication Technology (ICT) acquires a relevant role even in technical aspects, such as procurement and logistic (Grøtan and Asbjørnslett, 2007). These systems need to select information from their networks using a limited number of protocols, in order to achieve continuity and efficiency. The benefit of RE consists of properly selecting the information, and forward it to the nodes in the network as needed to respond to a variety of conditions. This approach is discussed in several architectures, i.e. supply chain, industrial symbiosis networks, medical and military teams,

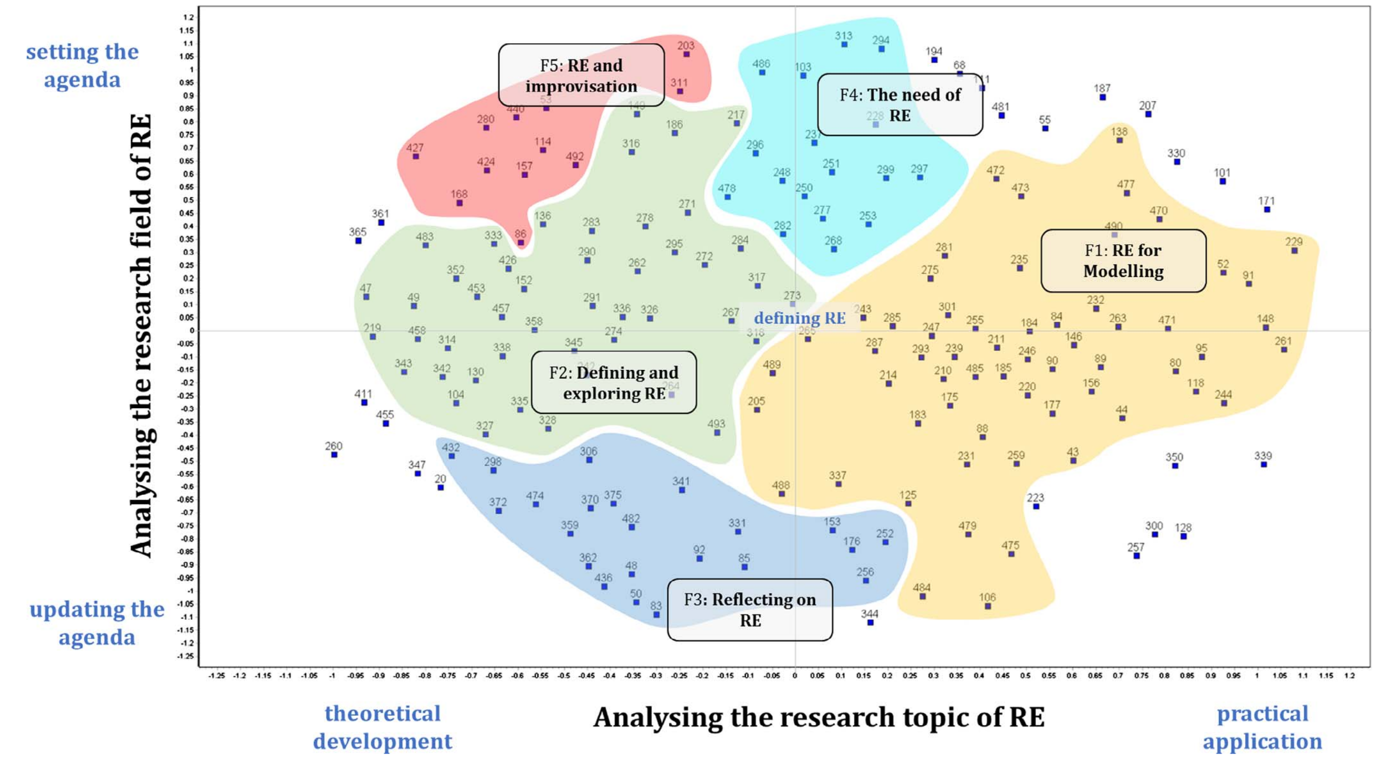

Fig. 4. MDS Map representing the research field of RE in a two-dimensional abstract space.

confirming a still open gap between modeling and real case scenarios (Schraagen, 2015). Resilience emerges also in the financial domain, how proved by the analysis of the global Financial Services System (FSS). Understanding how FSS actually works might generate positive response to unexpected crisis, following the principles of RE. FRAM is used to define a preliminary model of functional interdependencies among functions and agents of the FSS and then set the need of a standardized method to capture and better understand risk in the financial services industry (Sundström and Hollnagel, 2011).

3.3. Findings from multidimensional scaling

Multi-Dimensional Scaling (MDS) shows the conceptual proximity among the contributions in the core dataset, based on Pearson's correlation coefficients. We decide to develop a bi-dimensional MDS map (Fig. 4), where the position of each paper depends on its relationships with the other papers. The higher the number of co-citations, the closer to the center is the contribution, while the distance between two articles defines their degree of similarity on the research field. The resulting relative position of research factors, and a subsequent investigation of the articles based on their positioning, help to name the axes and give a meaningful interpretation of the graphical analysis.

In the MDS map, we acknowledge that the y-axis is a meta-dimension, describing the research stream of RE rather than RE itself. In particular it ranges from "setting the agenda", to "updating the agenda", conceptually moving from the need of a new approach for risk and safety management in complex socio-technical systems, i.e. RE, to the birth of the notion of RE, and then to more recent critical reflections on the field of study. The axis thereby includes a temporal dimension, as discussed in detail in Section 3.4.

The x-axis describes the field of research on RE, ranging from "theoretical development" to "practical application". It is interesting to observe how moving from the left to the center, the contributions reflect more traditional theoretical approaches, generally focused on the four cornerstones of RE, relying on Hollnagel's efforts to characterize resilience (Hollnagel, 2009). Consequently, the left part of the axis generally includes theoretical development, which propose modifications to this reasoning, including other properties necessary to characterize specific systems. The "practical application" generally includes models and methods for resilience, according to different perspectives. Moving from the center to the right, contributions range from individual, team, process and then system modeling, in a progressively wider perspective. It is possible to do some general observations about authoring, too. The famous paper by Leveson (2004), discussing the benefit of a systemic perspective on safety, is located in the upper central part of the MDS map, in the research factor 4 "The need of RE". This is in line with the meaning assigned to the axes, since it was conceived as a pioneering contribution arguing the need of a new perspective, focusing on interactions of system agents. About other relevant authors in the field, it is interesting to note that Hollnagel's contributions generally are located in the central area of the MDS map, confirming that his contributions reflect the traditional definition of RE and can be considered as leading the field, i.e. generally highly co-cited. It is also possible to observe that Woods' recent contributions lie in the left area of the MDS map. This result appears in line with the in-depth analysis of research factor 2 "Defining and exploring RE" (see Section 3.2.2), showing that Woods recently moved from the traditional definition and four cornerstones of resilience to slightly different perspectives. Furthermore, it is possible to observe the multiple contributions of Azadeh, lying in research factor 1 "RE for modeling" moreover generally in close proximity to each other, i.e. with similar co-citations. This result confirms the interest of the author in modeling RE, co-authoring a number of documents tightly related. Lastly, note that the MDS does not offer similar proximity concepts for other relevant authors in the field (e.g. Cook, Dekker, Nemeth, Saurin, Shirali, Wears), i.e. the ones authoring and/or co-authoring multiple contributions included in the core dataset.

3.4. Findings from temporal analysis

The temporal analysis confirms the significance of the research factors and the conceptual bi-dimensional MDS framework. As expected

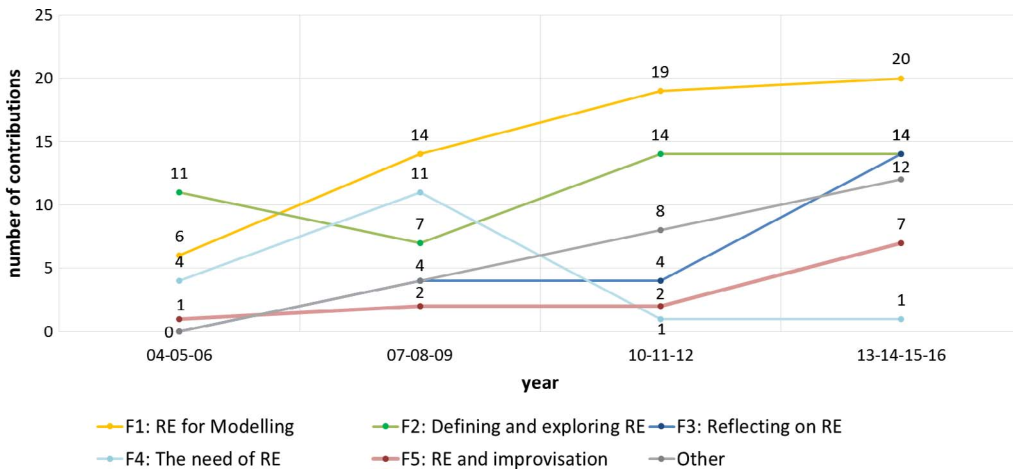

Fig. 5. Temporal evolution of research factors.

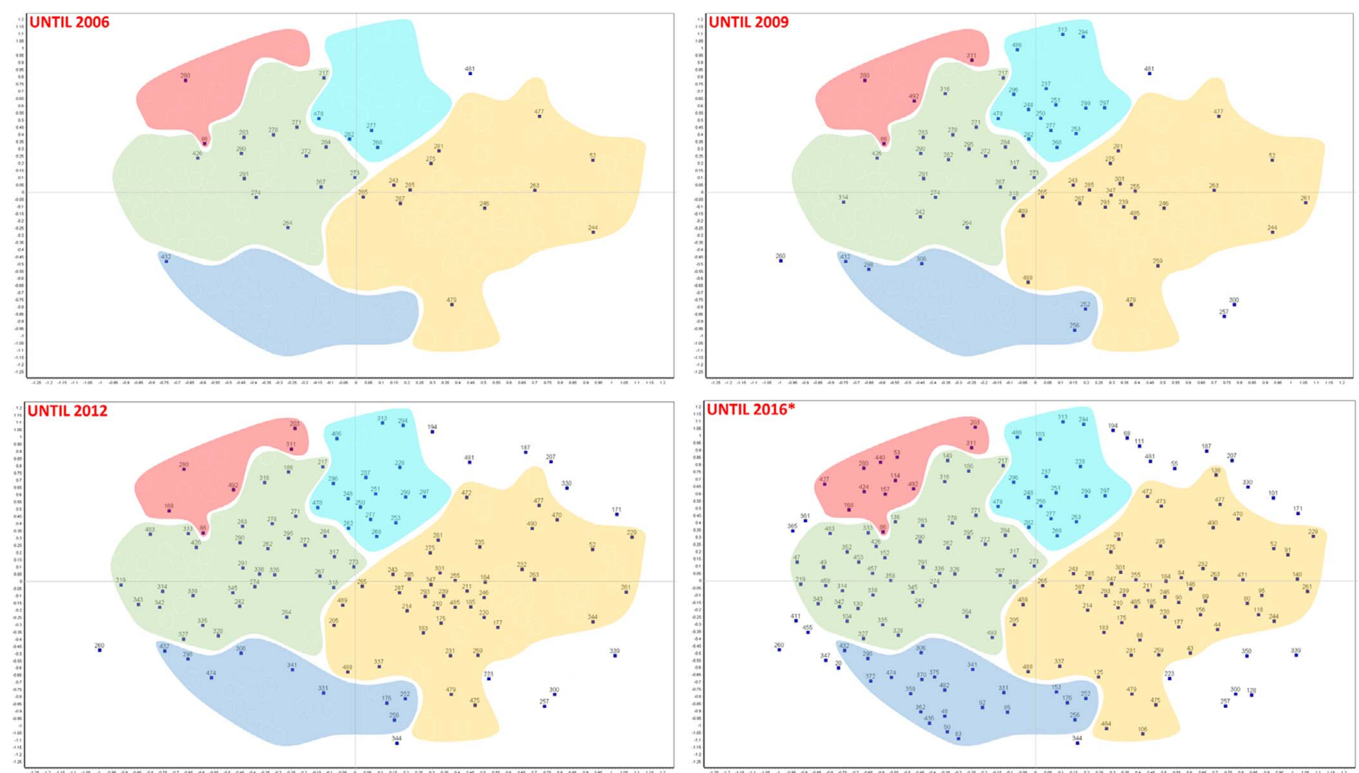

Fig. 6. Temporal evolution of the MDS Map.

(see Fig. 5) the number of papers addressing "The need of RE" (research factor 4) has decreased in recent years, while the increasing trend in the number of publications about "Reflecting on RE" (research factor 3) confirms the increasing interest of recent research on critical reflections. Research factor 1 "RE for Modelling" shows an approximately linear trend, confirming the continuous interest in defining models and methods, as shown in Fig. 6, moving from the center to the right, with approaches progressively characterized by a wider perspective. Research factor 2 "Defining and exploring RE" confirms the trend to move from the traditional definition of RE, as interpreted by the contributions appearing in recent years in the left side of the MDS map in Fig. 6. Furthermore, this analysis shows how research on "RE and improvisation" (research factor 5) is gaining an increasing interest in recent years.

4. Discussion

The number of contributions included in the search confirms an increasing interest in the field of RE. This manuscript explores the research domain by a meta-analysis of co-citations, in order to define the intellectual structure of research. Two multi-variate methodologies, i.e. factor analysis and multi-dimensional scaling, allow for the construction of five research factors as well as their relation to each other. These factors describe the main streams of research and guide the definition of potential future directions.

The traditional consensus (research factor 4: "The need of RE") of defining resilience as the capability of recovering safely and efficiently from abnormal events led to detail the theoretical benefits of RE to manage organizational flexibility and handle uncertainty, i.e. "looking forward" rather than "looking back". Even if RE was intended since the beginning (around 2004) to give systemic instruments to deal with risks proactively, especially if compared with traditional risk methods, the possibility to shift from a "knowledge for knowledge" to practical implications is still a matter of discussion.

4.1. Defining and measuring

Several studies in research factor "Defining and Exploring RE" explore the concept of resilience and the possibility of anchoring it to different aspects, depending on the specific domain and target of the study, e.g. (Dekker, 2006; Wilson et al., 2009; Woods et al., 2013, 2009). The four cornerstones of resilience (anticipating, learning, monitoring and responding) defined by Hollnagel, have contributed to create a wide consensus on resilience structure: resilience is something the system *does* rather than something the system *has*. This concept offers the possibility to develop questionnaire-based indicators (e.g. following the RAG) to qualitatively address system resilience. The RAG is supposed not to be an on-the-shelf method and thus it requires the analyst to adjust its structure, tailoring it to the organization being studied. Hollnagel himself acknowledges that the four cornerstones affect and are affected by the built environment. Furthermore, other recent studies, e.g. (Lay, 2011; Woods, 2007), move from these four cornerstones, addressing the need of explicitly considering other characteristics of resilience, e.g. noticing, planning, adapting, rebound, robustness, and graceful extensibility.

Even if the first concern relates to the possibility of measuring resilience, the core idea of the RAG defines a relevant research direction. Future studies should combine qualitative judgments and quantitative metric (where possible) to define the resilience of the organization at different system levels, considering the couplings and the interactions among different aspects. Since the actual structure misses this perspective, it would be necessary to add a systematic structure, e.g. by adopting a multi-criterial decision making technique such as the Analytic Hierarchy Process (AHP) or Analytic Network Process (ANP) (Saaty, 2008), proved to be effective for obtaining systematic evaluations from different metrics in socio-technical systems (Di Gravio et al., 2015). By the aid of these structures, it would be possible to develop specific semi-quantitative indicators for the specific process, rather than qualitative and general ones, with potential benefits in terms of understandability.

4.2. Modelling

In current socio-technical systems, there is a need for methods and models to understand resilience. The inherent complexity of activities at different levels lead to study how the work is done, understanding and managing the variability, rather than simply reducing it. This approach appears relevant especially in those contexts (aviation, air traffic control, healthcare, nuclear power plants, military operations, etc.) where there are non-negligible interactions among technical, human and organizational aspects. Some institutions (e.g. the Danish Maritime Accident Investigation Board) are currently dealing with this perspective, developing narrative of accidents taking into account the work-as-done as source of failure and successes and acknowledging the inevitable role of variability. Future research should focus on these aspects, developing models to deal with inherent complexity and emergent phenomena, in a wider perspective, e.g. based on STAMP, FRAM or even exploring System Dynamics or fuzzy reasoning. Further studies would need to define a structured and systematic perspective on these models, to make them reproducible and reliable. Furthermore, there would be the possibility to enhance their formulation developing, e.g. Monte Carlo (Patriarca et al., 2017b,c) or Bayesian Network simulations or following more user-friendly formulations (Albery et al., 2016) In addition, multi-layer structures would help gaining multi-perspective understanding of resilience, as recently discussed for FRAM (Patriarca and Bergström, 2017; Patriarca et al., 2017a).

What emerges also from this review in the field of RE is the limited interest in modeling the time dimension, even if it is relevant for many situations that RE aims to describe. Therefore, following a RE perspective, it is necessary to reflect upon the temporal organization in order to engineer resilience into it (Johansson and Lundberg, 2017). For example, in the FRAM, time is considered to have a special status deserving an aspect on its own, but it is suggested to be modelled as any of the other aspects (Hollnagel, 2012). Future research should explore how time may affect the system's functional resonance to identify operational guidelines to use it in future analyses, lacking the open gap in modeling analysis.

As emerged from research in ecology, a resilience-oriented perspective should span local, regional, national and global levels (Doorn, 2017; Liu et al., 2007). For example, linking local and global management is necessary for ensuring urban resilience (Sörensen et al., 2016). Therefore, the commensurable treats of resilience should be explored in order to range from micro, meso to macro levels of analysis, referring to different degrees of aggregation (Bergström and Dekker, 2014).

A still open question for RE can be summarized as follows: How can be RE used over temporal and spatial scales to for improving systems' resilience?

Research in this field could allow for RE to be credible for practical use in several work domains, filling the gap between theoretical and applied research, evolving the traditional attempts already discussed in literature.

4.3. RE and social questions

New studies would need to address other aspects of resilience and their relationships with RE. RE has been widely discussed as a phenomenon per se, or as a safety-related subject. Several perspectives collide on determining the relationship among RE and HRO, which are considered two similar theories. One interesting perspective (Dekker and Woods, 2010) defined RE as the action agenda of HRO with specific treats, i.e. not taking the past success as guarantee of future safety, distancing through differencing, fragmented problem solving, going against common interpretations and decisions, being able to bring in fresh perspectives, knowing the gap between work-as-done and work-as-imagined, and monitoring of safety monitoring (or meta-monitoring). Is this perspective still reasonable, or has RE since then defined itself and its relation to HRO in a more precise manner?

In socio-ecological research, it is argued how humanity needs to become an active steward of planetary boundaries in order to avoid long-term social and environmental disruption (Rockström et al., 2009). Similarly, a systemic perspective based on RE should allow human operators to understand which boundary can be transgressed without jeopardizing its safe operating space, supporting an appropriate distribution of resource and intelligence. In this context, the use of social network can allow for a significant improvement in resilient performance for education (Sigalit et al., 2017) as well as for emergency management, as intended by H2020 project Resolute (Bellini et al., 2017).

Recent contributions address the cases where resilience might not be effective, generating side effects on the system. At this step, future research would need to address these trades-off, according to both an economic perspective, e.g. cost-benefit analysis, social responsibility and professionalism. Similarly, there are still open ethical questions on the acceptance of individual danger, including the follows: Should resilience be seen as people thriving despite of, or because of, risk? Should resilience theory form a basis for moral judgment? How much should resilience be approached as a trait of the individual? (Bergström et al., 2015)

Further studies should also investigate the legal effects of RE. What are the effects of allowing individual and systemic variability in performance? What are the legal implications in case the variability of a specific task, enhanced (or not damped) on purpose, would concur to the accident? How does resilience affect accountability? How can RE be used to create a resilient and mutually supportive work environment to mitigate the effects of second-victimism? (Coughlan et al., 2017; Dekker and Breakey, 2016) More generally, this literature review proves the need for future research on RE to be multi-disciplinary, combining different perspective to achieve a holistic representation of the field.

4.4. On the technique for the analysis

The approach (FA and MDS) in this paper allows a meta-analysis of literature, as proved by some recent applications in other fields (Annarelli and Nonino, 2015; Costantino et al., 2016). In this paper, detailing the methodology, we recognize the need for defining the term *research factor*, linking the mathematical expression of factor from FA to a research dimension, based on a vague inherent consensus in recent literature. We also present a temporal representation of the analysis, showing the benefits of adopting MDS to relate different research factors. Furthermore, the analysis shows the benefits of adopting co-citations and FA: not restricting the initial dataset, using very limited subjective assumptions; filtering the contributions systematically; grouping contributions by some strong conceptual relations.

However, in rare cases, we included some contribution in a factor changing the outcome of the FA, after reading the full text. Even if this problem is limited by considering co-citations rather than citations, it confirms the adoption of FA and MDS as supporting tools for a meta-analysis of literature, rather than an on-the-shelf method. The outcomes of this study confirm the relevance of the approach, even considering the significance of the research factors in a temporal perspective. Additional research on the field may reproduce this approach in the next years, to evaluate the changes in the research domains.

5. Conclusions

This paper describes the research field of RE using a meta-analysis approach. The outcomes of the study are defined in terms of five research areas, which in combination with a temporal analysis, allow for critical reflections on the field. We can conclude that the original confused consensus of RE, which was defined in Söderköping in 2004, has nowadays been clarified by several contributions exploring different aspects of the field. Over the years, the positioning has changed; moving from a safety-related perspective towards a resilience per se representation. Based on this reflection, we can also confirm the need for RE in dealing with the system specificity, focusing on system functioning, work-as-done, and inherent features of the system. The focus of research also shifted recently from defining to modeling, in order to understand, represent, compare, and eventually, measure resilience. Regardless the high number of contributions dealing with these modeling aspects, this specific research stream still appears to be underdeveloped, at least in the sense of obtaining practical and operational implications based on the outcomes of the analysis. Furthermore, additional questions remain open about the interactions of RE with accountability, ethical, and legal aspects of work.

Appendix A. The core dataset of the article

ID	Authors, YEAR	Title	Source
478	Leveson (2004)	A new accident model for engineering safer systems	Safety Science
264	Patterson et al. (2005)	Collaborative cross-checking to enhance resilience	Proceedings of the Human Factors and Ergonomics Society
284	Amalberti (2006)	Optimum system safety and optimum system resilience: agonistic or antagonistic concepts?	Resilience Engineering: Concepts and Precepts
277	Axelsson (2006)	Structure for management of weak and diffuse signals	Resilience Engineering: Concepts and Precepts
281	Cook and Nemeth (2006)	Taking things in one's stride: cognitive features of two resilient performances	Resilience Engineering: Concepts and Precepts
290	Cook and Woods (2006)	Distancing through differencing: an obstacle to organizational learning following accidents	Resilience Engineering: Concepts and Precepts
273	Dekker (2006)	Resilience engineering: chronicling the emergence of confused consensus	Resilience Engineering: Concepts and Precepts
280	Dijkstra (2006)	Safety management in airlines	Resilience Engineering: Concepts and Precepts
282	Flin (2006)	Erosion of managerial resilience: from vasa to Nasa	Resilience Engineering: Concepts and Precepts
268	Hale and Heijer (2006a)	Defining resilience	Resilience Engineering: Concepts and Precepts
275	Hale and Heijer (2006b)	Is resilience really necessary? The case of railways	Resilience Engineering: Concepts and Precepts
287	Hale et al. (2006)	Auditing resilience in risk control and safety management systems	Resilience Engineering: Concepts and Precepts
291	Hollnagel and Sundström (2006)	States of resilience	Resilience Engineering: Concepts and Precepts
265	Hollnagel (2006)	Resilience: the challenge of the unstable	Resilience Engineering: Concepts and Precepts
274	Leveson et al. (2006)	Engineering resilience into safety-critical systems	Resilience Engineering: Concepts and Precepts
278	McDonald (2006)	Organizational resilience and industrial risk	Resilience Engineering: Concepts and Precepts
283	Sundström and Hollnagel (2006)	Learning how to create resilience in business systems	Resilience Engineering: Concepts and Precepts
271	Westrum (2006)	A typology of resilience situations	Resilience Engineering: Concepts and Precepts
272	Woods and Cook (2006)	Incidents-markers of resilience or brittleness?	Resilience Engineering: Concepts and Precepts
267	Woods (2006a)	Essential characteristics of resilience	Resilience Engineering: Concepts and Precepts
263	Woods (2006b)	Engineering organizational resilience to enhance safety: A progress report on the emerging field of resilience engineering	Proceedings of the Human Factors and Ergonomics Society
285	Wreathall (2006)	Properties of resilient organizations: an initial view	Resilience Engineering: Concepts and Precepts

255	Da Mata et al. (2007)	Application of resilience engineering on safety in offshore helicopter transportation	Proceedings of the 2006 IEEE Systems and Information Engineering Design Symposium, SIEDS'06
261	García-Serna et al. (2007)	New trends for design towards sustainability in chemical engineering: Green engineering	Chemical Engineering Journal
257	Grøtan and Asbjørnslett (2007)	ICT in resilient global logistics	Proceedings of the European Safety and Reliability Conference 2007, ESREL 2007 - Risk, Reliability and Societal Safety
260	Joyekurun (2007)	Weather hazards in ATM: Designing for resilient operations	ACM International Conference Proceeding Series
489	Miller and Xiao (2007)	Multi-level strategies to achieve resilience for an organization operating at capacity: A case study at a trauma center	Cognition, Technology and Work
256	Nemeth and Cook (2007)	Healthcare IT as a source of resilience	Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics
492	Nemeth et al. (2007)	Regularly irregular: How groups reconcile cross-cutting agendas and demand in healthcare	Cognition, Technology and Work
259	Qureshi et al. (2007)	Modeling industrial safety: A sociotechnical systems perspective	IEEM 2007: 2007 IEEE International Conference on Industrial Engineering and Engineering Management
486	Wears et al. (2007)	Emergency department status boards: User-evolved artefacts for inter- and intra-group coordination	Cognition, Technology and Work
262	Woods (2007)	Proactive safety management	Industrial Engineer
251	Back et al. (2008)	Resilience markers for safer systems and organizations	Lecture Notes in Computer Science including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)
252	Benn et al. (2008)	Improving performance reliability in surgical systems	Cognition, Technology and Work
250	Chialastri and Pozzi (2008)	Resilience in the aviation system	Lecture Notes in Computer Science including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)
301	Dekker et al. (2008)	Crew resilience and simulator training in aviation	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
296	Epstein (2008)	Unexampled events, resilience, and PRA	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
299	Grote (2008)	Rules management as source for loose coupling in high-risk systems	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
297	Hollnagel (2008a)	Safety management - looking back or looking forward	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
311	Hollnagel (2008b)	Investigation as an impediment to learning	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
481	Hollnagel (2008c)	Risk + barriers = safety?	Safety Science
298	Komatsubara (2008)	When resilience does not work	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
294	Le Coze and Dupré (2008)	The need for “translators” and for new models of safety	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
295	Mendoca (2008)	Measures of resilient performance	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
300	Nathanale and Marmaras (2008)	Work practices and prescription: a key issue for organizational resilience	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
313	Nemeth (2008a)	The ability to adapt	Resilience Engineering Perspective Volume 2 - Preparation and restoration
293	Nemeth (2008b)	Resilience engineering: the birth of a notion	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
253	Sheridan (2008)	Risk, human error, and system resilience: Fundamental ideas	Human Factors
306	Wears et al. (2008)	Resilience in the emergency department	Resilience Engineering Perspective Volume 1 -Remaining sensitive to the possibility of failure
314	Birkland and Waterman (2009)	The politics and policy challenges of disaster resilience	Resilience Engineering Perspective Volume 2 - Preparation and restoration
237	Boring (2009)	Reconciling resilience with reliability: The complementary nature of resilience engineering and human reliability analysis	Proceedings of the Human Factors and Ergonomics Society
248	Borys et al. (2009)	The fifth age of safety: The adaptive age	Journal of Health Services Research and Policy
239	Costella et al. (2009)	A method for assessing health and safety management systems from the resilience engineering perspective	Safety Science
247	Gomes et al. (2009)	Resilience and brittleness in the offshore helicopter transportation system: The identification of constraints and sacrifice decisions in pilots' work	Reliability Engineering and System Safety

488	Grote et al. (2009)	Coordination in high-risk organizations: The need for flexible routines	Cognition, Technology and Work
318	Hollnagel (2009)	The four cornerstones of resilience engineering	Resilience Engineering Perspective Volume 2 - Preparation and restoration
243	Madni and Jackson (2009)	Towards a conceptual framework for resilience engineering	IEEE Systems Journal
485	Morel et al. (2009)	How good micro/macro ergonomics may improve resilience, but not necessarily safety	Safety Science
246	Pasman (2009)	Learning from organizational incidents: Resilience engineering for high-risk process environments	Process Safety Progress
244	Wang and Ip (2009)	Evaluation and analysis of logistic network resilience with application to aircraft servicing	IEEE Systems Journal
477	Whitson and Ramirez-Marquez (2009)	Resiliency as a component importance measure in network reliability	Reliability Engineering and System Safety
242	Wilson et al. (2009)	Understanding safety and production risks in rail engineering planning and protection	Ergonomics
316	Woods et al. (2009)	An initial comparison of selected models of system resilience	Resilience Engineering Perspective Volume 2 - Preparation and restoration
317	Wreathall (2009)	Measuring resilience	Resilience Engineering Perspective Volume 2 - Preparation and restoration
219	Branlat and Woods (2010)	How do systems manage their adaptive capacity to successfully handle disruptions? A resilience engineering perspective	AAAI Fall Symposium - Technical Report
223	Dekker and Woods (2010)	The High Reliability Organization Perspective	Human Factors in Aviation
228	Erol et al. (2010)	Perspectives on measuring enterprise resilience	2010 IEEE International Systems Conference Proceedings, SysCon 2010
220	Herrera et al. (2010)	Proposing safety performance indicators for helicopter offshore on the Norwegian Continental Shelf	10th International Conference on Probabilistic Safety Assessment and Management 2010, PSAM 2010
470	Johansson and Hassel (2010)	An approach for modeling interdependent infrastructures in the context of vulnerability analysis	Reliability Engineering and System Safety
235	Kiswendsida et al. (2010)	How to learn from the resilience of Human-Machine Systems?	IFAC Proceedings Volumes IFAC-Papers Online)
217	Øien et al. (2010)	Development of early warning indicators based on Resilience Engineering	10th International Conference on Probabilistic Safety Assessment and Management 2010, PSAM 2010
231	Re and Macchi (2010)	From cognitive reliability to competence? An evolving approach to human factors and safety	Cognition, Technology and Work
229	Williams and Smart (2010)	Patient safety: a casualty of target success?	International Journal of Public Sector Management
232	Zhang and Lin (2010)	On the principle of design of resilient systems - application to enterprise information systems	Enterprise Information Systems
490	Zieba et al. (2010)	Principles of adjustable autonomy: A framework for resilient human-machine cooperation	Cognition, Technology and Work
475	Belmonte et al. (2011)	Interdisciplinary safety analysis of complex socio-technological systems based on the functional resonance accident model: An application to railway traffic supervision	Reliability Engineering and System Safety
330	Bergström et al. (2011)	Training organizational resilience in escalating situations	Resilience Engineering in Practice: A guidebook
205	De Carvalho (2011)	The use of Functional Resonance Analysis Method FRAM) in a mid-air collision to understand some characteristics of the air traffic management system resilience	Reliability Engineering and System Safety
337	Ferreira et al. (2011)	Measuring resilience in the planning of rail engineering work	Resilience Engineering in Practice: A guidebook
214	Furniss et al. (2011a)	A resilience markers framework for small teams	Reliability Engineering and System Safety
207	Furniss et al. (2011b)	Confessions from a Grounded Theory PhD: Experiences and lessons learnt	Conference on Human Factors in Computing Systems - Proceedings
326	Hollnagel (2011a)	Prologue: the scope of resilience engineering	Resilience Engineering in Practice: A guidebook
345	Hollnagel (2011b)	Epilogue: RAG- the resilience analysis grid	Resilience Engineering in Practice: A guidebook
333	Lay (2011)	Practices for noticing and dealing with the critical. A case study from maintenance of power plants	Resilience Engineering in Practice: A guidebook
203	Ng et al. (2011)	High reliability organization: A literature review	Annual International Conference of the American Society for Engineering Management 2011, ASEM 2011

342	Nyssen (2011)	From myopic coordination to resilience in socio-technical systems. A case study in a hospital	Resilience Engineering in Practice: A guidebook
328	Pariès (2011a)	Lessons from the Hudson	Resilience Engineering in Practice: A guidebook
327	Pariès (2011b)	Resilience and the ability to respond	Resilience Engineering in Practice: A guidebook
343	Pasquini et al. (2011)	Requisites for successful incident reporting in resilient organizations	Resilience Engineering in Practice: A guidebook
474	Reiman and Rollenhagen (2011)	Human and organizational biases affecting the management of safety	Reliability Engineering and System Safety
210	Saurin and Carim Júnior (2011)	Evaluation and improvement of a method for assessing HSMS from the resilience engineering perspective: A case study of an electricity distributor	Safety Science
211	Steen and Aven (2011)	A risk perspective suitable for resilience engineering	Safety Science
341	Stoop (2011)	No facts, no glory	Resilience Engineering in Practice: A guidebook
339	Sundström and Hollnagel (2011)	The importance of functional interdependencies in financial services systems	Resilience Engineering in Practice: A guidebook
338	Tjørhom and Aase (2011)	The art of balance: using upward resilience traits to deal with conflicting goals	Resilience Engineering in Practice: A guidebook
336	Woods and Branlat (2011)	Basic patterns in how adaptive systems fail	Resilience Engineering in Practice: A guidebook
335	Woods (2011)	Resilience and the ability to anticipate	Resilience Engineering in Practice: A guidebook
331	Wreathall (2011)	Monitoring - a critical ability in resilience engineering	Resilience Engineering in Practice: A guidebook
344	Zimmermann et al. (2011)	Is the aviation industry ready for resilience? Mapping human factors assumptions across the aviation sector	Resilience Engineering in Practice: A guidebook
194	Bukowski and Feliks (2012)	Multi-dimensional concept of supply chain resilience	Congress Proceedings - CLC 2012: Carpathian Logistics Congress
186	De Carvalho et al. (2012)	Analysis of information exchange activities to actualize and validate situation awareness during shift changeovers in nuclear power plants	Human Factors and Ergonomics In Manufacturing
184	Dinh et al. (2012)	Resilience engineering of industrial processes: Principles and contributing factors	Journal of Loss Prevention in the Process Industries
187	Grøtan and Størseth (2012)	Integrated safety management based on organizational resilience	Advances in Safety, Reliability and Risk Management - Proceedings of the European Safety and Reliability Conference, ESREL 2011
483	Grote (2012)	Safety management in different high-risk domains - All the same?	Safety Science
171	Hémond and Robert (2012a,b)	Preparedness: The state of the art and future prospects	Disaster Prevention and Management: An International Journal
472	Henry and Emmanuel Ramirez-Marquez (2012)	Generic metrics and quantitative approaches for system resilience as a function of time	Reliability Engineering and System Safety
177	Huber et al. (2012)	A program to support the construction and evaluation of resilience indicators	Work
168	Robbins et al. (2012)	Resilience engineering: Learning to embrace failure	Communications of the ACM
175	Saurin and Carim Junior (2012)	A framework for identifying and analyzing sources of resilience and brittleness: A case study of two air taxi carriers	International Journal of Industrial Ergonomics
183	Shirali et al. (2012a)	Assessing resilience engineering based on safety culture and managerial factors	Process Safety Progress
185	Shirali et al. (2012b)	Challenges in building resilience engineering RE) and adaptive capacity: A field study in a chemical plant	Process Safety and Environmental Protection
176	Wachs et al. (2012)	Identification of non-technical skills from the resilience engineering perspective: A case study of an electricity distributor	Work
362	Amalberti (2013)	Resilience and safety in health care: Marriage or divorce?	Resilient Healthcare
436	Anderson et al. (2013)	Resilience engineering in healthcare: moving from epistemology to theory and practice	5th REA symposium proceedings
136	Apneseth et al. (2013)	Measuring resilience in integrated planning	Oil and Gas, Technology and Humans: Assessing the Human Factors of Technological Change
473	Barker et al. (2013)	Resilience-based network component importance measures	Reliability Engineering and System Safety
365	Braithwaite et al. (2013)	Health care as a complex adaptive system	Resilient Healthcare

149	Cedergren (2013)	Designing resilient infrastructure systems: A case study of decision-making challenges in railway tunnel projects	Journal of Risk Research
361	Cook (2013)	Resilience, the second story, and progress on patient safety	Resilient Healthcare
493	Dekker et al. (2013)	Complicated, complex, and compliant: Best practice in obstetrics	Cognition, Technology and Work
156	Dolif et al. (2013)	Resilience and brittleness in the ALERTA RIO system: A field study about the decision-making of forecasters	Natural Hazards
372	Fairbanks et al. (2013)	Separating resilience from success	Resilient Healthcare
482	Hale and Borys (2013a)	Working to rule, or working safely? Part 1: A state of the art review	Safety Science
484	Hale and Borys (2013b)	Working to rule or working safely? Part 2: The management of safety rules and procedures	Safety Science
130	Hegde et al. (2013)	A bottom-up approach to understanding the efficacy of event-analysis in healthcare: Paradigm shift from safety to resilience engineering	Proceedings of the Human Factors and Ergonomics Society
359	Hollnagel et al. (2013)	Preface: On the need for resilience in health care	Resilient Healthcare
138	Le Coze (2013)	New models for new times. An anti-dualist move	Safety Science
424	Longstaff et al. (2013)	Translating resilience: a framework to enhance communication and implementation	5th REA symposium proceedings
440	Lundberg and Woltjer (2013)	The resilience analysis matrix RAM): visualizing functional dependencies in complex socio-technical systems	5th REA symposium proceedings
148	Pasman et al. (2013)	A holistic approach to control process safety risks: Possible ways forward	Reliability Engineering and System Safety
457	Woltjer et al. (2013)	Resilience in ATM operations: incorporating robustness and resilience in safety assessment	5th REA symposium proceedings
157	Rankin et al. (2013a)	A case study of factor influencing role improvisation in crisis response teams	Cognition, Technology and Work
458	Rankin et al. (2013b)	"Staying ahead of the aircraft" and managing surprise in modern airliners	5th REA symposium proceedings
375	Robson (2013)	Resilient health care	Resilient Healthcare
153	Saurin et al. (2013)	Identification of non-technical skills from the resilience engineering perspective: A case study of an electricity distributor	Safety Science
146	Shirali et al. (2013)	A new method for quantitative assessment of resilience engineering by PCA and NT approach: A case study in a process industry	Reliability Engineering and System Safety
453	Walker et al. (2013)	Reducing the potential for cascade: recognizing and mitigating situations that threaten business viability	5th REA symposium proceedings
432	Wears and Morrison (2013)	Levels of resilience: moving from resilience to resilience engineering	5th REA symposium proceedings
370	Wears and Vincent (2013)	Relying on resilience: Too much of a good thing?	Resilient Healthcare
152	Woltjer et al. (2013)	Resilience engineering in air traffic management: Increasing resilience through safety assessment in SESAR	SIDs 2013 - Proceedings of the SESAR Innovation Days
426	Woods et al. (2013)	The stress-strain model of resilience operationalizes the four cornerstones of resilience engineering	5th REA symposium proceedings
84	Azadeh and Salehi (2014)	Modeling and optimizing efficiency gap between managers and operators in integrated resilient systems: The case of a petrochemical plant	Process Safety and Environmental Protection
89	Azadeh et al. (2014a)	Assessment of resilience engineering factors in high-risk environments by fuzzy cognitive maps: A petrochemical plant	Safety Science
90	Azadeh et al. (2014b)	Performance evaluation of integrated resilience engineering factors by data envelopment analysis: The case of a petrochemical plant	Process Safety and Environmental Protection
347	Becker et al. (2014)	An emergent means to assurgent ends: societal resilience for safety and sustainability	Becoming Resilient
427	Bracco et al. (2014)	Turning variability into emergent safety: the resilience matrix for providing strong responses to weak signals	5th REA symposium proceedings
125	Dekker and Pruchnicki (2014)	Drifting into failure: theorising the dynamics of disaster incubation	Theoretical Issues in Ergonomics Science
83	Fairbanks et al. (2014)	Resilience and resilience engineering in health care	Joint Commission Journal on Quality and Patient Safety

471	Francis and Bekera (2014)	A metric and frameworks for resilience analysis of engineered and infrastructure systems	Reliability Engineering and System Safety
118	Goerger et al. (2014)	Engineered resilient systems: A DoD perspective	Procedia Computer Science
128	Grøtan (2014)	Hunting high and low for resilience: Sensitization from the contextual shadows of compliance	Safety, Reliability and Risk Analysis: Beyond the Horizon - Proceedings of the European Safety and Reliability Conference, ESREL 2013
106	Haavik (2014)	On the ontology of safety	Safety Science
101	Herrera et al. (2014)	The SCALES framework for identifying and extracting resilience related indicators: Preliminary findings of a go-around case study	SIDs 2014 - Proceedings of the SESAR Innovation Days
85	Hollnagel (2014a)	Resilience engineering and the built environment	Building Research and Information
358	Hollnagel (2014b)	Becoming resilient	Becoming Resilient
103	Hopkins (2014)	Issues in safety science	Safety Science
350	Kitamura (2014)	Resilience engineering for safety of nuclear power plant with accountability	Becoming Resilient
114	Lundberg and Rankin (2014)	Resilience and vulnerability of small flexible crisis response teams: Implications for training and preparation	Cognition, Technology and Work
104	Praetorius and Hollnagel (2014)	Control and resilience within the maritime traffic management domain	Journal of Cognitive Engineering and Decision Making
352	Rankin et al. (2014a)	A framework for learning from adaptive performance	Becoming Resilient
86	Rankin et al. (2014b)	Resilience in everyday operations: A framework for analyzing adaptations in high-risk work	Journal of Cognitive Engineering and Decision Making
111	Reniers et al. (2014)	Resilience of chemical industrial areas through attenuation-based security	Reliability Engineering and System Safety
88	Ross et al. (2014)	Inpatient diabetes care: Complexity, resilience and quality of care	Cognition, Technology and Work
95	Salzano et al. (2014)	The application of System Dynamics to industrial plants in the perspective of Process Resilience Engineering	Chemical Engineering Transactions
91	Saurin and Sanches (2014)	Lean construction and resilience engineering: Complementary perspectives of variability	22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014
92	Saurin et al. (2014)	The design of scenario-based training from the resilience engineering perspective: A study with grid electricians	Accident Analysis and Prevention
455	Siegel and Schraagen (2014)	Developing resilience signals for the Dutch railway system	5th REA symposium proceedings
43	Azadeh et al. (2015)	A unique algorithm for the assessment and improvement of job satisfaction by resilience engineering: Hazardous labs	International Journal of Industrial Ergonomics
50	Bergström et al. (2015)	On the rationale of resilience in the domain of safety: A literature review	Reliability Engineering and System Safety
68	Bukowski and Feliks (2015)	A unified model of systems dependability and process continuity for complex supply chains	Safety and Reliability: Methodology and Applications - Proceedings of the European Safety and Reliability Conference, ESREL 2014
44	Grabowski and Roberts (2015)	Reliability seeking virtual organizations: Challenges for high reliability organizations and resilience engineering	Safety Science
53	Lundberg and Johansson (2015)	Systemic resilience model	Reliability Engineering and System Safety
48	Nemeth and Herrera (2015)	Building change: Resilience Engineering after ten years	Reliability Engineering and System Safety
80	Okoh and Haugen (2015)	Improving the robustness and resilience properties of maintenance	Process Safety and Environmental Protection
52	Praetorius et al. (2015)	Modeling Vessel Traffic Service to understand resilience in everyday operations	Reliability Engineering and System Safety
411	Schraagen (2015)	Resilience and networks	6th REA symposium proceedings
55	Van Der Beek and Schraagen (2015)	ADAPTER: Analyzing and developing adaptability and performance in teams to enhance resilience	Reliability Engineering and System Safety
49	Woltjer et al. (2015)	Towards understanding work-as-done in air traffic management safety assessment and design	Reliability Engineering and System Safety
47	Woods (2015)	Four concepts for resilience and the implications for the future of resilience engineering	Reliability Engineering and System Safety
20	Shirali et al. (2016)	Assessment of resilience engineering factors based on system properties in a process industry	Cognition, Technology and Work

References

Albery, S., Borys, D., Tepe, S., 2016. Advantages for risk assessment: Evaluating learnings from question sets inspired by the FRAM and the risk matrix in a manufacturing environment. Saf. Sci. 89, 180–189. http://dx.doi.org/10.1016/j.ssci.2016.06.005.

Amalberti, R., 2013. Resilience and safety in health care: Marriage or divorce? In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), Resilient Health Care, pp. 27–38.

Amalberti, R., 2006. Optimum system safety and optimum system resilience: Agonistic or antagonistic concepts? In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 253–272.

Anderson, J.E., Ross, A.J., Jaye, P., 2013. Resilience engineering in healthcare: moving from epistemology to theory and practice. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25 – 27 June 2013.

Annarelli, A., Nonino, F., 2015. Strategic and operational management of organizational resilience: Current state of research and future directions. Omega 1–18. http://dx.doi.org/10.1016/j.omega.2015.08.004.

Apneseth, K., Wahl, A.M., Hollnagel, E., 2013. Measuring resilience in integrated planning. In: Albrechtsen, E., Besnard, D. (Eds.), Oil and Gas, Technology and Humans: Assessing the Human Factors of Technological Change. Health, Safety and Environment (HSE) Competence Centre, Statoil, Norway.

Axelsson, L., 2006. Structure for management of weak and diffuse signals. In: Hollnagel, E., Woods, D.D., Leveson, W. (Eds.), Resilience Engineering: Concepts and Precepts, pp. 151–154.

Azadeh, A., Alizadeh Bonab, N., Salehi, V., Zarrin, M., 2015. A unique algorithm for the assessment and improvement of job satisfaction by resilience engineering: Hazardous labs. Int. J. Ind. Ergon. 49, 68–77. http://dx.doi.org/10.1016/j.ergon.2015.06.002.

Azadeh, A., Salehi, V., 2014. Modeling and optimizing efficiency gap between managers and operators in integrated resilient systems: The case of a petrochemical plant. Process Saf. Environ. Prot. 92.

Azadeh, A., Salehi, V., Arvan, M., Dolatkhah, M., 2014a. Assessment of resilience engineering factors in high-risk environments by fuzzy cognitive maps: A petrochemical plant. Saf. Sci. 68, 99–107. http://dx.doi.org/10.1016/j.ssci.2014.03.004.

Azadeh, A., Salehi, V., Ashjari, B., Saberi, M., 2014b. Performance evaluation of integrated resilience engineering factors by data envelopment analysis: The case of a petrochemical plant. Process Saf. Environ. Prot. 92, 231–241. http://dx.doi.org/10.1016/j.psep.2013.03.002.

Back, J., Furniss, D., Hildebrandt, M., Blandford, A., 2008. Resilience markers for safer systems and organisations. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). http://dx.doi.org/10.1007/978-3-540-87698-4_11.

Bakx, G.C.H., Nyce, J.M., 2015. Risk and safety in large-scale socio-technological (military) systems: a literature review. J. Risk Res. 9877, 19. http://dx.doi.org/10.1080/13669877.2015.1071867.

Barker, K., Ramirez-Marquez, J.E., Rocco, C.M., 2013. Resilience-based network component importance measures. Reliab. Eng. Syst. Saf. 117. http://dx.doi.org/10.1016/j.ress.2013.03.012.

Becker, P., Abrahamsson, M., Tehler, H., 2014. An emergent means to assurgent ends: societal resilience for safety and sustainability. In: Nemeth, C.P., Hollnagel, E. (Eds.), Becoming Resilient. Ashgate Publishing, Ltd, pp. 1–12.

Bellini, E., Nesi, P., Coconea, L., Gaitanidou, E., Ferreira, P., Simoes, A., Candelieri, A., 2017. Towards resilience operationalization in urban transport system: The RESOLUTE project approach. In: Risk, Reliability and Safety: Innovating Theory and Practice - Proceedings of the 26th European Safety and Reliability Conference, ESREL 2016.

Belmonte, F., Schön, W., Heurley, L., Capel, R., 2011. Interdisciplinary safety analysis of complex socio-technological systems based on the functional resonance accident model: An application to railway traffic supervisio. Reliab. Eng. Syst. Saf. 96. http://dx.doi.org/10.1016/j.ress.2010.09.006.

Benn, J., Healey, A.N., Hollnagel, E., 2008. Improving performance reliability in surgical systems. Cogn. Technol. Work 10, 323–333. http://dx.doi.org/10.1007/s10111-007-0092-x.

Bergström, J., Dahlström, N., Dekker, S., Petersen, K., 2011. Training organisational resilience in escalating situations. In: Hollnagel, E., Pariès, J., Woods, D.D, Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing, Ltd, pp. 45–56.

Bergström, J., Dekker, S.W.A., 2014. Bridging the macro and the micro by considering the meso: Reflections on the fractal nature of resilience. Ecol. Soc. 19. http://dx.doi.org/10.5751/ES-06956-190422.

Bergström, J., Van Winsen, R., Henriqson, E., 2015. On the rationale of resilience in the domain of safety: A literature review. Reliab. Eng. Syst. Saf. 141, 131–141. http://dx.doi.org/10.1016/j.ress.2015.03.008.

Birkland, T.A., Waterman, S., 2009. The politics and policy challenges of disaster resilience. In: Nemeth, C.P., Hollnagel, E., Dekker, S. (Eds.), Resilience Engineering Perspectives. Volume 2: Preparation and Restoration. Ashgate Publishing, Ltd, pp. 15–38.

Boring, R.L., 2009. Reconciling resilience with reliability: The complementary nature of resilience engineering and human reliability analysis. In: Proceedings of the Human Factors and Ergonomics Society. Sandia National Laboratories, Albuquerque, NM, United States, pp. 1589–1593.

Borys, D., Else, D., Leggett, S., 2009. The fifth age of safety: The adaptive age. J. Heal. Serv. Res. Policy 1, 19–27.

Bracco, F., Piccinno, T.F., Dorigatti, G., 2014. Turning variability into emergent safety: The resilience matrix for providing strong responses to weak signals. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25–27 June 2013, pp. 23–27.

Braithwaite, J., Clay-Williams, R., Nugus, P., Plumb, J., 2013. Health care as a complex adaptive system. In: Hollnagel, E., Braithwaite, J., Wears, R.L (Eds.), Resilient Health Care. Ashgate Publishing, Ltd, pp. 57–76.

Branlat, M., Woods, D.D., 2010. How do systems manage their adaptive capacity to successfully handle disruptions? A resilience engineering perspective. In: AAAI Fall Symposium - Technical Report.

Bukowski, L.A., Feliks, J., 2015. A unified model of systems dependability and process continuity for complex supply chains. In: Safety and Reliability: Methodology and Applications - Proceedings of the European Safety and Reliability Conference, ESREL 2014.

Bukowski, L.A., Feliks, J., 2012. Multi-dimensional concept of supply chain resilience. In: Congress Proceedings - CLC 2012: Carpathian Logistics Congress.

Carayon, P., Hancock, P., Leveson, N., Noy, I., Sznelwar, L., van Hootegem, G., 2015. Advancing a sociotechnical systems approach to workplace safety – developing the conceptual framework. Ergonomics 58, 548–564. http://dx.doi.org/10.1080/00140139.2015.1015623.

Cedergren, A., 2013. Designing resilient infrastructure systems: a case study of decision-making challenges in railway tunnel projects. J. Risk Res. 16, 563–582. http://dx.doi.org/10.1080/13669877.2012.726241.

Chialastri, A., Pozzi, S., 2008. Resilience in the aviation system. Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics). doi: http://dx.doi.org/10.1007/978-3-540-87698-4_10.

Cook, R., 2013. Resilience, the second story, and progress on patient safety. In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), Resilient Health Care. Ashgate Publishing, Ltd, pp. 19–26.

Cook, R.I., Nemeth, C., 2006. Taking thigs in one's stride: cognitive features of two resilient performances. In: Hollnagel, E., Woods, D.D, Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 205–222.

Cook, R.I., Woods, D.D., 2006. Distancing through differencing: An obstacle to organizational learning following accidents. In: Hollnagel, E., Woods, D.D, Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 329–338.

Costantino, F., Di Gravio, G., Nonino, F., Patriarca, R., 2016. Evolution of the intellectual structure of research on pricing strategy of low cost carriers. Res. Transp. Bus. Manage. http://dx.doi.org/10.1016/j.rtbm.2016.07.005.

Costella, M.F., Saurin, T.A., de Macedo Guimarães, L.B., 2009. A method for assessing health and safety management systems from the resilience engineering perspective. Saf. Sci. 47. http://dx.doi.org/10.1016/j.ssci.2008.11.006.

Coughlan, B., Powell, D., Higgins, M.F., 2017. The Second Victim, a review.pdf. Eur. J. Obstet. Gynecol. Reprod. Biol. 213, 11–16. http://dx.doi.org/10.1016/j.ejogrb.2017.04.002.

Crane, D., 1969. Social structure in a group of scientists: a test of the "invisible college" hypothesis. Am. Sociol. Rev. 34, 335–352. http://dx.doi.org/10.2307/2092499.

Da Mata, T.F., Gajewski, D.W., Hall, C.K., Lacerda, M.C., Santos, A.G., Gomes, J.O., Woods, D.D., 2007. Application of resilience engineering on safety in offshore helicopter transportation. In: Proceedings of the 2006 IEEE Systems and Information Engineering Design Symposium, SIEDS'06. Universidade Federal do Rio de Janeiro, pp. 228–233. doi: 10.1109/SIEDS.2006.278681.

De Carvalho, P.V.R., 2011. The use of Functional Resonance Analysis Method (FRAM) in a mid-air collision to understand some characteristics of the air traffic management system resilience. Reliab. Eng. Syst. Saf. 96. http://dx.doi.org/10.1016/j.ress.2011.05.009.

De Carvalho, P.V.R., Benchekroun, T.-H., Gomes, J.O., 2012. Analysis of information exchange activities to actualize and validate situation awareness during shift changeovers in nuclear power plants. Hum. Factors Ergon. Manuf. 22. http://dx.doi.org/10.1002/hfm.20201.

Dekker, S., 2006. Resilience engineering: Chronicling the emergence of confused consensus. In: Hollnagel, E., Woods, D.D, Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 77–94.

Dekker, S., Bergström, J., Amer-Wåhlin, I., Cilliers, P., 2013. Complicated, complex, and compliant: Best practice in obstetrics. Cogn. Technol. Work 15. http://dx.doi.org/10.1007/s10111-011-0211-6.

Dekker, S., Dahlstrom, N., van Winsen, R., Nyce, J.M., 2008. Crew resilience and simulator training in aviation. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing, Ltd, pp. 119–126.

Dekker, S., Pruchnicki, S., 2014. Drifting into failure: theorising the dynamics of disaster incubation. Theor. Issues Ergon. Sci. 15. http://dx.doi.org/10.1080/1463922X.2013.856495.

Dekker, S.W.A., Breakey, H., 2016. Just culture: Improving safety by achieving substantive, procedural and restorative justice. Saf. Sci. 85, 187–193. http://dx.doi.org/10.1016/j.ssci.2016.01.018.

Dekker, S.W.A., Woods, D.D., 2010. The High Reliability Organization Perspective. In: Salas, E., Maurino, D. (Eds.), Human Factors in Aviation. Academic Press Elsevier, pp. 123–143. doi: http://dx.doi.org/10.1016/B978-0-12-374518-7.00005-5.

Dermot Williams, M., Smart, A., 2010. Patient safety: a casualty of target success? Int. J. Public Sect. Manage. 23. http://dx.doi.org/10.1108/09513551011058457.

Di Gravio, G., Mancini, M., Patriarca, R., Costantino, F., 2015. Overall safety performance of Air Traffic Management system: Forecasting and monitoring. Saf. Sci. 72, 351–362. http://dx.doi.org/10.1016/j.ssci.2014.10.003.

Di Stefano, G., Gambardella, A., Verona, G., 2012. Technology push and demand pull perspectives in innovation studies: Current findings and future research directions. Res. Policy 41, 1283–1295. http://dx.doi.org/10.1016/j.respol.2012.03.021.

Dijkstra, A., 2006. Safety management in airlines. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 183–203.

Dinh, L.T.T., Pasman, H., Gao, X., Mannan, M.S., 2012. Resilience engineering of industrial processes: Principles and contributing factors. J. Loss Prev. Process Ind. 25. http://dx.doi.org/10.1016/j.jlp.2011.09.003.

Dolif, G., Engelbrecht, A., Jatobá, A., da Silva, A.J.D., Gomes, J.O., Borges, M.R.S., Nobre, C.A., de Carvalho, P.V.R., 2013. Resilience and brittleness in the ALERTA RIO system: A field study about the decision-making of forecasters. Nat. Hazards 65. http://dx.doi.org/10.1007/s11069-012-0448-2.

Doorn, N., 2017. Resilience indicators: opportunities for including distributive justice concerns in disaster management. J. Risk Res. 20, 711–731. http://dx.doi.org/10.

1080/13669877.2015.1100662.
Epstein, S., 2008. Unexampled events, resilience, and PRA. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing Ltd, pp. 49–62.
Erol, O., Henry, D., Sauser, B., Mansouri, M., 2010. Perspectives on measuring enterprise resilience. In: 2010 IEEE International Systems Conference Proceedings, SysCon 2010. School of Systems and Enterprises, Stevens Institute of Technology, Hoboken, NJ, United States, pp. 587–592. doi: http://dx.doi.org/10.1109/SYSTEMS.2010.5482333.
Fairbanks, R.J., Perry, S., Bond, W., Wears, R.L., 2013. Separating resilience from success. In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), Resilient Health Care. Resilient Health Care, pp. 159–168.
Fairbanks, R.J., Wears, R.L., Woods, D.D., Hollnagel, E., Plsek, P., Cook, R.I., 2014. Resilience and resilience engineering in health care. Jt. Comm. J. Qual. Patient Saf. 40.
Ferreira, P., Wilson, J.R., Ryan, B., Sharples, S., 2011. Measuring resilience in the planning of rail engineering work. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing Ltd, pp. 145–156.
Flin, R., 2006. Erosion of managerial resilience: from Vasa to NASA. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing Ltd, pp. 223–234.
Francis, R., Bekera, B., 2014. A metric and frameworks for resilience analysis of engineered and infrastructure systems. Reliab. Eng. Syst. Saf. 121, 90–103. http://dx.doi.org/10.1016/j.ress.2013.07.004.
Furniss, D., Back, J., Blandford, A., Hildebrandt, M., Broberg, H., 2011a. A resilience markers framework for small teams. Reliab. Eng. Syst. Saf. 96. http://dx.doi.org/10.1016/j.ress.2010.06.025.
Furniss, D., Blandford, A., Curzon, P., 2011b. Confessions from a Grounded Theory PhD: Experiences and lessons learnt. In: Conference on Human Factors in Computing Systems - Proceedings. doi: http://dx.doi.org/10.1145/1978942.1978960.
García-Serna, J., Pérez-Barrigón, L., Cocero, M.J., 2007. New trends for design towards sustainability in chemical engineering: Green engineering. Chem. Eng. J. 133. http://dx.doi.org/10.1016/j.cej.2007.02.028.
Goerger, S.R., Madni, A.M., Eslinger, O.J., 2014. Engineered resilient systems: A DoD perspective. In: Procedia Computer Science. doi: http://dx.doi.org/10.1016/j.procs.2014.03.103.
Gomes, J.O., Woods, D.D., Carvalho, P.V.R., Huber, G.J., Borges, M.R.S., 2009. Resilience and brittleness in the offshore helicopter transportation system: The identification of constraints and sacrifice decisions in pilots' work. Reliab. Eng. Syst. Saf. 94. http://dx.doi.org/10.1016/j.ress.2008.03.026.
Grabowski, M., Roberts, K.H., 2015. Reliability seeking virtual organizations: Challenges for high reliability organizations and resilience engineering. Saf. Sci. http://dx.doi.org/10.1016/j.ssci.2016.02.016.
Grøtan, T.O., 2014. Hunting high and low for resilience: Sensitization from the contextual shadows of compliance. In: Safety, Reliability and Risk Analysis: Beyond the Horizon - Proceedings of the European Safety and Reliability Conference, ESREL 2013.
Grøtan, T.O., Asbjørnslett, B.E., 2007. ICT in resilient global logistics. In: Proceedings of the European Safety and Reliability Conference 2007, ESREL 2007 - Risk, Reliability and Societal Safety. Norwegian University of Science and Technology (NTNU), SINTEF Technology and Society, pp. 2349–2356.
Grøtan, T.O., Størseth, F., 2012. Integrated safety management based on organizational resilience. In: Advances in Safety, Reliability and Risk Management - Proceedings of the European Safety and Reliability Conference, ESREL 2011. Department of Production and Quality Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, pp. 1732–1740.
Grote, G., 2012. Safety management in different high-risk domains - All the same? Saf. Sci. 50. http://dx.doi.org/10.1016/j.ssci.2011.07.017.
Grote, G., 2008. Rules management as source for loose coupling in high-risk systems. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure, pp. 91–100.
Grote, G., Weichbrodt, J.C., Günter, H., Zala-Mezö, E., Künzle, B., 2009. Coordination in high-risk organizations: The need for flexible routines. Cogn. Technol. Work 11. http://dx.doi.org/10.1007/s10111-008-0119-y.
Haavik, T.K., 2014. On the ontology of safety. Saf. Sci. 67. http://dx.doi.org/10.1016/j.ssci.2013.09.004.
Hale, A., Borys, D., 2013a. Working to rule, or working safely? Part 1: A state of the art review. Saf. Sci. 55. http://dx.doi.org/10.1016/j.ssci.2012.05.011.
Hale, A., Borys, D., 2013b. Working to rule or working safely? Part 2: The management of safety rules and procedures. Saf. Sci. 55. http://dx.doi.org/10.1016/j.ssci.2012.05.013.
Hale, A., Guldenmund, F., Goossens, L., 2006. Auditing resilience in risk control and safety management systems. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 289–314.
Hale, A., Heijer, T., 2006a. Defining resilience. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing Ltd, pp. 35–40.
Hale, A., Heijer, T., 2006b. Is resilience really necessary? The case of railways. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 125–148.
Hegde, S., Hettinger, A.Z., Fairbanks, R.J., Wreathall, J., Lewis, V., Wears, R., Bisantz, A. M., 2013. A bottom-up approach to understanding the efficacy of event-analysis in healthcare: Paradigm shift from safety to resilience engineering. In: Proceedings of the Human Factors and Ergonomics Society. doi: http://dx.doi.org/10.1177/1541931213571146.
Hémond, Y., Robert, B., 2012a. Preparedness: The state of the art and future prospects. Disaster Prev. Manage. An Int. J. 21, 404–417. http://dx.doi.org/10.1108/09653561211256125.
Hémond, Y., Robert, B., 2012b. Evaluation of state of resilience for a critical infrastructure in a context of interdependencies. Int. J. Crit. Infrastructures 8, 95–106. http://dx.doi.org/10.1504/IJCIS.2012.049030.
Henry, D., Emmanuel Ramirez-Marquez, J., 2012. Generic metrics and quantitative approaches for system resilience as a function of time. Reliab. Eng. Syst. Saf. 99. http://dx.doi.org/10.1016/j.ress.2011.09.002.
Herrera, I.A., Hollnagel, E., Håbrekke, S., 2010. Proposing safety performance indicators for helicopter offshore on the Norwegian Continental Shelf. In: 10th International Conference on Probabilistic Safety Assessment and Management 2010, PSAM 2010.
Herrera, I.A., Pasquini, A., Ragosta, M., Vennesland, A., 2014. The SCALES framework for identifying and extracting resilience related indicators: Preliminary findings of a go-around case study. In: SIDs 2014 - Proceedings of the SESAR Innovation Days. EUROCONTROL.
Hollnagel, E., 2014a. Resilience engineering and the built environment. Build. Res. Inf. 42. http://dx.doi.org/10.1080/09613218.2014.862607.
Hollnagel, E., 2014b. Becoming resilient. In: Nemeth, C.P., Hollnagel, E. (Eds.), Becoming Resilient. Ashgate Publishing, Ltd, pp. 179–192.
Hollnagel, E., 2012. FRAM: The Functional Resonance Analysis Method: Modelling Complex Socio-technical Systems. Ashgate, Farnham (UK).
Hollnagel, E., 2011. Prologue: The scope of resilience engineering. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing Ltd, MINES ParisTech, France, pp. xxix–xxxix.
Hollnagel, E., 2011b. Epilogue: RAG - the resilience analysis grid. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing, Ltd, pp. 275–296.
Hollnagel, E., 2010. The ETTO principle: efficiency-thoroughness trade-off - "why things that go right sometimes go wrong. Risk Anal. 30, 153–154. http://dx.doi.org/10.1111/j.1539-6924.2009.01333.x.
Hollnagel, E., 2009. The four cornerstones of resilience engineering. In: Nemeth, C.P., Hollnagel, E., Dekker, S. (Eds.), Resilience Engineering Perspectives. Volume 2: Preparation and Restoration. Ashgate Publishing, Ltd, pp. 117–134.
Hollnagel, E., 2008a. Safety management - looking back or looking forward. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing Ltd, pp. 63–77.
Hollnagel, E., 2008b. Investigation as an impediment to learning. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing, Ltd, pp. 259–268.
Hollnagel, E., 2008c. Risk + barriers = safety? Saf. Sci. 46, 221–229. http://dx.doi.org/10.1016/j.ssci.2007.06.028.
Hollnagel, E., 2006. Resilience – the challenge of the unstable. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 9–18.
Hollnagel, E., Braithwaite, J., Wears, R.L., 2013. Preface: On the need for resilience in health care. In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), Resilient Health Care. Ashgate Publishing, Ltd, pp. 2–3.
Hollnagel, E., Sundström, G., 2006. States of resilience. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 339–346.
Hopkins, A., 2014. Issues in safety science. Saf. Sci. 67, 6–14. http://dx.doi.org/10.1016/j.ssci.2013.01.007.
Huber, G.J., Gomes, J.O., De Carvalho, P.V.R., 2012. A program to support the construction and evaluation of resilience indicators. Work 41. http://dx.doi.org/10.3233/WOR-2012-0528-2810.
Huber, S., van Wijgerden, I., de Witt, A., Dekker, S.W.A., 2009. Learning from organizational incidents: Resilience engineering for high-risk process environments. Process Saf. Prog. 28. http://dx.doi.org/10.1002/prs.10286.
Johansson, B.J.E., Lundberg, J., 2017. Resilience and the temporal dimension – the chimera of timely response. Theor. Issues Ergon. Sci. 18, 110–127. http://dx.doi.org/10.1080/1463922X.2016.1154231.
Johansson, J., Hassel, H., 2010. An approach for modelling interdependent infrastructures in the context of vulnerability analysis. Reliab. Eng. Syst. Saf. 95. http://dx.doi.org/10.1016/j.ress.2010.06.010.
Joyekurun, R., 2007. Weather hazards in ATM: Designing for resilient operations. In: ACM International Conference Proceeding Series. doi: http://dx.doi.org/10.1145/1362550.1362610.
Kaiser, H.F., 1958. The VARIMAX criterion for analytic rotation in factor analysis. Psychometrika 23, 187–201.
Kiswendsida, A.O., Enjalbert, S., Vanderhaegen, F., 2010. How to learn from the resilience of Human-Machine Systems?. In: IFAC Proceedings Volumes (IFAC-PapersOnline).
Kitamura, M., 2014. Resilience engineering for safety of nuclear power plant with accountability. In: Nemeth, C.P., Hollnagel, E. (Eds.), Becoming Resilient. Ashgate Publishing, Ltd, pp. 47–62.
Kline, P., 1994. An Easy Guide to Factor Analysis. Routledge, Abingdon, Oxon.
Komatsubara, A., 2008. When resilience does not work. In: Hollnagel, E., Nemeth, C., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing, Ltd, pp. 79–90.
Lay, E., 2011. Practices for noticing and dealing with the critical. A case study from maintenance of power plants. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing Ltd, pp. 87–100.
Le Coze, J.C., 2013. New models for new times. An anti-dualist move. Saf. Sci. 59. http://dx.doi.org/10.1016/j.ssci.2013.05.010.
Le Coze, J.C., Dupré, M., 2008. The need for "translators" and for new models of safety. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing Ltd, pp. 11–27.
Leveson, N., 2004. A new accident model for engineering safer systems. Saf. Sci. http://dx.doi.org/10.1016/S0925-7535(03)00047-X.
Leveson, N., Dulac, N., Zipkin, D., Cutcher-Gershenfeld, J., Carroll, J., Barrett, B., 2006. Engineering resilience into safety-critical systems. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate

Publishing, Ltd, pp. 95–124.
Liu, J., Dietz, T., Carpenter, S.R., Alberti, M., Folke, C., Moran, E., Pell, A.N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C.L., Schneider, S.H., Taylor, W.W., 2007. Complexity of Coupled Human and Natural Systems. Science (80-.). 317, 1513–1516. doi: http://dx.doi.org/10.1126/science.1144004.
Longstaff, P.H., Koslowski, T.G., Geoghegan, W., 2013. Translating resilience: A framework to enhance communication and implementation. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25–27 June 2013. doi: http://dx.doi.org/10.1108/09604529610149239.
Lundberg, J., Johansson, B.J., 2015. Systemic resilience model. Reliab. Eng. Syst. Saf. 141. http://dx.doi.org/10.1016/j.ress.2015.03.013.
Lundberg, J., Rankin, A., 2014. Resilience and vulnerability of small flexible crisis response teams: Implications for training and preparation. Cogn. Technol. Work 16, 143–155. http://dx.doi.org/10.1007/s10111-013-0253-z.
Lundberg, J., Rollenhagen, C., Hollnagel, E., 2009. What-You-Look-For-Is-What-You-Find – The consequences of underlying accident models in eight accident investigation manuals. Saf. Sci. 47, 1297–1311. http://dx.doi.org/10.1016/j.ssci.2009.01.004.
Lundberg, J., Woltjer, R., 2013. The Resilience Analysis Matrix (RAM): Visualizing functional dependencies in complex socio-technical systems. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25–27 June 2013.
Madni, A.M., Jackson, S., 2009. Towards a conceptual framework for resilience engineering. IEEE Syst. J. 3. http://dx.doi.org/10.1109/JSYST.2009.2017397.
McDonald, N., 2006. Organisational resilience and industrial risk. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 155–180.
Mendoca, D., 2008. Measures of resilient performance. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing, Ltd, pp. 29–48.
Miller, A., Xiao, Y., 2007. Multi-level strategies to achieve resilience for an organisation operating at capacity: A case study at a trauma centre. Cogn. Technol. Work 9. http://dx.doi.org/10.1007/s10111-006-0041-0.
Morel, G., Amalberti, R., Chauvin, C., 2009. How good micro/macro ergonomics may improve resilience, but not necessarily safety. Saf. Sci. 47. http://dx.doi.org/10.1016/j.ssci.2008.03.002.
Nathanale, D., Marmaras, N., 2008. Work practices and prescription: a key issue for organizational resilience. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing Ltd, pp. 101–118.
Nemeth, C., Cook, R., 2007. Healthcare IT as a source of resilience. In: Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics. doi: http://dx.doi.org/10.1109/ICSMC.2007.4413721.
Nemeth, C.P., 2008a. The ability to adapt. In: Nemeth, C.P., Hollnagel, E., Dekker, S. (Eds.), Resilience Engineering Perspectives. Volume 2: Preparation and Restoration. Ashgate Publishing, Ltd.
Nemeth, C.P., 2008b. Resilience engineering: the birth of a notion. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing, Ltd, pp. 3–10.
Nemeth, C.P., Herrera, I., 2015. Building change: Resilience Engineering after ten years. Reliab. Eng. Syst. Saf. 141. http://dx.doi.org/10.1016/j.ress.2015.04.006.
Nemeth, C.P., Nunnally, M., O'Connor, M.F., Brandwijk, M., Kowalsky, J., Cook, R.I., 2007. Regularly irregular: How groups reconcile cross-cutting agendas and demand in healthcare. Cogn. Technol. Work 9. http://dx.doi.org/10.1007/s10111-006-0058-4.
Ng, E.-H., Beruvides, M.G., Tolk, J.N., Hartley, R.S., 2011. High reliability organization: A literature review. In: Annual International Conference of the American Society for Engineering Management 2011, ASEM 2011.
Nyssen, A.S., 2011. From myopic coordination to resilience in socio-technical systems: A case study in a hospital. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing, Ltd, pp. 219–236.
Øien, K., Massaiu, S., Tinmannsvik, R.K., Størseth, F., 2010. Development of early warning indicators based on Resilience Engineering. In: 10th International Conference on Probabilistic Safety Assessment and Management 2010, PSAM 2010.
Okoh, P., Haugen, S., 2015. Improving the robustness and resilience properties of maintenance. Process Saf. Environ. Prot. 94, 212–226. http://dx.doi.org/10.1016/j.psep.2014.06.014.
Pariès, J., 2011a. Lessons from the Hudson. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing, Ltd, pp. 9–28.
Pariès, J., 2011b. Resilience and the ability to respond. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing, Ltd, pp. 3–8.
Pasman, H.J., 2009. Learning from the past and knowledge management: Are we making progress? J. Loss Prev. Process Ind. 22, 672–679. http://dx.doi.org/10.1016/j.jlp.2008.07.010.
Pasman, H.J., Knegtering, B., Rogers, W.J., 2013. A holistic approach to control process safety risks: Possible ways forward. Reliab. Eng. Syst. Saf. 117, 21–29. http://dx.doi.org/10.1016/j.ress.2013.03.010.
Pasquini, A., Pozzi, S., Save, L., Sujan, M., 2011. Requisites for successful incident reporting in resilient organisations. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing, Ltd, pp. 237–256.
Patriarca, R., Bergström, J., 2017. Modelling complexity in everyday operations: Functional resonance in maritime mooring at quay. Cogn. Technol. Work 1–19. http://dx.doi.org/10.1007/s10111-017-0426-2.
Patriarca, R., Bergström, J., Di Gravio, G., 2017a. Defining the Functional Resonance Analysis space: combining Abstraction Hierarchy and FRAM. Reliab. Eng. Syst. Saf. 165, 34–46. http://dx.doi.org/10.1016/j.ress.2017.03.032.
Patriarca, R., Di Gravio, G., Costantino, F., 2017b. A Monte Carlo evolution of the Functional Resonance Analysis Method (FRAM) to assess performance variability in complex systems. Saf. Sci. 91, 49–60. http://dx.doi.org/10.1016/j.ssci.2016.07.016.
Patriarca, R., Di Gravio, G., Costantino, F., Tronci, M., 2017c. The functional resonance analysis method for a systemic risk based environmental auditing in a sinter plant: A semi-quantitative approach. Environ. Impact Assess. Rev. 63, 72–86. http://dx.doi.org/10.1016/j.eiar.2016.12.002.
Patterson, E.S., Woods, D.D., Cook, R.I., Render, M.L., 2005. Collaborative cross-checking to enhance resilience. In: Proceedings of the Human Factors and Ergonomics Society. VA Getting at Patient Safety (GAPS) Center, Cincinnati VAMC Institute for Ergonomics, Ohio State University, pp. 512–516.
Pava, C., 1986. Redesigning sociotechnical system design: concepts and methods for the 1990s.pdf. J. Appl. Behav. Sci. 22, 201–221.
Pilkington, A., Meredith, J., 2009. The evolution of the intellectual structure of operations management — 1980–2006: A citation / co-citation analysis. J. Oper. Manage. 27, 185–202. http://dx.doi.org/10.1016/j.jom.2008.08.001.
Praetorius, G., Hollnagel, E., 2014. Control and resilience within the maritime traffic management domain. J. Cogn. Eng. Decis. Mak. 8, 303–317. http://dx.doi.org/10.1177/1555343414560022.
Praetorius, G., Hollnagel, E., Dahlman, J., 2015. Modelling Vessel Traffic Service to understand resilience in everyday operations. Reliab. Eng. Syst. Saf. 141. http://dx.doi.org/10.1016/j.ress.2015.03.020.
Qureshi, Z.H., Ashraf, M.A., Amer, Y., 2007. Modeling industrial safety: A sociotechnical systems perspective. In: IEEM 2007: 2007 IEEE International Conference on Industrial Engineering and Engineering Management. doi: http://dx.doi.org/10.1109/IEEM.2007.4419519.
Ramos-Rodríguez, A., Ruíz-Navarro, J., 2004. Changes in the intellectual structure of strategic management research: a bibliometric study of the Strategic Management Journal, 1980–2000. Strateg. Manage. J. 25, 981–1004.
Rankin, A., Dahlbäck, N., Lundberg, J., 2013a. A case study of factor influencing role improvisation in crisis response teams. Cogn. Technol. Work 15. http://dx.doi.org/10.1007/s10111-011-0186-3.
Rankin, A., Lundberg, J., Woltjer, R., 2014a. A framework for learning from adaptive performance. In: Nemeth, C.P., Hollnagel, E. (Eds.), Becoming Resilient. Ashgate Publishing, Ltd, pp. 79–96.
Rankin, A., Lundberg, J., Woltjer, R., Rollenhagen, C., Hollnagel, E., 2014b. Resilience in everyday operations: A framework for analyzing adaptations in high-risk work. J. Cogn. Eng. Decis. Mak. 8. http://dx.doi.org/10.1177/1555343413498753.
Rankin, A., Woltjer, R., Field, J., Woods, D.D., 2013. "Staying ahead of the aircraft" and Managing Surprise in Modern Airliners. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25–27 June 2013.
Re, A., Macchi, L., 2010. From cognitive reliability to competence? An evolving approach to human factors and safety. Cogn. Technol. Work 12. http://dx.doi.org/10.1007/s10111-010-0148-1.
Reiman, T., Rollenhagen, C., 2011. Human and organizational biases affecting the management of safety. Reliab. Eng. Syst. Saf. 96. http://dx.doi.org/10.1016/j.ress.2011.05.010.
Reniers, G.L.L., Sörensen, K., Khan, F., Amyotte, P., 2014. Resilience of chemical industrial areas through attenuation-based security. Reliab. Eng. Syst. Saf. 131. http://dx.doi.org/10.1016/j.ress.2014.05.005.
Righi, A.W., Saurin, T.A., Wachs, P., 2015. A systematic literature review of resilience engineering: Research areas and a research agenda proposal. Reliab. Eng. Syst. Saf. 141, 142–152. http://dx.doi.org/10.1016/j.ress.2015.03.007.
Robbins, J., Krishnan, K., Allspaw, J., Limoncelli, T., 2012. Resilience engineering: Learning to embrace failure. Commun. ACM 55. http://dx.doi.org/10.1145/2366316.2366331.
Robson, R., 2013. Resilient health care. In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), Resilient Health Care. Ashgate Publishing Ltd, Farnham, England, pp. 191–204.
Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J.A., 2009. Planetary boundaries: exploring the safe operating space for humanity. Ecol. Soc. 14. http://dx.doi.org/10.1038/461472a.
Ross, A.J., Anderson, J.E., Kodate, N., Thompson, K., Cox, A., Malik, R., 2014. Inpatient diabetes care: Complexity, resilience and quality of care. Cogn. Technol. Work 16. http://dx.doi.org/10.1007/s10111-012-0247-2.
Rowlands, I., 1999. Patterns of author cocitation in information policy: Evidence of social, collaborative and cognitive structure. Scientometrics 44, 533–546.
Saaty, T.L., 2008. Decision making with the analytic hierarchy process. Int. J. Serv. Sci. 1, 83. http://dx.doi.org/10.1504/IJSSCI.2008.017590.
Salzano, E., Di Nardo, M., Gallo, M., Oropallo, E., Santillo, L.C., 2014. The application of system dynamics to industrial plants in the perspective of process resilience engineering. Chem. Eng. Trans. http://dx.doi.org/10.3303/CET1436077.
Saurin, T.A., Carim Junior, G.C., 2012. A framework for identifying and analyzing sources of resilience and brittleness: A case study of two air taxi carriers. Int. J. Ind. Ergon. 42. http://dx.doi.org/10.1016/j.ergon.2011.12.001.
Saurin, T.A., Carim Júnior, G.C., 2011. Evaluation and improvement of a method for assessing HSMS from the resilience engineering perspective: A case study of an electricity distributor. Saf. Sci. 49. http://dx.doi.org/10.1016/j.ssci.2010.09.017.
Saurin, T.A., Sanches, R.C., 2014. Lean construction and resilience engineering: Complementary perspectives of variability. In: 22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014.
Saurin, T.A., Wachs, P., Henriqson, É., 2013. Identification of non-technical skills from the resilience engineering perspective: A case study of an electricity distributor. Saf. Sci. 51. http://dx.doi.org/10.1016/j.ssci.2012.06.010.
Saurin, T.A., Wachs, P., Righi, A.W., Henriqson, É., 2014. The design of scenario-based training from the resilience engineering perspective: A study with grid electricians.

Accid. Anal. Prev. 68. http://dx.doi.org/10.1016/j.aap.2013.05.022.
Schraagen, J.M., 2015. Resilience and networks. In: Proceedings of the 6th Resilience Engineering Association Symposium. Lisbon (Portugal), 22–25 June 2015.
Shafique, M., 2013. Thinking inside the box? Intellectual structure of the knowledge base of innovation research (1988–2008). Strateg. Manage. J. 34, 62–93.
Sheridan, T.B., 2008. Risk, human error, and system resilience: fundamental ideas. Hum. Factors J. Hum. Factors Ergon. Soc. 50, 418–426. http://dx.doi.org/10.1518/001872008X250773.
Shirali, G.A., Mohammadfam, I., Ebrahimipour, V., 2013. A new method for quantitative assessment of resilience engineering by PCA and NT approach: A case study in a process industry. Reliab. Eng. Syst. Saf. 119. http://dx.doi.org/10.1016/j.ress.2013.05.003.
Shirali, G.A., Motamedzade, M., Mohammadfam, I., Ebrahimipour, V., Moghimbeigi, A., 2016. Assessment of resilience engineering factors based on system properties in a process industry. Cogn. Technol. Work 18. http://dx.doi.org/10.1007/s10111-015-0343-1.
Shirali, G.H.A., Mohammadfam, I., Motamedzade, M., Ebrahimipour, V., Moghimbeigi, A., 2012a. Assessing resilience engineering based on safety culture and managerial factors. Process Saf. Prog. 31. http://dx.doi.org/10.1002/prs.10485.
Shirali, G.H.A., Motamedzade, M., Mohammadfam, I., Ebrahimipour, V., Moghimbeigi, A., 2012b. Challenges in building resilience engineering (RE) and adaptive capacity: A field study in a chemical plant. Process Saf. Environ. Prot. 90. http://dx.doi.org/10.1016/j.psep.2011.08.003.
Siegel, A.W., Schraagen, J.M., 2014. Developing resilience signals for the Dutch railway system. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25–27 June 2013, pp. 191–196.
Sigalit, W., Sivia, B., Michal, I., 2017. Factors associated with nursing students' resilience: communication skills course, use of social media and satisfaction with clinical placement. J. Prof. Nurs. 33, 153–161. http://dx.doi.org/10.1016/j.profnurs.2016.08.006.
Sörensen, J., Persson, A., Sternudd, C., Aspegren, H., Nilsson, J., Nordström, J., Jönsson, K., Mottaghi, M., Becker, P., Pilesjö, P., Larsson, R., Berndtsson, R., Mobini, S., 2016. Re-thinking urban flood management-time for a regime shift. Water (Switzerland) 8, 1–15. http://dx.doi.org/10.3390/w8080332.
Steen, R., Aven, T., 2011. A risk perspective suitable for resilience engineering. Saf. Sci. 49. http://dx.doi.org/10.1016/j.ssci.2010.09.003.
Stoop, J., 2011. No facts, no glory. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook2. Ashgate Publishing, Ltd.,, pp. 199–218.
Sundström, G.A., Hollnagel, E., 2011. The importance of functional interdependencies in financial services systems. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing, Ltd, pp. 171–192.
Sundström, G., Hollnagel, E., 2006. Learning how to create resilience in business systems. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 235–252.
Tjørhom, B., Aase, K., 2011. The art of balance: Using upward resilience traits to deal with conflicting goals. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing Ltd, pp. 157–170.
Turner, B.A., 1975. Man-Made Disasters. Michigan University, Longman.
Van Der Beek, D., Schraagen, J.M., 2015. ADAPTER: Analysing and developing adaptability and performance in teams to enhance resilience. Reliab. Eng. Syst. Saf. 141. http://dx.doi.org/10.1016/j.ress.2015.03.019.
Wachs, P., Righi, A.W., Saurin, T.A., 2012. Identification of non-technical skills from the resilience engineering perspective: A case study of an electricity distributor. Work 41. http://dx.doi.org/10.3233/WOR-2012-0565-3069.
Walker, K.E., Deary, D.S., Woods, D.D., 2013. Reducing the Potential for Cascade: Recognizing and Mitigating Situations that Threaten Business Viability. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25–27 June 2013.
Wang, D., Ip, W.H., 2009. Evaluation and analysis of logistic network resilience with application to aircraft servicing. IEEE Syst. J. 3. http://dx.doi.org/10.1109/JSYST.2009.2017395.
Wears, R.L., Morrison, J.B., 2013. Levels of Resilience : Moving from Resilience to Resilience Engineering. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25–27 June 2013.
Wears, R.L., Perry, S.J., Anders, S., Woods, D.D., 2008. Resilience in the emergency department. In: Hollnagel, E., Nemeth, C.P., Dekker, S. (Eds.), Resilience Engineering Perspective Volume 1 - Remaining Sensitive to the Possibility of Failure. Ashgate Publishing, Ltd 293–210.
Wears, R.L., Perry, S.J., Wilson, S., Galliers, J., Fone, J., 2007. Emergency department status boards: User-evolved artefacts for inter- and intra-group coordination. Cogn. Technol. Work 9, 163–170. http://dx.doi.org/10.1007/s10111-006-0055-7.
Wears, R.L., Vincent, C.A., 2013. Relying on resilience: Too much of a good thing? In: Hollnagel, E., Braithwaite, J., Wears, R.L. (Eds.), Resilient Health Care. Ashgate Publishing, Ltd, pp. 135–144.
Westrum, R., 2006. A typology of resilience situations. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 55–66.
Whitson, J.C., Ramirez-Marquez, J.E., 2009. Resiliency as a component importance measure in network reliability. Reliab. Eng. Syst. Saf. 94. http://dx.doi.org/10.1016/j.ress.2009.05.001.
Williams, M.D., Smart, A., 2010. Patient safety: a casualty of target success? Int. J. Public Sect. Manage. 23, 416–430. http://dx.doi.org/10.1108/09513551011058457.
Wilson, J.R., Ryan, B., Schock, A., Ferreira, P., Smith, S., Pitsopoulos, J., 2009. Understanding safety and production risks in rail engineering planning and protection. Ergonomics 52. http://dx.doi.org/10.1080/00140130802642211.
Woltjer, R., Haraldsson, J., Pinska-Chauvin, E., Josefsson, B., 2013. Resilience in ATM operations: Incorporating Robustness and Resilience in Safety Assessment. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25–27 June 2013.
Woltjer, R., Pinska-Chauvin, E., Laursen, T., Josefsson, B., 2015. Towards understanding work-as-done in air traffic management safety assessment and design. Reliab. Eng. Syst. Saf. 141. http://dx.doi.org/10.1016/j.ress.2015.03.010.
Woltjer, R., Pinska-Chauvin, E., Laursen, T., Josefsson, B., 2013. Resilience engineering in air traffic management: Increasing resilience through safety assessment in SESAR. In: SIDs 2013 - Proceedings of the SESAR Innovation Days. Division of Information and Aeronautical Systems, Swedish Defence Research Agency FOI, Linköping, Sweden.
Woods, D., 2003. Creating foresight: how resilience engineering can tarnsform NASA's approach to risky decision making.
Woods, D., Branlat, M., 2011. Basic patterns in how adaptive systems fail. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing, Ltd, pp. 127–144.
Woods, D.D., 2015. Four concepts for resilience and the implications for the future of resilience engineering. Reliab. Eng. Syst. Saf. 141. http://dx.doi.org/10.1016/j.ress.2015.03.018.
Woods, D.D., 2011. Resilience and the ability to anticipate. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook2. Ashgate Publishing, Ltd, pp. 121–126.
Woods, D.D., 2007. Proactive safety management. Ind. Eng. 39.
Woods, D.D., 2006a. Essential characteristics of resilience. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 21–34.
Woods, D.D., 2006b. Engineering organizational resilience to enhance safety: a progress report on the emerging field of resilience engineering. Proceedings of the Human Factors and Ergonomics Society Annual Meeting 2237–2241. http://dx.doi.org/10.1177/154193120605001910.
Woods, D.D., Chan, Y.J., Wreathall, J., 2013. The Stress-Strain Model of Resilience Operationalizes the Four Cornerstones of Resilience Engineering. In: Proceedings of the 5th Resilience Engineering Association Symposium. Soesterberg (The Netherlands), 25–27 June 2013.
Woods, D.D., Cook, R.I., 2006. Incidents – markers of resilience or brittleness? In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 69–76.
Woods, D.D., Schenck, J., Allen, T.T., 2009. An initial comparison of selected models of system resilience. In: Nemeth, C.P., Hollnagel, E., Dekker, S. (Eds.), Resilience Engineering Perspectives. Volume 2: Preparation and Restoration. Ashgate Publishing, Ltd, pp. 73–94.
Wreathall, J., 2011. Monitoring - a critical ability in resilience engineering. In: Resilience Engineering in Practice: A Guidebook. Safety and Security in Work and its Environment, Brazil, pp. 61–68.
Wreathall, J., 2009. Measuring resilience. In: Nemeth, C.P., Hollnagel, E., Dekker, S. (Eds.), Resilience Engineering Perspectives. Volume 2: Preparation and Restoration. Ashgate Publishing, Ltd, pp. 95–114.
Wreathall, J., 2006. Properties of resilient organizations: An initial view. In: Hollnagel, E., Woods, D.D., Leveson, N. (Eds.), Resilience Engineering: Concepts and Precepts. Ashgate Publishing, Ltd, pp. 275–286.
Zhang, W.J., Lin, Y., 2010. On the principle of design of resilient systems - application to enterprise information systems. Enterp. Inf. Syst. 4, 99–110. http://dx.doi.org/10.1080/17517571003763380.
Zieba, S., Polet, P., Vanderhaegen, F., Debernard, S., 2010. Principles of adjustable autonomy: A framework for resilient human-machine cooperation. Cogn. Technol. Work 12. http://dx.doi.org/10.1007/s10111-009-0134-7.
Zimmermann, K., Pariès, J., Amalberti, R., Hummerdal, H.D., 2011. Is the aviation industry ready for resilience? apping human factors assumptions across the aviation sector. In: Hollnagel, E., Pariès, J., Woods, D.D., Wreathall, J. (Eds.), Resilience Engineering in Practice: A Guidebook. Ashgate Publishing, Ltd 257–274.