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Determinants of safety outcomes and performance: A systematic literature review of research in four high-risk industries

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ABSTRACT

Introduction: In spite of increasing governmental and organizational efforts, organizations still struggle to improve the safety of their employees as evidenced by the yearly 2.3 million work-related deaths worldwide. Occupational safety research is scattered and inaccessible, especially for practitioners. Through systematically reviewing the safety literature, this study aims to provide a comprehensive overview of behavioral and circumstantial factors that endanger or support employee safety. *Method:* A broad search on occupational safety literature using four online bibliographical databases yielded 27.527 articles. Through a systematic reviewing process 176 online articles were identified that met the inclusion criteria (e.g., original peer-reviewed research; conducted in selected high-risk industries; published between 1980-2016). Variables and the nature of their interrelationships (i.e., positive, negative, or nonsignificant) were extracted, and then grouped and classified through a process of bottom-up coding. *Results:* The results indicate that safety outcomes and performance prevail as dependent research areas, dependent on variables related to management & colleagues, work(place) characteristics & circumstances, employee demographics, climate & culture, and external factors. Consensus was found for five variables related to safety outcomes and seven variables related to performance, while there is debate about 31 other relationships. Last, 21 variables related to safety outcomes and performance appear understudied. *Conclusions:* The majority of safety research has focused on addressing negative safety outcomes and performance through variables related to others within the organization, the work(place) itself, employee demographics, and—to a lesser extent—climate & culture and external factors. *Practical applications:* This systematic literature review provides both scientists and safety practitioners an overview of the (under)studied behavioral and circumstantial factors related to occupational safety behavior. Scientists could use this overview to study gaps, and validate or falsify relationships. Safety practitioners could use the insights to evaluate organizational safety policies, and to further development of safety interventions.

1. Introduction

The number of occupational accidents exceeds 313 million annually worldwide (International Labour Organization [ILO], 2015), underscoring the relevance of occupational health and safety for organizations. According to ILO (1998) occupational accidents include work-related events that are unexpected or unplanned and result in one or more workers suffering a personal injury, disease, or death. These regrettable events have serious physical and emotional consequences for the employees involved, have severe impacts on coworkers, first responders, and families, and result in costs estimated at 4% of the global gross domestic product (ILO, 2015). The origin of occupational safety as a topic of interest for organizations can be traced back to the 19th century, when rapid industrialization was characterized by economic, technical, and social changes on an unprecedented scale (Swuste, Van Gulijk, & Zwaard, 2010). However, improving safety proved much more complicated than expected, causing a division between the scientific and the corporate worlds (Swuste, Van Gulijk, Zwaard, & Oostendorp, 2014). Whereas science tried to understand accidents as processes of causes and effects, organizations adhered to their trusted theory of accident proneness: the idea that some people are predisposed to be more susceptible to accidents (Arbous & Kerrich, 1951). In this study we therefore aim to provide an overview of the most prevalent safety factors studied over the past 35 years, provide an overview of the determinants of safety outcomes, and ultimately bridge the gap between the scientific and the corporate worlds. Whereas previous research provided overviews of the literature from a historical perspective (e.g., Swuste et al., 2010, 2014), or focused on a specific topic (e.g., Clarke, 2013; Wagstaff & Lie, 2011), or a specific domain (e.g., Abdul-Aziz & Hussin, 2003; Mearns & Yule, 2009), our study delivers a comprehensive overview of the occupational safety literature over the last 35 years, covering a broad range of topics in four different domains (construction, (offshore) petro chemistry, warehouses, and manufacturing). Before we describe our methodology and results, we will provide a short overview of the main variables in occupational safety research literature. Finally, we will critically review our findings and discuss implications for both practice and research, as well as directions for future research.

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1.1. Safety outcomes and performance

The ultimate end goal in occupational safety is the reduction or – preferably – elimination of negative safety outcomes. These negative safety outcomes come in different forms like incidents, accidents, and injuries. These events are often distinguished from each other based on Heinrich's pyramid (for more information see Heinrich, 1931), which classifies unwanted safety-related events based on their outcomes. We will use a similar, although compressed, classification. We classify negative outcomes that have the potential to inflict harm as *incidents*, such as near misses and employee errors. We classify incidents that result in property or financial damage as *accidents*, and we classify accidents that result in mental or physical damage as *injuries*, including those accidents that resulted in fatalities.

The leading line of thought is that good or better performance leads to the decrease or absence of negative safety outcomes (Christian, Bradley, Wallace, & Burke, 2009). As such, improved performance can be viewed as both a precursor of negative safety outcomes and as a goal in itself. Safety performance has been defined as those 'actions or behaviors that individuals exhibit in almost all jobs to promote the health and safety of workers, clients, the public, and the environment' (Burke, Sarpy, Tesluk, & Smith-Crowe, 2002) and is considered to consist of two components: safety compliance and safety participation (e.g., Neal & Griffin, 2002; Neal, Griffin, & Hart, 2000). Safety compliance refers to 'following safety procedures and carrying out work in a safe manner,' whereas safety participation refers to 'helping coworkers, promoting the safety program within the workplace, demonstrating initiative, and putting effort into improving safety in the workplace' (Neal et al., 2000).

1.2. Determinants

A wide variety of possible precursors and determinants of safety have been studied. Examining the work environment, Bjerkan (2010) distinguishes between the physical work environment and the mental work environment. Whereas the physical work environment refers to tangible elements like machinery, the mental work environment refers to elements like job demands and working hours. Related elements that have attracted considerable attention from researchers are culture (e.g., Guldenmund, 2000) and climate (e.g., Zohar, 2010).

Another topic of interest is the influence of (other) employees. Elements such as manager attitudes (e.g., Mullen, 2004), leadership styles (e.g., Kelloway, Mullen, & Francis, 2006), and pressure exerted by colleagues (Choudhry, 2012) are all considered important influencers of behavior. However, characteristics of individual employee such as age and experience, are considered important as well (e.g., Basha & Maiti, 2013).

Finally, there are several external elements that might influence occupational safety. What are the effects of stakeholders, legislation, and external control bodies (e.g., Ko, Mendeloff, & Gray, 2010)?

2. Method

To examine the foci of research to date, we conducted a systematic search in the occupational safety literature from 1980 to 2015. A systematic review of the literature is typically based on a 'detailed and comprehensive plan and search strategy derived a priori' in order to reduce bias (Uman, 2011). In contrast to a meta-analysis we do not strive to come to a 'single quantitative estimate or summary effect size' using statistical techniques (Uman, 2011). Instead, we aim to present an overview of topics addressed in both quantitative and qualitative research on occupational safety, and their general direction. This approach is similar to approaches in previous systematic reviews (e.g., Ahonen, Benavides, & Benach, 2007; Kringos, Boerma, Hutchinson, Van der Zee, & Groenewegen, 2010). Below, we will elaborate on our systematic selection process and analysis.

2.1. Literature search

Our aim was to capture as much of the available literature on occupational safety as possible. We therefore chose a literature search using broad search terms as a starting point, as opposed to citation networks that may result in overlooking new and less frequently cited literature. Our literature search was conducted using the following bibliographic databases: Scopus, Web of Science, PsycInfo, and Business Source Elite. We used combinations of keywords that emerged from the literature as key indicators of occupational safety: *safety performance*; *safety participation*; *safety compliance*; *occupatio**; and *employ**. This resulted in a total of 27,527 records published between 1979 and 2015.

2.2. Article selection

The further selection of articles was performed in steps, as depicted in Fig. 1. Based on the available information in Endnote we removed duplicates, articles written in languages other than English, and – as a quality assurance – non-peer reviewed articles ($n = 16{,}302$). This step reduced the selection to 11,225 articles. Not all non-peer reviewed articles could be excluded based on the information available in Endnote. This resulted in the removal of articles matching this criterion during multiple phases of the selection process. Then, three consecutive steps were completed. First, the first author evaluated the titles and marked articles that did not meet the following inclusion criteria: (a) describe safety in an occupational setting; (b) focus on interventions, determinants, or measurement of occupational safety; (c) conducted in the construction, warehouse, manufacturing, offshore, or petrochemical sector; (d) published in a peer-reviewed journal; and (e) be written in English. The four domains of construction, (offshore) petro chemistry, warehouses, and manufacturing were included based on a combination of elements. First, the construction and manufacturing sector combined accounted for more than a fifth of all fatal accidents that occurred in 2013 in the EU-28 (Eurostat, 2016). Second, the Dutch Inspectorate SZW mentions that the construction and chemistry are among those sectors where employees are subject to high health and safety risks (Inspectorate SZW, 2016), furthermore, the chemical sector has proven to be a domain where accidents can have a big environmental impact (e.g., Deepwater Horizon in 2010). Third, the domain of warehouses was included as employees here are subject to a high number of (mechanical) risks, such as forklifts and conveyors. Fourth, these four domains share a number of similarities that makes them relatively comparable: they represent highly technical environments with a number of occupational risks and are staffed with mostly blue-collar workers. Lastly, other well-studied areas are excluded as they represent highly specific risks (e.g., underground mining), require employees to be highly educated and trained (e.g., aviation), or mainly have a focus on the safety of others (e.g., hospitals). A random sample of 10% of the articles was assessed for eligibility by the second author, which resulted in a substantial Cohen's kappa for inter-coder reliability (.73). Based on the screening of titles, 6,558 articles were excluded and 4,667 articles remained. When there was any doubt or disagreement during this step, the article was retained for the next round of analysis. We repeated this process by reading the abstracts of the remaining articles. The Cohen's kappa over the sample of abstracts ($n = 474$) was again substantial (.68). After exclusion of 2,600 articles based on abstract content, a sample of 2,067 articles remained. As the initial search was conducted during October 2014, we repeated our search during October 2015 so as to include all relevant articles published in the last months of 2014. This returned 24 additional articles, which underwent the same process of selection. From these 2,091 records we excluded any remaining gray and white literature ($n = 324$) and articles that were not published online ($n = 614$). The majority of the remaining articles were directly available for download. To retrieve the 222 articles that were published online but were unavailable to us through the subscriptions of the University of Twente we used a combination of ResearchGate and other

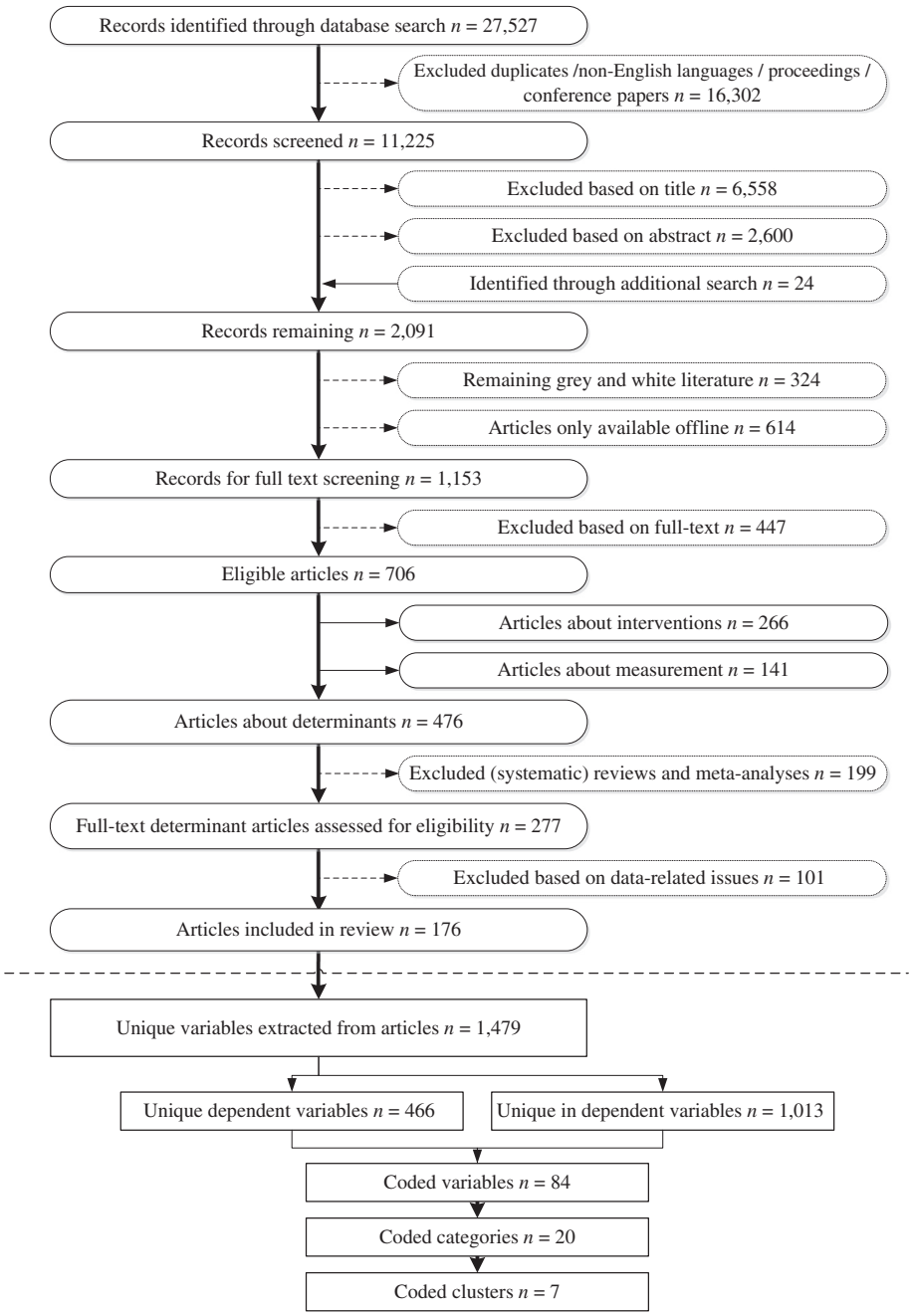

Fig. 1. Flow diagram of study selection and extracted variables.

university libraries. The full texts of the 1,153 articles were read and an additional 447 articles were excluded.

The remaining articles ($n = 706$) were read and assigned to one or multiple of three categories: research involving determinants of occupational safety ($n = 476$); interventions research ($n = 266$); and research concerned with measurement tools ($n = 141$). The latter two groups were excluded from further analysis as they did not meet the current study focus. From the 476 articles focusing on determinants of occupational safety, 199 articles were excluded, mostly on the premise that they did not report on empirical data, or the reported data was not unique (e.g., editorials, reviews, meta-analysis). Inclusion of reviews and meta-analysis could distort the results, as the same data could be included twice.

The final step involved reading the full texts of all remaining articles again. All 277 remaining articles were read by one of the authors, who in the process marked potentially problematic articles. All of these marked articles were discussed by two of the authors. Based on the outcome of these discussions, a joint decision on whether or not to include these articles was made. This resulted in the exclusion of an additional 101 articles based on their full text, because they did not meet the inclusion criteria (e.g., dependent variable was not safety-related ($n = 40$); data-related issues, e.g., moderators, discrepancies between *results* and *conclusion/discussion* ($n = 29$); or analysis-related issues, e.g., solely factorial analyses, articles that presented relationships as being significant but had corresponding significance values that were above .10 ($n = 32$)).

2.3. Analysis

For each article, we coded the following: a *unique number*, *reference data* according to the APA formatting style, *type of industry* in which the study was conducted, *type of methodology* used to conduct the research,

number of participants that participated in the study, and *aim* of the study. Each article was dissected in terms of the (hypothesized) relationship between dependent and independent variables by one of the authors. Each relationship was assigned a row in a matrix, which described the relationship between two variables (e.g., the influence of *safety climate* on *safety performance*). For mediating relationships, we split the hypothesized relationship and created an additional line. For example, the relationship between variables A and C, which was mediated by variable B, was transformed into two rows, in which one row was concerned with the relationship between variables A and B, and the other row was concerned with the relationship between variables B and C. Finally, we assessed the effect each independent variable had on the dependent variable(s) (positive, negative, or inconclusive), and what the type of relationship was (correlation, regression, different). The indication about the type of relationship was not further included in the analysis. As such, numbers in the result section do not indicate causal relationships between variables. They do represent the number of times a positive, negative, or insignificant relation between two variables was found in the analyzed studies. A special type of relationship not anticipated at first was the (inverted) u-shaped relationship. These relationships are coded as '(−)U'. Relationships from quantitative studies were coded as inconclusive if the statistical significance was above the generally accepted threshold of .05. For relationships from qualitative studies we followed the conclusions presented in the article. Studies with significance levels above .10, in which the authors report on significant relationships, were excluded entirely from the dataset. From our corpus of 176 articles we initially extracted 2,202 relations. We excluded 96 relationships because they did not match the aim of our review (e.g., based on information about type of industry and regions) or involved moderating relationships and variables.

Within the 2,106 relationships, 1,479 unique variables names were identified, many of which were only unique in name but had similar meanings (e.g., *occupational accident* and *work accident*). To reduce clutter, we recoded variables with similar meanings into a new variable name. Using Microsoft Excel, we extracted 466 unique dependent and 1,013 unique independent variable values. Through a process of bottom-up coding two of the authors categorized these unique variables into 84 variables, categorized into 20 categories, which together formed seven clusters (see Fig. 2). Some of the variables (3%) proved difficult to categorize. Therefore, we omitted 29 dependent and 97 independent variables from the final analysis, resulting in a total of 1,946 fully coded relationships between variables in 174 articles.

3. Results

We will begin by presenting the relationships between the seven clusters, followed by a more in-depth analysis of the results per cluster and their corresponding categories. An overview of all relationships between clusters is presented in Table 1. It is noteworthy that in terms of dependent (on the horizontal axis) and independent variables (on the vertical axis), the clusters of safety outcomes and performance together account for 63% of all dependent variables, while the clusters of performance, work(place) characteristics & circumstances, climate & culture, management & colleagues, and employee demographics prevail (96%) among the independent clusters. All corresponding references are included in Appendix A.

Below we will present the results on a more specific level per cluster, starting with the safety outcomes and performance of the more dependent clusters. However, to avoid presenting the same information twice, we will focus on the independent clusters: performance, work(place) characteristics & circumstances, climate & culture, management & colleagues, employee demographics, and external. For each of these clusters we will start by presenting the number of relationships with the dependent clusters of safety outcomes and performance. This may cause that some relations between independent clusters are not described in more detail, for example the 18 relations between the external cluster and the climate & culture cluster. The cluster descriptions will be followed by a summary in a table, providing the number of relationships and their nature per variable. Finally, we will highlight the most promising results per category.

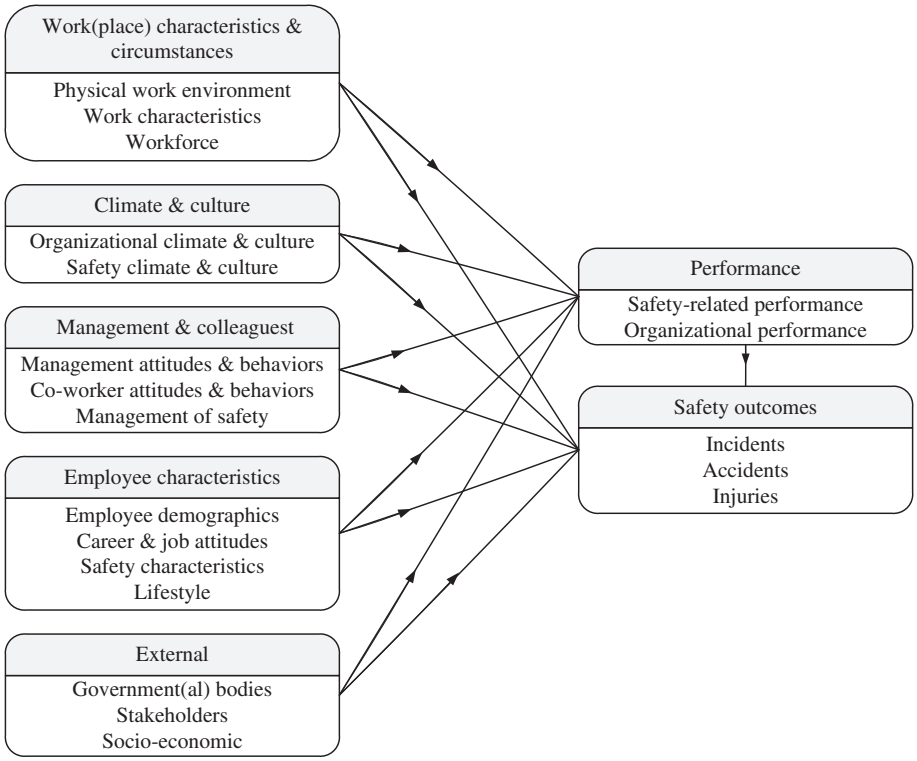

Fig. 2. Clusters and their associated categories. * Note: the term 'Safety outcomes' refers to negative events in the form of incidents, accidents, or injuries.

Table 1
Relationships between variables at the cluster level. Dependent clusters on the horizontal axis, independent clusters on the vertical axis.

	Safety outcomes[a]	Performance	Work(place) char. & circumstances	Climate & culture	Management & colleagues	Employee demographics	External	Total
Safety outcomes[a]	13	3	4	3	7	2	1	33
Performance	54	28	10	7	7	11	1	118
Work(place) char. & circumstances	254	112	61	14	37	46	1	525
Climate & culture	23	40	8	7	9	22	1	110
Management & colleagues	167	247	33	31	134	70	15	697
Employee demographics	174	103	29	27	37	52	1	423
External	12	5	2	18	3	0	0	40
Total	697	538	147	107	234	203	20	1,946

Note: This table also shows relationships within clusters, i.e., different variables grouped in the same cluster that have been related in included articles.
[a] The term 'Safety outcomes' refers to negative events in the form of incidents, accidents, or injuries.

3.1. Safety outcomes

The most prevalent dependent cluster turns out to be safety outcomes, accounting for over a third of all dependent variables. Within this cluster, we see that research is most concerned with the categories injuries and fatalities (56%) and accidents (31%), and less with incidents (13%).

The most prominent cluster related to safety outcomes, with 254 relationships, was work(place) characteristics & circumstances, followed by the cluster of employee demographics, which accounted for 174 relationships. The management & colleagues cluster accounted for 167 relationships with safety outcomes, while the performance cluster accounted for only 54 relationships. Finally, the clusters climate & culture and external together accounted for 35 of the relationships with safety outcomes. It is worth mentioning that over half of the relationships in the climate & culture cluster are accounted for by the variable safety climate, with 13 relations.

3.2. Performance

The performance cluster plays both a dependent and an independent role in safety research. The relationships between the performance variables and the safety outcomes cluster are depicted in Table 2. Our review found 28 negative relationships between the category of *safety-related performance* and the cluster safety outcomes, 4 positive relationships, and 14 relationships that did not reach significance. The relationships in this cluster are centered around the variables safety performance, safety compliance, and safety participation, all of which fall into the *safety-related performance* category. However, Personal Protective Equipment (PPE) use was hardly ever mentioned.

As a dependent variable, the category of *safety-related performance* accounts for the vast majority of relationships ($n = 492$), while the category *organizational performance* accounts for only 46 relationships.

Table 2
Relationships between performance and safety outcomes.

Performance	Safety outcomes[a]		
	+	−	*ns*
Safety-related performance	*4*	*28*	*14*
Safety performance	0	6	2
PPE use	0	4	0
Safety compliance	1	9	3
Safety participation	3	9	9
Organizational performance	*3*	*3*	*2*
Organizational performance	0	0	0
Financial performance	1	0	1
(Employee) work performance	2	1	0
Organizational quality performance	0	1	0
Production performance	0	1	1
Environmental performance	0	0	0
Total	*7*	*31*	*16*

[a] Note: the term 'Safety outcomes' refers to negative events in the form of incidents, accidents, or injuries.

Performance is mostly studied in relation to the categories of *management of safety*, *management attitudes & behaviors*, *work characteristics*, *safety climate & culture*, and (*employee*) *safety characteristics*. Combined, these categories account for 66% of all relationships with performance. As depicted in Table 2, the category of safety-related performance indicates that most of the relations with safety outcomes are negative, with 28 out of a total 46 relationships resulting in fewer negative events in the form of incidents, accidents, or injuries. Out of the 46 relationships only four relationships result in more incidents, accident, or injuries. A total of 14 relationships are found to be non-significant. Below, the relationship between the more independent variables and the clusters of safety outcomes and performance will be further discussed.

3.3. Work(place) characteristics & circumstances

The cluster of work(place) characteristics & circumstances was related 254 times to safety outcomes and 112 times to performance. The cluster consisted of the categories: *physical work environment*, *work characteristics*, and *workforce*. The numbers of relationships between the variables in these categories, safety outcomes, and performance are depicted in Table 3.

Table 3
Relationships between work(place) characteristics & circumstances, safety outcomes & performance.

Work(place) characteristics & circumstances	Safety outcomes[a]			Performance		
	+	−	*ns*	+	−	*ns*
Physical work environment	*29*	*12*	*57*	*10*	*2*	*17*
Company size	3	2	0	3	1	8
Workplace hazards	7	0	7	1	0	2
(safety) equipment	4	5	28	2	0	2
Safety of equipment	5	3	11	4	0	1
Physical workplace (design)	10	2	11	0	1	4
Work characteristics	*52*	*23*	*62*	*20*	*11*	*21*
Work characteristics	1	0	4	0	0	1
Perceived work(place) safety	0	0	2	0	4	1
Goal setting	1	2	2	3	0	2
Stress	3	0	1	0	0	0
Shifts	5	5	14	0	1	0
Working hours	11	0	1	0	0	1
Job demands	11	0	9	1	0	2
Job resources	2	13	10	8	0	5
Production (pressure)	16	2	12	1	6	8
Task clarity	1	0	1	1	0	1
(Safety) control	1	1	6	6	0	0
Workforce	*6*	*3*	*10*	*4*	*2*	*25*
Contract type	0	0	0	0	1	8
Job level	0	2	1	0	1	4
Workforce quantity	0	1	4	0	0	0
Workforce composition	4	0	1	0	0	7
Unions	1	0	3	3	0	6
HR	1	0	1	1	0	0
Total	*87*	*38*	*129*	*34*	*15*	*63*

[a] Note: the term 'Safety outcomes' refers to negative events in the form of incidents, accidents, or injuries.

3.3.1. Physical work environment

The category *physical work environment* accounted for a total of 98 relationships with the cluster negative safety outcomes and 29 relationships with the performance cluster. Looking at the individual variables in this category, one can see that the size of the company does not seem to matter in relation to either outcomes or performance. Workplace hazards clearly affect negative safety outcomes; however, the relationship with performance is less clear. In this category, (safety) equipment is studied most often, although the majority of the relationships fail to reach significance. However, the safety of equipment seems important for performance. The physical workplace (design) mainly seems to increase negative safety outcomes.

3.3.2. Work characteristics

The category *work characteristics* was related 137 times to negative safety outcomes and 52 times to performance. In this category, six variables stand out. The relationship between shiftwork and negative safety outcomes is heavily studied, although its direction remains unclear. Working hours are positively related to negative safety outcomes, as are job demands and production pressure. Job resources are negatively related to negative safety outcomes, and they are positively related to performance. The control employees have over their own work and safety is positively related to performance.

3.3.3. Workforce

The category *workforce* has been related 19 times to safety outcomes and 31 times to performance. The majority of these relationships are not significant. Contract type does not seem to be related to performance, while relationships with outcomes are lacking overall. Workforce composition is mostly positively related to outcomes, while it does not affect performance. The majority of relationships among unions, outcomes, and performance are not significant.

3.4. Climate & culture

A total of 23 relationships were found between the cluster climate & culture and safety outcomes, and 40 relationships were found between climate & culture and performance. The cluster consists of the categories *organizational climate & culture* and *safety climate* & culture. The number of relationships between the variables in each category and the clusters safety outcomes and performance are depicted in Table 4.

Looking at the category *organizational climate & culture*, most relationships are found between climate and outcomes ($n = 9$). While not well established, most of these relationships are negative. With a total of 36 relationships, safety climate is by far the most studied variable in the *safety climate & culture* category. The 25 positive relationships between safety climate and performance particularly stand out.

3.5. Management & colleagues

The cluster management & colleagues was related to the cluster safety outcomes 167 times, and with the performance cluster 247 times. The management & colleagues cluster consisted of the categories *management attitudes & behaviors*, *co-worker attitudes & behaviors*, and *management of safety*. The numbers of relationships between the variables in each category, safety outcomes, and performance are depicted in Table 5.

3.5.1. Management attitudes & behaviors

The *management attitudes & behaviors* category was related 43 times to the safety outcomes cluster, and 80 times to the performance cluster. Two variables in this category stand out. Concerning the relationships between leadership (style) and outcomes, it is striking that most of them are not significant, while the majority of the relationships with performance are positive. The relationship between management attitudes and performance is studied intensively, and all of the relationships that reach significance are positive.

3.5.2. Co-worker attitudes & behaviors

The category *co-worker attitudes & behaviors* was related 12 times to safety outcomes, and 17 times to performance. Interestingly, no positive relationships were found between the category *co-worker attitudes & behaviors* and outcomes, and no negative relationships with performance were found.

3.5.3. Management of safety

The majority of relationships in this cluster could be attributed to the *management of safety* category, as it was related 112 times to safety outcomes, and 150 times to performance. Six variables stand out in terms of their numbers of relations. Inspections are predominately negatively related to outcomes, while their relationship with performance is mostly positive. Surprisingly, most relationships between safety representation and outcomes are not significant. The majority of the relationships among rewards, outcomes and performance are not significant. Accident reducing measures are negatively related to outcomes and positively related to performance. Two of the most represented variables are training and (safety) communication. Both are mostly positively related to performance.

Table 4
Relationships between climate & culture, safety outcomes & performance.

Climate & culture	Safety outcomes[a]			Performance		
	+	−	*ns*	+	−	*ns*
Organizational climate & culture	*0*	*5*	*4*	*2*	*0*	*0*
Organizational climate	0	5	4	1	0	0
Organizational culture	0	0	0	1	0	0
Safety climate & culture	*2*	*6*	*6*	*29*	*1*	*8*
Safety climate	1	6	6	25	1	7
Safety culture	1	0	0	4	0	1
Total	*2*	*11*	*10*	*31*	*1*	*8*

[a] Note: the term 'Safety outcomes' refers to negative events in the form of incidents, accidents, or injuries.

Table 5
Relationships between management & colleagues, safety outcomes & performance.

Management & colleagues	Safety outcomes[a]			Performance		
	+	−	*ns*	+	−	*ns*
Management attitudes & behaviors	*4*	*15*	*24*	*44*	*1*	*35*
Leadership (style)	0	3	14	14	1	8
Management attitudes	2	5	5	23	0	21
Management behaviors	2	3	4	5	0	3
Safety importance for management	0	4	1	2	0	3
Co-worker attitudes & behaviors	*0*	*4*	*8*	*8*	*0*	*9*
Co-worker attitudes	0	2	3	5	0	6
Co-worker behaviors	0	2	5	3	0	3
Management of safety	*12*	*39*	*61*	*85*	*7*	*58*
Management of safety	2	2	0	3	0	2
Inspections	2	7	5	8	2	6
Accident analysis & record keeping	1	3	2	3	0	5
Safety representation	3	1	16	2	0	4
Sanctions	0	1	0	2	2	1
Rewards	1	5	7	3	0	9
Accident reducing measures	0	5	8	6	1	3
Training	1	5	11	15	1	10
(safety) Communication	2	8	6	28	1	6
Safety policies & procedures	0	1	1	10	0	4
(safety) Meetings & activities	0	1	5	5	0	8
Total	*16*	*58*	*93*	*137*	*8*	*102*

[a] Note: the term 'Safety outcomes' refers to negative events in the form of incidents, accidents, or injuries.

3.6. Employee demographics

Our review found a total of 174 relationships between the cluster employee demographics and safety outcomes, and it found 103 relationships with performance. This cluster consists of the categories *employee demographics*, *career & job attitudes*, *safety characteristics*, and *lifestyle*. The number of relationships between the variables in each category, safety outcomes, and performance are depicted in Table 6.

3.6.1. Employee demographics

The *employee demographics* category was related 55 times to the safety outcomes cluster and 30 times to the performance cluster. The relationship between age and outcomes has been heavily studied. Concerning gender, the results for both outcomes and performance are inconclusive, with no clear majority of positive or negative relations. The relationship between disabilities and performance seems to be understudied, as no research in our sample has discussed the relationship between the two variables.

3.6.2. Career & job attitudes

The category *career & job attitudes* was related 72 times to safety outcomes and 28 times to performance. The two variables tenure/experience and trust are frequently studied in relation to both outcomes and performance. While tenure/experience is mostly negatively related to outcomes, and mostly positively related to performance, it should be noted that, again, a U-shaped relationship was found between tenure/experience and performance in one study. For the relationship between trust and outcomes, the results seem inconclusive as both positive and negative results are found, while the relationship between trust and performance is mostly positive.

3.6.3. Safety characteristics

The category *safety characteristics* was related 20 times to safety outcomes and 37 times to performance. The focus in this category is on the relationship between safety knowledge (sharing) and performance. No fewer than 15 positive relationships were found, indicating that the more safety knowledge within the organization, the better the performance. The same holds for (safety) motivation, which was positively related to performance nine times. It is striking that we failed to find any studies relating responsibility and performance.

3.6.4. Lifestyle

Just over 10% of all relationships in this cluster were accounted for by the category *lifestyle*, making it an understudied topic. This category was related 27 times to safety outcomes, and just 8 times to performance.

Table 6
Relationships between employee demographics, safety outcomes & performance.

Employee demographics	Safety outcomes[a]			Performance		
	+	−	*ns*	+	−	*ns*
Employee demographics	*14*	*24*	*17*	*15*	*2*	*13*
Age	7	8[b]	12	3	1	6
Gender (female)	3	3	1	0	0	2
Education	2	4	1	3	1	3
Disabilities	2	0	2	0	0	0
Psychophysical states	0	9	1	9	0	2
Career & job attitudes	*15*	*29*	*28*	*16*	*1*	*11*
Tenure/experience	9	18	16	6[c]	1	7
Employee work attitudes	0	3	3	4	0	1
Trust	6	8	9	6	0	3
Safety characteristics	*5*	*3*	*12*	*26*	*2*	*9*
Employee safety attitudes	1	1	4	2	0	1
(safety) Motivation	1	0	4	9	1	5
Safety knowledge (sharing)	2	1	2	15	1	3
Responsibility	1	1	2	0	0	0
Lifestyle	*8*	*5*	*14*	*4*	*2*	*2*
Work-life balance	0	3	2	2	0	0
Marital status	0	0	3	1	0	0
Children	1	0	0	0	0	2
Lifestyle	2	2	7	1	0	0
Lifestyle disorders & substance abuse	5	0	2	0	2	0
Total	*42*	*61*	*71*	*61*	*7*	*35*

[a] Note: the term 'Safety outcomes' refers to negative events in the form of incidents, accidents, or injuries.
[b] Age 1 time–U-shaped relationship with outcomes.
[c] Tenure/experience 1 time U-shaped relationship with performance.

Table 7
Relationships between external, safety outcomes & performance.

External	Safety outcomes[a]			Performance		
	+	−	*ns*	+	−	*ns*
Government(al) bodies	*2*	*1*	*0*	*0*	*0*	*3*
Law & legislation	1	0	0	0	0	3
Government(al) bodies	1	1	0	0	0	0
Stakeholders	*0*	*0*	*0*	*0*	*0*	*0*
Client involvement	0	0	0	0	0	0
Customer satisfaction	0	0	0	0	0	0
Socio-economic	*3*	*4*	*2*	*1*	*0*	*1*
Economic factors	3	2	0	1	0	1
Insurance & costs of safety	0	2	2	0	0	0
Total	*5*	*5*	*2*	*1*	*0*	*4*

[a] Note: the term 'Safety outcomes' refers to negative events in the form of incidents, accidents, or injuries.

3.7. External

Our review yielded only 12 relationships between the external cluster and safety outcomes, and a mere five relationships with performance. The external cluster consists of the categories *government(al) bodies*, *stakeholders*, and *socio-economic*. The number of relationships between the variables in each category, safety outcomes, and performance are depicted in Table 7.

The category *government(al) bodies* was related three times to safety outcomes and three times to performance. Laws & legislation have not been successfully related to performance and only once to safety outcomes. The category *stakeholders* was not related to either safety outcomes or performance. As both variables in the *stakeholders* category weren't linked to either safety outcomes or performance it is of added value to include these in Table 7. However, the overall analysis revealed that these variables were present in the literature, as the variable *client involvement* was related 17 times to the variable *safety climate*, and the variables *injury rate*, *safety participation*, and *safety climate* were each related one time to the variable *customer satisfaction*. For both the sake of completeness, and uncovering it as a potential gap in research we included these variables nevertheless. Lastly, the category of *socio-economic* variables is the most prominent of the three. However, the focus is rather one-sided in favor of outcomes.

The most prevalent results are summarized in the figure below, where categories and the number of relationships with performance and outcomes are depicted (Fig. 3).

4. Discussion

The results demonstrate that the majority of published research on occupational health and safety from 1980 to 2015 has focused on safety outcomes and performance. The studied relationships were not equally distributed among the independent clusters with predictors. The majority of research focused on the effects of management & colleagues, work(place) characteristics and circumstances, and employee demographics on safety outcomes and performance, and less on climate & culture and external variables. In the three sections that follow we will discuss the most important findings of this study. First, we will discuss those variables about which there is some degree of consensus. Second,

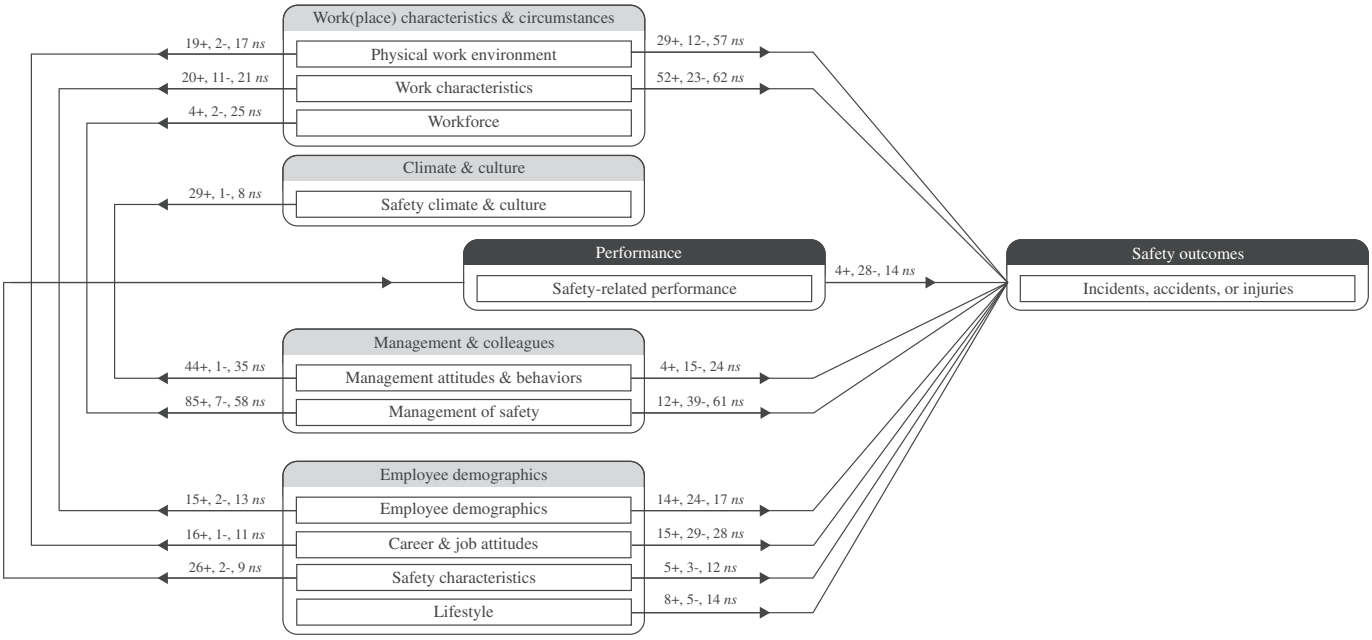

Fig. 3. The most prevalent categories related to performance and safety outcomes and their corresponding number of positive (+), negative (−) and non-significant (*ns*) relations. * Note: the term 'Safety outcomes' refers to negative events in the form of incidents, accidents, or injuries.

we will discuss those variables whose effects are cause for debate. Third, we will discuss possible gaps that our review has brought to light.

4.1. Consensus in safety research

We have set the threshold for consensus at a two-thirds majority supporting one of the three possible outcomes: positive relationship, negative relationship, or non-significant relationship. Here we will briefly discuss those variables that have been investigated more than five times. We will focus particularly on those variables on which organizations –to some extent– can exert influence.

The majority of relationships between safety performance and outcomes were negative, indicating that more or better safety performance is related to fewer incidents, accidents, and injuries. This finding is in agreement with the meta-analysis by Christian et al. (2009). The same holds for the relationships between safety compliance and outcomes, which is in line with research from other fields (e.g., Neal et al., 2000). Working hours and lifestyle disorders were positively related to negative safety outcomes. This positive relationship indicates an increase in incidents, accidents, or injuries if the variables increase or are more present. These relationships are not surprising, as it can be expected that more or longer working hours will result in a higher chance of being affected by negative safety outcomes – as is underlined by Wagstaff and Lie (2011) – as well as the negative nature of lifestyle disorders (e.g., Melamed & Oksenberg, 2002).

The remaining relationships were mostly related to performance, and all relationship directions were positive. Organizations that want to improve performance should therefore focus on (safety) control, safety climate, management behaviors, (safety) communication, safety policies & procedures, psychophysical states, and safety knowledge (sharing). The category psychophysical states was also negatively related to safety outcomes, indicating a reduction in incidents, accidents, or injuries.

4.2. Debates in safety research

Various variables show inconsistent or contradictory effects in safety research and do not reveal a consensus. Our review yielded 36 variables related to safety outcomes or performance that were studied more than five times but did not result in clear findings. The majority of these relationships are subject to debate, as the results of the relevant studies are either positive or negative and non-significant.

The relationship between safety participation and outcomes is not as clear as that between safety performance and safety compliance. Most studies either found a negative relationship – indicating that more or higher safety participation leads to fewer incidents, accidents or injuries – or a non-significant relationship.

Looking at the cluster of work(place) characteristics & circumstances, workplace hazards tend to be positively related to safety outcomes, although an equal number of relationships failed to reach significance. The same is clear for the relationship between physical workplace (design) and outcomes. The relationship between the safety of equipment and outcomes is mostly non-significant. One possible explanation is offered by Saari (1982), who found that although machine guarding initially reduced the number of accidents, it did not overcome accidents that occurred during maintenance and repair tasks, "when machine guarding is not easily possible" (Saari, 1982, p. 91).

Looking at the effects of shifts on safety outcomes, the results are mostly non-significant. However, we also found an equal number of positive and negative relationships. A more in-depth comparison of the different types of shifts might clarify the nature of this relationship,

as research found that rotating shifts have more adverse effects than permanent night shifts (Muecke, 2005). Ignoring the number of relationships that failed to reach significance, there seem to be fairly strong positive and negative relationships between job demands & resources and outcomes, and between job resources and performance. It would be useful to further explore the usability of job demands and resources in addressing occupational safety, as its effects reach beyond safety outcomes and performance (Bakker & Demerouti, 2007). The relationships among production (pressure), safety outcomes, and performance are inconclusive. Neglecting the non-significant results, production (pressure) seems to increase negative safety outcomes and reduce performance.

Although the link between safety climate and performance is well established, this is not the case for safety outcomes. The results illustrate a negative relationship with safety outcomes, although an equal number of non-significant relationships were found. This ambiguity is in agreement with research in other fields, where researchers have not only found that safety climate might act as a mediator between more distal elements and safety outcomes (e.g., Wallace, Popp, & Mondore, 2006) but also that the mediating role of the safety climate is very limited (e.g., DeJoy, Schaffer, Wilson, Vandenberg, & Butts, 2004).

In the management & colleagues cluster, many relationships are subject to debate. Considering the influence of management attitudes and behaviors, the field could definitely benefit from additional research. Whereas the relationship with safety outcomes is truly unclear, the findings regarding performance, leadership (style) and management attitudes tend to be more unanimous and indicate favorable influences on performance. The influence of co-workers on performance is almost equally distributed between positive and non-significant relations. Based on our results, it can be expected that inspections are good for the prevention of negative safety outcomes and have a positive influence on performance, although there are some contradictory findings. The effect of rewards on negative safety outcomes is mostly insignificant, in line with the relationship between rewards and performance. This might be explained by the very strict conditions under which rewards are effective (e.g., Schwartz & Sharpe, 2010). Surprisingly, accident-reducing measures are more likely to be associated with good performance than with the prevention of negative safety outcomes.

Although our results illustrate that there is no clear consensus on the relationship between training and performance, training tends to have a positive effect on performance. Whereas the relationship between (safety) communication and performance was rather clear, this was not the case for safety communication's relationship with safety outcomes. The effect of (safety) meetings & activities on performance is unclear, as most of the found relationships did not reach significance. The remaining relationships in our review indicate a positive effect of (safety) meetings & activities on performance.

Last, we will discuss the cluster of employee characteristics. One study might explain the seemingly inconclusive results between age and negative safety outcomes and performance. Siu, Phillips, and Leung (2003) found that "age has a curvilinear effect on occupational injuries in which the frequency of injury increases with age first, then declines." Gender does not seem to affect safety outcomes, as there are as many positive as negative relationships. Results concerning the variable tenure/experience, and its relationships with safety outcomes and performance, seem inconclusive at first. However, similar to the age variable relationship, Siu et al. (2003) found a curvilinear relationship with performance, indicating that performance would decrease at first and then increase with more tenure/experience. However, this relationship has not yet been examined for safety outcomes, so the lack of clarity for this relationship remains. Future research should further examine the relationship between (safety) motivation and performance, which, based on our results, is expected to be positive.

4.3. Gaps

Our review brought to light 21 variables that have not, or have hardly, been studied in relation to either negative safety outcomes or performance. Two variables have not been directly related to either outcomes or performance: client involvement and customer satisfaction. Client involvement has been successfully related to safety climate (Votano & Sunindijo, 2014). Future research should examine the possible effects that client involvement could have on performance and safety outcomes. Customer satisfaction might have an indirect influence but is more likely to be considered a dependent variable. We found that customer satisfaction was studied as a dependent variable in relation to injury rates, safety participation, and safety climate, with mixed results.

The direct relationships between five variables and safety outcomes appear to lack investigation. These variables are contract type, safety culture, sanctions, children, and law & legislation. Of these five, only the variables contract type and sanctions are directly controllable by the organization, although it is strange that the relationship between safety culture and safety outcomes and the relationship between law & legislation and safety outcomes lack research. Sanctions seem to be one of the most promising variables, as it has been successfully related to occupational safety through safety performance (e.g., Hasan & Jha, 2013).

The relationship between performance and 14 variables appears to have been scarcely investigated. These variables are organizational culture, work characteristics, stress, shifts, working hours, workforce quantity, HR, organizational climate, disabilities, responsibility, marital status, lifestyle, government(al) bodies, and insurance & costs of safety. Of these variables, work characteristics, working hours, and responsibility seem to be the most promising leads for future research as they can be dealt with to some extent by the organization. The concept of responsibility seems particularly interesting, as previous research in the education field associated increased responsibility with increased levels of self-confidence and perceived capability (Clouder, 2009).

4.4. Limitations

The conducted literature review has some limitations that will be discussed in relation to the steps conducted in this study. With regard to the literature search and selection of articles some potential limitations need to be addressed. In finding appropriate literature, the choice was made to use online databases only. This might have resulted in a shifted distribution of articles over the years, due to older publications that might not be digitally available. On the other hand, and this was our main rationale to use online publications only, it increases the replicability and controllability of this study as online articles are easily accessible to other researchers. Our literature search did not include keywords like 'injury' and 'injuries,' that might be common in this or adjoining fields. This deliberate choice was made in order to direct the focus towards determinants of safety, instead of the wide range of potential occupational safety outcomes such as injuries, near misses, accidents, incidents, or lost-time rates. Due to the sheer number of publications it was not feasible to include each and every study that was conducted across the four industries of interest. However, the selection method applied in this review was thorough and transparent, and it provides other scholars with the opportunity to perform complementary reviews. Limiting the included literature to four specific domains lead to the absence of certain relationships that have been established in other domains. The gaps identified in our research are purely based on gaps present in the included literature. With regard to the analysis of the data, a potential limitation is related to the lack of interrater reliability in selecting articles based on their full text, and the extraction of individual relationships from the articles. Instead, potentially problematic cases were discussed and decided upon by two of the authors together. The same holds true for the recoding of extracted variables, as this whole process was done by two of the authors together. In the process

of recoding variables from the bottom up, we have exchanged some depth and accuracy in favor of clarity and concision. In analyzing the data, differences in power and magnitude across different studies were not taken into account. A study performed with as few as 10 participants has the same 'power' assigned to it as a study with over 1000 participants. Although this might have implications when looking for specific solutions, it does capture the overall orientation in the safety literature. Our method of analysis did not allow for the inclusion of moderating variables or relationships. Although this might have some impact on the results, we believe the impact to be small due to the small number of moderating variables that were excluded. Finally, although we report the number of positive, negative, and non-significant relationships found, it must be noted that these are underestimates of the total number of relationships in the literature. In particular, the latter – non-significant relations – will suffer from both underreporting and underpublishing.

4.5. Practical applications

The results of this systematic review provide several practical leads for safety practitioners. First, there is an increasing need among practitioners for grounded knowledge about the field of occupational safety. Our results provide practitioners with a comprehensive overview of the elements present in literature, which serves as good starting point for getting up to speed with the field. Second, the comprehensive overview of the elements and the nature of their relation with negative safety outcomes and performance, provides practitioners with a number of useful leads in the development and evaluation of interventions aimed at improving occupational safety.

5. Conclusion

This systematic review mapped scientific research from 1980 to 2015 in the domains of construction, (offshore) petro chemistry, warehouses, and manufacturing. In doing so, it showed that research is focused on improving safety outcomes and performance through variables associated with work(place) characteristics & circumstances, climate & culture, management & colleagues, employee demographics, and external factors.

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Appendix A. Reference materials

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