Multilevel Safety Climate in the UK Rail Industry:

A Cross Validation of the Zohar and Luria MSC Scale

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1. Introduction

The railway maintenance industry involves complex human machine interactions and safety critical operations with considerable risks for health and safety of its employees (Mills, 2005; Morgan, Abbott, Furness, & Ramsay, 2016), including maintenance of railway track, overhead lines, signalling systems, power supplies, security systems and inspection of rail assets (e.g., stations and bridges). Despite a downward trend in injury rates in UK workplaces[1], accident occurrence in the rail industry remains an on-going issue (Evans, 2011). Results from the RSSB Annual Safety Performance Report for 2016/17, show that there were 164 major injuries to members of the UK rail workforce during this period.

Network Rail (2017) has recently identified three principal safety risks for rail workers: being hit by a train, on-track plant, or a road rail vehicle; electrocution from overhead power lines or conductor rails; and trips and falls. The potential accidents and injuries associated with these operations may present significant costs for organisations and individual workers. The seriousness of these events, alongside injury rates consistently above zero, provides a clear rationale for further research to identify, examine and understand the factors that may help to reduce the influence of accident risk in railway work (Morgan et al., 2016). Organizations in

[1] In 2017, the government agency "Network Rail" reported a general decrement for two principal normalized accident indices: FWI and LTIFR. FWI index provides an estimation of "Fatalities and Weighted Injuries" normalised per one million hours worked. This index passed from 0.157 in 2013/14 to 0.079 in 2015/16. On the other hand, the second index provides a estimation of the "Lost Time Injury Frequency Rate" (LTIFR) normalised per one hundred thousand hours worked. Again, data provided by Network Rail showed that LTIFR decreased as well from 0.585 in 2013/14 to 0.492 in 2015/16. This data is consultable on-line: http://www.networkrail.co.uk/

the railway industry are keen to find ways in which to reduce accidents and associated costs, and as such have attempted to evaluate and improve safety climate. This effort has been stimulated by findings from studies conducted in allied safety-critical domains which suggest that safety climate is positively associated with safety behaviour and accident reduction.

In the railway industry, the interaction between human and organizational factors plays a crucial role in maintaining safe work operations (Morgan et al., 2016). Although major accidents are often attributed to human error alone, it has been argued that organisations are ultimately responsible because they shape the safety climate within which railway workers operate (Itoh, Andersen, & Seki, 2004; Reason, 1997). The safety climate includes the way in which railway workers perceive safety values, priorities, procedures, and conduct themselves in a safe manner when carrying out their operational activities (Morrow, McGonagle, Dove-Steinkamp, Walker Jr, Marmet, & Barnes-Farrell, 2010). Empirical research in the railway industry, suggest safety climate models might be a useful supplement to the traditional analysis of accident and incident data trends (Itoh et al. 2004; Morgan et al., 2016), to proactively identify those areas in the organizations that might be particularly vulnerable to the latent risks associated with deficiencies of safety systems (Griffin & Curcuruto, 2016; Reason, 2008). Safety climate is particularly important when workplace accidents is relatively rare event, when accident/incident reporting is incomplete, or, more generally, whenever reporting systems are applied as retrospective indices of safety levels (Itoh et al., 2004).

Despite extensive research investigating safety climate, the exploration of its factor structure and the validity of specific safety climate scales have not been tested in a sample of UK rail workers. In a safety critical context like the rail industry it is important to assess and report valid dimensions that correspond to the critical aspects of safety climate in this specific context (Zohar, 2010). If these dimensions are not measured appropriately, organizational interventions and recommendations might not align with the most important aspects of safety for the situations . This lack of alignment may reduce the effectiveness of organizational safety management systems and efforts to improve safety. Therefore, the primary aim of the present research is to understand further the nature of safety climate in the rail industry by investigating its internal factor composition at different organizational levels (managerial and group levels).

The second aim is to contribute to the validation of Zohar and Luria's Multilevel Safety Climate scale (acronym: MSC; 2005) in a UK based rail infrastructure worker sample. This scale considers two distinct levels of safety climate in complex industrial organizations (Brondino, Silva, & Pasini, 2012; Griffin & Curcuruto, 2016), and it has been widely used in previous safety research across a broad range of industrial sectors (Huang, et al., 2017): a) organizational top management (Zohar, 1980); b) direct work supervisors (Zohar, 2000). Finally, in order to provide a broader understanding of safety climate in the rail industry, explore the nomological network of Zohar and Luria's scale by examining associations of the scale with validated psychometric measures that are relevant in safety, risk and health management in the workplace, such as: workers' safety priority (Kines et al., 2011); efficacy of safety systems (Kines et al., 2011); perceived organizational support (Edwards, Webster, Van Laar, Easton , 2008); reporting attitudes (Probst & Graso, 2013); risk propensity (Meertens & Lion, 2008); safety compliance and safety participation behaviours (Neal, Griffin & Hart, 2000); and workers' self-reported accident experience (Probst & Graso, 2013).

2. Safety climate in the rail industry

2.1. Conceptual foundations, definitions and distinctiveness of safety climate.

The construct of safety climate originates from the more general notion of organisational climate, which in organisational psychology is defined as the perceptions among employees of the value of safety in the organisation (Griffin & Curcuruto, 2016). Safety climate is often thought of as "shared perceptions with regard to safety policies, procedures and practices" (Zohar, 2011, p.143). Given that safety climate provides an insight into attitudes and perceptions about safety, positive safety climate can be associated with lower levels of worker engagement in unsafe behaviour (Hofmann & Stetzer, 1996) and higher levels of commitment to safety compliance, safety participation, and safety citizenship behaviours (Curcuruto & Griffin, 2018; Griffin & Neal, 2000; Hofmann, Morgerson, & Gerras, 2003). A large number of studies have identified the key organizational elements which support safety climate in the workplace. Systematic literature reviews and meta-analyses appoint to a stable cluster of organizational antecedents which are consistently associated with safety climate (Griffin & Curcuruto, 2016; Flin, Mearns, O'Connor, & Bryden, 2000; Nahrgang, Morgeson, & Hofmann, 2011), such as: management commitment (Fruhen, Mearns, Flin, & Kirwan, 2014); workforce involvement and participation (Curcuruto, Conchie, Mariani, & Violante, 2015); safety training (Neal, Griffin, & Hart, 2000); safety communication (Brondino, Payne, Bergman, 2012); safety management systems, policies and practices (Griffin et al., 2014).

Much of the research on safety climate overlaps with work on the allied construct safety culture, and the extent to which the two constructs can be differentiated has been the focus of scientific debate for many years (Flin et al., 2000; Griffin & Curcuruto, 2016; Guldenmund, 2010; 2000; Mearns, Flin, Gordon, & Fleming, 1998; Reason, 1997; Zohar, 1980). Both constructs emphasize the way safety is valued in the organization and describe the processes through which the meaning attached to safety influences safety outcomes in the organization (Griffin & Curcuruto, 2016). Many examples from research and practice show that the meaning of climate and culture is often conflated (Zohar, 2010). For example, numerous studies of safety culture use survey instruments that are more accurately defined as measures of safety climate (Mearns et al., 1998; Zohar, 2010). Many researchers agree that safety climate can be regarded as a “snapshot” of the state of safety, providing a cross-sectional indicator of the underlying safety culture of a work group, plant or organization (Brondino et al., 2012; Flin et al., 2000; Griffin & Neal., 2000). Griffin and Curcuruto (2016) noted that safety culture refers to the implicit safety values and assumptions that guide individuals’ work conduct, and safety climate refers to the priority of these values and assumptions at a given point in time as perceived by employees (Guldenmund, 2010; Zohar, 2010). Overall, assessing safety climate provides understanding current safety conditions in industries and organizations and provides insights into the factors that can be changed to improve safety . For these reasons, our present validation study focuses on the construct of safety climate. .

2.2 Safety climate assessment and outcomes for industries and organizations.

Safety climate is linked to a variety of safety-related outcomes (e.g. Barbaranelli, Petitta. & Probst, 2015; Beus et al., 2010; Clarke, 2006; DeJoy , 2004; Hofmann & Stetzer, 1996: Neal & Griffin, 2006). However, these links have not been consistent across all safety climate studies (Clarke, 2006). In addition, findings from studies exploring the factor structure of safety climate have also been mixed (Morrow et al., 2010). This equivocality is potentially due to the complex nature of safety climate, which is both a multilevel construct (i.e. applies at the group and organisational levels), and a multidimensional construct (i.e. comprising different elements such as management commitment and safety training practices) (Griffin & Curcuruto, 2016; Kines et al., 2011). This complexity might lead to inconsistent findings across, and sometimes within, industries (Clarke, 2006; Flin et al., 2000; Griffin & Curcuruto, 2016; Guldenmund, 2000; Huang et al., 2017).

Efforts to standardise and validate safety climate measures have been made in some industries including nuclear, electrical and trucking domains (Barbaranelli et al., 2016; Brondino et al., Griffin & Curcuruto, 2016). At the time of writing we are aware of only one study which has (indirectly) assessed the factor structure of a safety-climate-related questionnaire in the rail industry. Research conducted by Morrow et al, (2010) examined safety climate and safety behaviour in a sample of rail mechanics based in North America. Although their findings revealed three dimensions of safety climate: *management of safety, co-worker safety,* and *work-safety tension,* they utilised a non-standardised approach by combining items from a range of previous measures.

No studies to date have tested the validity of a safety climate measure for UK rail workers. This domain-specific research need is amplified further because the UK rail industry faces pressure to periodically report safety climate results to external regulators such as the Office of Rail and Road (ORR), Rail Safety Standards Board (RSSB) and Rail Accident Investigation Branch (RAIB).

2.3 Multilevel model of safety climate

Zohar and Luria (2005) suggest that safety climate should be considered as a multilevel construct, measured at various levels of a company such as the group and organisational level. They developed and tested the Multilevel Safety Climate Scale (MSC) using data collected from workers across the manufacturing industry. The results showed that safety climate can vary within and across companies working in the same industry. Subsequent studies and meta-analyses have revealed significant positive associations with safety behaviour at both the group (Curcuruto, Guglielmi, & Mariani, 2013; Mariani, Curcuruto, Matic, Sciacovelli, & Toderi, 2017; Johnson, 2007; Zohar, 2000) and organizational level (Brondino et al., 2012; Christian, Bradley, Wallace, & Burke, 2009; Huang et al., 2017; Nahrgang, Morgeson, & Hofmann, 2011).

The multilevel safety climate scale developed by Zohar and Luria (2005) comprises two measures, both containing 16 items. The organisation-level safety climate items measure perceptions of top management’s commitment to safety and the priority of safety when competing demands arise. The group-level items are concerned with assessing perceptions of the interaction between supervisors and group members, and whether or not supervisors highlight safety priority over competing demands, like production speed.

A small number of studies have attempted to validate the group safety climate tool (e.g., Huang et al., 2013a; Huang et al., 2013b; Huang et al., 2017; Johnson, 2007; Navarro et al., 2013) in different safety critical domains, producing contrasting results. Johnson (2007) conducted confirmatory factor analysis (CFA) on data from 292 heavy manufacturing organisations. Three factors emerged; *supervisor caring behaviour, supervisor compliance behaviour,* and supervisor *coaching behaviour*. Navarro et al. (2013) also attempted to validate the group safety climate measure using a sample of 566 nuclear industry workers, again using CFA. Although a single factor emerged as a superior model, in line with the original construct, it must be noted that the authors adapted the items to make them more nuclear safety-specific and also incorporated perceptions of group member practices and behaviours. More recently, a study by Huang et al, (2017) tested the MSC scale using an Item Response Theory method using data from 29,179 front line workers from 46 various industries, including manufacturing, construction and transportation. The analysis successfully reduced the original 32-item safety climate tool down to 8 or 4 item scales at each level.

2.4 Multilevel safety climate scale (MSC) in the rail industry: research aims and hypotheses

The mixed findings regarding the MSC factor structure across work domains suggests that determining the factor structure in specific contexts will ensure greater validity and utility for measurement, feedback, and intervention (Gao, Chan, Utama, & Zahoor, 2016). This study will provide useful insights into the multilevel safety climate scale in the rail industry sector, by conducting a systematic cross-validation process.

In the remaining part of this article, a cross-validation process for the MSC scale in a sample of maintenance workers in the rail industry is described. Empirical findings are presented in relation to complementary steps of validation in this industrial sector: (i) The investigation of the internal factor structure of the MSC scale in the rail industry through explorative factor analysis (EFA). This step was considered essential due to the absence of previous published validation studies on the MSC scale in the rail sector. ii) A confirmative test of the dimensionality of the MSC scale through confirmative factor analysis (CFA) and structural equation modelling (SEM). This validation step will verify the goodness of the factor structure emerged from the EFA analyses conducted in the previous validation step. Moreover, the emerged factor structure will be compared against other conceptual concurrent factor structures of the MSC scale, as described in former studies conducted in different industrial contexts. iii) A final step of construct validation involved the definition of a nomological network of the factors underlying the MSC scale in the rail industry.

For construct validation of the safety climate scale we investigated the nomological network of constructs expected to relate to safety climate based on various conceptual grounds (Curcuruto, Mearns, & Mariani, 2016; Judge, Erez, Bono, & Thoresen, 2003). It is important to show that safety climate dimensions are conceptually distinct and related to diverse constructs in predictable ways. In the present study, we investigate the nomological validity of the MSC scale by assessing the correlations of the climate dimensions with existing measures related to managerial safety dimensions (i.e. *safety priority; safety systems*) and organizational social support dimensions (i.e. perceived supervisor support; perceived peer support; perceived support to change).

In accordance with previous safety research literature, managerial safety dimensions (priorities and systems) (Neal & Griffin, 2006), and sources of social support in organizations (Mearns & Reader, 2008) are both expected to be positively associated with safety climate dimensions. On the one hand, safety systems and priorities directly communicate to the workforce the importance of safety values and safety related instances in the implementation of the work activities (Griffin & Neal, 2000). On the other hand, psychological mechanisms of social support in organizations have been discussed in the academic literature (Reader, Mearns, Lopes, & Kuha, 2017) as a way for the employees to expresses high levels of safety commitment that they perceive in their organization, by creating a supportive working environment for co-workers, supervisors and managers. This is a way to reciprocate the attention that they perceive to receive from company management with respect to their health and safety. Therefore, we advance a first research hypothesis on organizational factors associated with the MSC scale:

Research hypothesis H1). MSC scale dimensions will be positively related with existing measures of safety management dimensions (h1a) and sources of organizational social support (h1b).

In addition to managerial and organizational dimensions, past safety research has also considered the role of individual differences in shaping safety perceptions and activities in organizational settings (Christian, Bradley, Wallace & Burke., 2009). In our validation study, we will consider an expected positive association between safety climate and safety reporting attitudes, and the negative association with risk orientations of employees. Research findings suggest that in organizational contexts characterized by a positive safety climate, employees will develop more positive attitudes toward reporting issues and safety risks (Griffin & Curcuruto, 2016; Probst & Graso, 2013). Also, a previous meta-analytic study revealed negative associations between risk orientations or propensities and safety climate related dimensions (Christian et al., 2009). These findings suggest that organizations characterized by high levels of safety climate do not support risk oriented attitudes and actions in the implementation of work activities. In line with these reflections, we introduce the following hypothesis on the links between the MSC scale dimensions and individual difference factors.

Research hypothesis H2). MSC scale dimensions will be positively related with existing measures of employee safety reporting attitudes (h2a) and negatively associated with measures assessing employees risk orientations and propensities (h2b).

Moreover, the association of safety climate dimensions with safe work performance is an essential element for validating safety climate tools in new industrial contexts. Past safety research (Clarke, 2006; Christian et al., 2009; Griffin & Curcuruto, 2016) has emphasised the association of safety climate dimensions with two main categories of work conduct (Griffin & Neal, 2000): safety compliance and safety participation. Safety compliance refers to the behaviours that are about engaging in core safety tasks, such as compliance with the organisation's safety rules and regulations, and following safety procedures. On the other hand, safety participation refers to employee's voluntary participation in safety activities, which aims to contribute to the development of a supportive safety environment. Using longitudinal data, Neal and Griffin (2006) showed that safety performance had a lagged effect on the number of subsequent accidents, supporting the validity of this construct and demonstrating the importance of employees' behaviours in organisational safety outcomes. Thus, safety performance has been increasingly used as the criterion variable of safety climate research (e.g. Clarke & Ward, 2006;Griffin & Curcuruto, 2016; Mullen & Kelloway; 2009).

In line with past research, we aim to advance the following research hypothesis on the association of safety climate and safety performances.

Research hypothesis H3). MSC scale dimensions will be positively related with existing measures of employee safety compliance behaviour (h3a) and safety participation behaviour (h3b).

Finally, we intend to explore the relationship of the safety climate dimensions with accident indices from the rail industry. Recent studies (Payne, Bergman, Rodrıguez, Beus, & Henning, 2010) and literature reviews (Griffin & Curcuruto, 2016) report that high levels of safety climate are negatively associated with the occurrence of negative accident events, such as property damage and injuries. Therefore, our study investigates the relationship between safety climate factors in the railway industry and the experience of critical events for workers and organizations such as accident experiences and subsequent damage to people (injuries) and companies (property damages). In accordance with previous research, we expected to find a negative correlation between safety climate and accident events and their negative consequences. Therefore, we advance our fourth and last research hypothesis

Research hypothesis H4). MSC scale dimensions will be negatively associated with overall indices assessing workers' personal exposure to accident events (h4a) and accident damage (h4b) with negative consequences for people (injuries) and organizations (property damage; plant damage; damage to the equipment).

Figure 1 presents the original MSC factor structure, with the overall nomological network and the principal research hypotheses, in support of our contribution for the validation of the MSC scale in the railway industry.

Insert figure 1 here

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3. Method

3.1 Participants

The participants were employed by a safety critical infrastructure maintenance organisation in the UK. A total of 536 questionnaires were received and 8 were removed from the analysis due to incomplete responses. The present study retained data 528 participants (including direct and non-direct employees) from the rail department. This rail workforce is involved in safety critical operational work that includes; maintenance of railway track, overhead lines, signalling system, power supplies, security systems and inspection of rail assets (e.g. stations and bridges). The age of participants was as follows; 6.6% aged between 16-24, 29.9% aged between 25-34, 24.1% aged between 35-44, 25.9% aged between 45-54, 12.3% aged between 55-64 and 0.9% aged 65+ (missing entries, 0.2%). 86.9% of the participants were male and 12.7% were female. 40.5% of the sample reported being responsible for other staff and 57.6% having no responsibility for other staff (missing data, 1.9%).

3.2 Measures

3.2.1 MSC questionnaire.

Participants responded to items concerning safety in relation to top management (organizational level) and their direct line manager (group level) on a five-point Likert scale ranging from, never (1) to always (5) using the original questionnaire developed by Zohar and

Luria (2005). The organisational level section includes sixteen safety-related statements (α = .95) oriented towards 'top management' e.g. "Top management in this company tries to continually improve safety levels in each department". The group level section also consists of 16 items (α = .88) framed around the respondents' 'direct line manager' e.g. "My direct line manager frequently tells us about the hazards in our work". High scores on both sections represent superior safety at the organisational and group level.

3.2.2. Nomological network measures

In order to provide an additional contribution to the construct validation of the MSC questionnaire, we included in our questionnaire survey other measures related to relevant dimensions described in the safety literature.

Safety priority was measured with seven items from the homonym scale developed by Kines et al., (2011). All item responses were recorded on a four-point Likert scale ranging from strongly disagree (1) to strongly agree (4). An example of an item is: "We who work here never accept risk-taking even if the work schedule is tight". In the present sample, the reliability of the scale was good (α = .80).

Safety systems were evaluated using a specific seven-item scale developed by Kines et al., (2011). Respondents utilise a four-point Likert scale ranging from strongly disagree (1) to strongly agree (4). An example of an item is: "We who work here consider early planning for safety as meaningless". In the present sample, the reliability of the scale was good (α = .82). *Perceived supervisor support* was assessed using the five-item "managerial support" sub-scale included in the UK Health and Safety Executive's Management Standards Stress Indicator Tool (for origin information and psychometric properties see Edwards, Webster, Van Laar, & Easton, 2008). Participants were asked to rate different aspects of the relationship with their direct line manager on a scale ranging from never (1) to always (5). An example of an item is:

“My line manager encourages me at work”. The reliability of the scale results were very good (α = .87).

Perceived peer support was assessed using the four-item “peer support” sub-scale included in the UK Health and Safety Executive’s Management Standards Stress Indicator Tool (see Edwards et al., 2008). Participants were asked to rate different aspects of the work interactions with their colleagues on a scale ranging from never (1) to always (5). An example of an item is: “My colleagues are willing to listen to my work-related problems”. In the present sample, the reliability of the scale was good (α = .81).

Perceived support for organisational change was assessed using the three-item “change” sub-scale included in the UK Health and Safety Executive’s Management Standards Stress Indicator Tool (see Edwards et al., 2008). Participants were asked to respond to items concerning how well organisational change is managed and communicated at work.. Answers were collected on a scale ranging from never (1) to always (5). An example item is: “I have sufficient opportunities to question managers about change at work”. In the present sample, the reliability of the scale was fairly good (α = .77).

Safety compliance and *safety participation* behaviours were measured using the two distinct scales developed by Neal, Griffin and Hart (2000) using a five-point Likert scale ranging from strongly agree (1) to strongly disagree (5). Four items measured compliance with safety procedures (α = .94). An example of an item is: “I believe it is important to always use safe/standard work procedures”. Four items measured participation in safety related activities. An example item is: “I put in extra effort to improve the safety of the workplace”. In the present sample, the reliability of the scale was very good (α = .89).

Reporting attitudes were assessed using a scale by Probst and Graso (2013) which comprised of six items and a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7). An example of an item is: “Nothing gets fixed, so why bother reporting an accident or injury” In the present sample, the reliability of the scale was fairly good (α = .76).

Risk propensity was measured using the Risk Propensity Scale (RPS; Meertens & Lion, 2008) which is composed of seven items like “I do not take risks with my health”. Participants report their answers on a nine-point Likert scale. (1 = totally disagree; 9 = totally agree). The tool was developed to measure general tendency to take risks. In the present sample, the reliability of the scale was good (α = .80).

Accident exposure and accident damages. Two indices assessed the amount of personal exposure to accidents and personal experiences of negative consequences for people and organizations. These two indices were adapted from a pre-existing scale created by Probst and Graso (2013). This allowed us to collect relevant information about the exposure and actual occurrence of accident events characterizing this typology of industry. Based on information provided by HSEQ staff, the following categories of accidents were included in the survey: *i)* slip *ii)* trip *iii)* fall *iv)* contact with hazardous materials *v)* heat or cold exposure *vi)* being caught in or between objects *vii)* motor vehicle incident *viii)* repetitive motion *ix)* being struck or stepped on *x)* rubbed or abraded *xi)* inhaled hazardous substance *xii)* electrical current shock *xiii)* to collapse under an object or a rock *xiv)* improper lifting *xv)* being accidently hit by another worker *xvi)* exposure to excessive dust *xvii)* being hit by an object *xviii)* fall from height.

The participants were asked to indicate if they had been personally exposed to any of the specific types of critical accident events reported above during the previous twelve months. Each affirmative answer was coded with a “1”, whereas negative answers were coded with a “zero”. Finally, a first overall index of “accident exposure” was obtained by summing the number of “Yes” responses. In the present research sample, this first overall index presented a good reliability (α = .82).

Furthermore, the participants were asked to indicate if the accident events they had reported produced any negative outcome for members of their work-team (in terms of injuries), or other types of loss to the company (damage to property/plant/equipment). As for the former "accident exposure" index, every affirmative answer was coded with a "1", whereas negative answers were coded with a "zero". In this way, we obtained a second distinct overall index of "accident damage" by summing the number of "Yes" responses. In the present research sample, this second overall index presented an acceptable degree of reliability (α = .74).

Accident reporting index. Finally, in order to compare the self-report accident information provided by our research sample with more objective accident data reports recorded by a relevant UK government agency (Network Rail), we asked our research participants to indicate if the accident events to which they refer - and which produced an actual damage to people or to the company - were effectively reported and recorded in the safety systems of their company (Probst & Graso, 2013). We use this information to compare the self-report information provided by our worker sample with the annual accident statistics provided by Network Rail. According with our research aims, we referred to the Lost Time Injury Frequency Rate (LTIFR) reported by Network Rail for 2015/16, the year to which our research participants referred their accident experiences, as defined above. The annual reports provided by Network Rail refer to the overall rail industrial sample in UK, and they are publicly consultable on-line (http://www.networkrail.co.uk/)

3.3 Procedure

Survey preparation. The study design was approved by a university ethics committee. Study measures were combined into one questionnaire which was printed and also made available via an online survey site. Before the final distribution of the questionnaires, an informal qualitative interview session about the contents of the questionnaire was arranged, involving members of the HSEQ department of the business unit. This preliminary phase of interviews was arranged in order to verify the appropriateness of the original scales and item wording for rail workers in the company. A few minor amendments were then made, such as changing the wording from ‘plant’ to 'organisation' and changing the wording from ‘supervisor’ to ‘line manager’. In this phase, specific typologies of work accidents characterizing the industry context were also verified, to be included as items in *accident experience* scale, as mentioned above in the “measures” section, for example “fall from height".

Survey administration. Employees were invited to attend voluntary workshops during work hours, and were given time to complete the questionnaire. The aim of the research study was described as an attempt to understand participant perceptions of safety. One research team member (RK) attended all workshops in order to distribute and collect questionnaires. After completing questionnaires, participants were asked to place them in blank envelopes, seal the envelopes, and post them in a ballot box. For employees unable to attend a workshop, a link to the online version of the questionnaire was distributed via safety newsletters and briefings. The final section of the questionnaire contained a study debrief.

3.4. Data Analysis

Given the absence of previous adaptations and validation studies of the MSC in the rail industry, we adopted a cross-validation approach, which is frequently advised in literature, using both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). A cross-validation approach presents undoubted advantages for the validation of new psychometric measure tools, or to test the validity of existent measure model in new work samples or industrial contexts. Essentially, a cross-validation methodology combines the statistical capabilities of EFA and CFA to analyse the factor dimensionality of new survey measures, and then, to test the statistical adequacy of the identified factor models (Mariani, Soldà, & Curcuruto, 2015). In a measure validation perspective, EFA techniques enable to identify the most appropriate factor structure for a given research sample, like the rail maintenance sample in the current research (Curcuruto et al., 2013). On the other hand, CFA is a set of statistical techniques which permit to test the stability and the replicability of an existent factor structure model in new industrial samples (Curcuruto et al., 2016).

According with our validation strategy, our data were randomly split into two equal parts using the SPSS 24.0 for Windows software package. Half of the data were used to conduct EFA in the SPSS 24.0 for Windows software package, and the remaining data were submitted to CFA in the Analysis of Moment Structures (AMOS) version 24. Finally, the analysis of the nomological network was conducted on the whole research sample.

3.4.1. Exploratory factor analysis (EFA)

EFA is a powerful method to reduce variable complexity by summarizing a large quantity of variables as a smaller number of factors (Thompson, 2004). In the current study, EFA was used first to identify the factor structure of safety climate. Half of the sample (N = 264) were used to conduct exploratory factor analysis (EFA). Before EFA, both the Kaiser-Mayer-Olkin (KMO) measure of sampling accuracy and Barlett's test of sphericity were conducted to evaluate the appropriateness of using the EFA method in this study. As a frequently-used extraction method whenever EFA is conducted, principal axis factoring (PAF) was selected for data extraction. In this method, variables are put together according to their mutual correlations and then combined to form a certain number of components (Choudhry, Fang, & Lingard, 2009). The Oblimin oblique rotation method was used to interpret latent variables underlying a factor due to the potential correlations among these factors. The threshold of 0.50 was considered to be the minimum factor loading when determining an item to load on a latent factor (Hair, Black, Babin, & Anderson, 2010; Lingard & Sublet, 2002).

3.4.2. Confirmatory factor analysis (CFA)

CFA was conducted to test the goodness of the factor pattern previously verified with EFA, using the second remaining half of the sample (N = 264). CFA is usually used to test whether measures of a construct are consistent with a researcher's understanding of the nature of that construct. As such, the objective of confirmatory factor analysis is to test whether the data fit a hypothesized measurement model of the construct.

AMOS version 24.0 was used in the current study. For model estimation, maximum likelihood method was applied. For model evaluation, a number of frequently-used fit indices were adopted in the current study, including the ratio of model chi-square to the degrees of freedom (Chi2/df), root mean square error of approximation (RMSEA), comparative fit index (CFI), and the AIC and BIC indices. A Chi2/df value less than 5 indicates an acceptable model fit to the data. RMESA values of less than 0.05 indicate a good fit, whereas values ranging from 0.05 to 0.08 are acceptable. CFI ranges from 0 to 1. Values over 0.90 are considered to be acceptable model fit to the data, whereas values higher than .95 are considered good.

Moreover, AIC index (Akaike information criterion) and BIC index (Bayesian information criterion) are criteria for model selection among a finite set of models. AIC index is a measure of the relative quality of statistical models for a given set of data. Given a collection of models for the data, AIC estimates the quality of each model, relative to each of the other models. Hence, AIC provides a means for model selection. AIC is founded on information theory: it offers a relative estimate of the information lost when a given model is used to represent the process that generates the data. Similarly, BIC is another criterion for model selection among a finite set of models. When fitting models, it is possible to increase the likelihood by adding parameters, but doing so may result in overfitting. In line with these principles, the model with the lowest AIC and BIC indices must be preferred.

3.4.3 Nomological network

Beyond testing the internal factor structure of the MSC questionnaire, we also investigated the nomological network of the safety climate factors in relation safety priority (Kines et al., 2011), safety systems (Kines et al., 2011), perceived supervisor support (see Edwards et al., 2008), perceived peer support (see Edward et al., 2008), perceived support for (organisational) change (see Edwards et al., 2008), safety compliance (Neal et al., 2000), safety participation (Neal et al., 2000), reporting attitudes (Probst & Graso, 2013), accident exposure and experience (Probst & Graso, 2013), risk propensity (Meertens & Lion, 2008). In the results section, we will present the correlation of the safety climate factors with these measures. All the correlations were reported using the *r* Pearson index.

4. Results

4.1. Exploratory factor analysis (EFA)

Sample. The first half of the split data (N = 264) was used to conduct EFA on the original MSC items, randomly obtained from the overall sample using SPSS. 36.5% of this half sample was composed of rail construction workers. 17.3% of the workers were logistic staff. 11.8% were engineers. 9.8% of workers were part of the assembly staff. 7.4% were maintenance workers. Overall, 87.5% of the workers were males. The average of job tenure was 4.7 years (sd = 6.4).

Statistical analysis results. The Kaiser-Mayer-Olkin (KMO) measure of sampling accuracy was 0.819 and Barlett's test of sphericity was significant ($p < 0.001$), indicating that the data were appropriate for factor analysis (Kaiser, 1974). The 32 items of MSC questionnaire were subjected to a factor analysis with PAF extraction and Oblimin rotation method. This yielded a result of three factors, which explained 65.61% of variance. Factors 1, 2 and 3 explained 50.41%, 10.92%, and 4.28% of the variance, respectively. As shown in Table 1, the final result includes 29 items with factor loadings above 0.50 on one of these factors. The factor loadings of each item are also shown in this table. The first factor corresponded to the original organizational safety climate (OCS) construct envisaged by Zohar & Luria (2005), and consisted of 16 items representing perceptions of top management commitment to safety. The second factor was interpreted as 'supervisors' safety communication' (SSC), as it included six items which reflected supervisors' communication initiatives aimed to promote safety instances and concerns to their workers. The third factor was explained as 'supervisors' safety monitoring' (SSM), since it comprised five items focused on supervisors' monitoring behaviour like checking, controlling, and influencing coworkers' compliance and conformity with safety regulations and procedures. The correlations between the three latent factors were: .67 (between OSC and SSC), .64 (between OSC and SSM), .72 (between SSC and SSM).

In order to reduce the effect of cross-loading, a factor loading cut-off value of 0.60 (Comery & Lee, 1992; Johnson, 2007) was established. This led us to keep all the original sixteen items of the original OSC dimension, six items from the emerged SSC factor dimension, and five items from the SSM factor. The following SEM analyses were developed on this set of 27 items. After the adjustments, all the factors included at least five items, and the Cronbach's alpha coefficients for the resulting factor scales were .93 (OSC), .89 (SSC), and .82 (SSM), respectively, which were all above 0.70 and considered to be acceptable (Litwin, 1995; Zhou, Fang, & Mohamed, 2010). In every case, the average of the item loading on every factor was higher than the correlation among the latent factors, giving us additional evidence of internal discriminative validity among the components of the model (Fornell & Larcker, 1981).

In summary, the organizational safety climate level was identified by a single factor as in the original model by Zohar and Luria (2005), the group safety climate level was explained by two factors that represent communication (SSC) and monitoring (SSM) safety initiatives enacted by the supervisors.

To include about here table 1

4.2. Confirmatory factor analysis (CFA)

A proposed measurement model of MSC composed of the three factors which emerged from EFA (OSC, SSC, SSM), was examined in the second stage of our cross validation study.

Sample. The remaining half of the data (N = 264) not previously used for the EFA was eventually submitted to CFA analysis. 31.9% of this second half sample was composed of rail construction workers. 18.7% of the workers were part of the logistic staff. 11.3% were maintenance workers. 8.9% were assembly workers. 6.4% were engineers. Overall, 88.1% of the workers were males. The average job tenure was 6.4 (sd = 7.1)

Statistical analysis results. Table 2 shows results of the measurement model with the statistical fit indices. In addition, we have reported a set of findings from potential concurrent measurement models which could have been tested in the light of existing studies on the MSC. *Alternative model 1* presented the original measurement configuration as proposed by Zohar and Luria (2005), with two single factors for both organizational and group levels of safety climate. *Alternative model 2* attempted to combine the original model proposed by Zohar and Luria (2005) with the findings provided by Johnson (2007). In this way the model included four factors: a single factor for the organizational safety climate level, and three additional factors representing the three safety supervision related dimensions identified by Johnson (2007) at the level of group safety climate: caring, coaching, and compliance. Finally, due to the self-report method used to collect our data, a first order model defined by a single method-factor was included in our analysis (with all items loading on a single first order factor), in order to control potential method-bias effects. However, as reported in Table 2, the statistical analyses did not provide adequate support for the hypothesis that method bias affected our findings (Chi2/df = 8.02; CFI = .76; RMSEA = .13).

Model comparisons. According to the findings reported in Table 2, the factor model emerging from EFA presented fit indices which were all at the acceptable level for the measurement model, and better against all the other alternative model solutions (Chi2/df = 2.95, RMSEA = .06, CFI = 0.94). Moreover, in the current study, the statistical analyses also showed that the factor model solution which emerged from EFA presented the lowest AIC and BIC index values, providing additional support for the goodness of the hypothesized measurement model. Figure 2 presents our modified research model in light of the findings from EFA and CFA analyses.

To include about here table 2

4.3. Nomological network

In addition to the factor analysis of the MSC questionnaire, we aimed to provide a further validation step of the tool in the rail industry context by providing a nomological network analysis. In table 3, we report the correlations of the safety climate factors with already validated measures related to safety, risk and health management in the workplace.

At a general level, we found that the measures of the three factors of safety climate presented higher mutual correlations compared with correlations with the other measures included in our analysis. More specifically, organizational safety climate presented strong correlations with both the two measures of the group safety climate factors (respectively: .66 with the factor supervisor safety communication and .58 with supervisor safety monitoring). The correlation between SSC and SSM was also high (.71), but not so high for us to conclude that a substantial shared identity exists between the two factors (Johnson, 2007).

The statistical results support all our hypotheses, and in the directions we expected. The measures of the three safety climate factors which emerged from the factor analyses (OSC; SSC; SSM), were all positively correlated with managerial factors *(hypothesis H1a)* and social support factors *(hypothesis H1b)* (max: .64; min: .39). In all these cases, the managerial and social support measures presented higher correlations with the OSC factor rather than with SSC and SSM factors, except for the case of the measure of *perceived supervisor support*, which presented the highest correlation with the SSC factor (.64).

This general correlation pattern was replicated for the individual difference factors we included in this research *(hypothesis H2)*. Here, we found positive correlations in the case of reporting attitudes (max: .49; min: .35), and negative correlations in the case of employees' risk orientations (max: -. 31; min: -.21), with the OSC factor presenting again the highest correlations.

Regarding the *hypothesis H3* concerning the links between the factors of safety climate and safety-related work conduct, both safety compliance and safety participation presented a positive correlation with all the three safety climate factors (max: .43; min. .31). However, in this case the supervisor related safety climate factors presented the highest correlation values, with safety compliance more highly correlated with the SSM factor (.43), and safety participation displaying its highest correlation with the factor of SSC (.37).

With regards to our final research hypothesis concerning the relationship between safety climate and the personal experience of accidents in the workplace *(hypothesis H4)*, as expected, we found negative correlations between the accident indices (accident exposure; accident damage) and all three safety climate factors (max: -.33; min -.13). Similar to *hypotheses H1* and *H2*, the factor OSC presented the highest correlation values (respectively: -.33 with the 'accident exposure' index; -.22 with the 'accident damage' index).

Finally, and notably, we verified a substantial differentiation between correlation patterns of the SSC and SSM factors with the other measures included in our nomological network analysis. Compared with the SSC factor, the SSM presented stronger correlations with measures such as: safety priority (.39), safety systems (.45), reporting attitudes (.41), risk orientation (-.28), and safety compliance behaviour (.43). On the other hand, SSC presented higher correlations with measures like: perceived supervisor support (.64), perceived peer support (.45), perceived support for (organisational) change (.54), and safety participation behaviour (.36). All correlations are reported in table 3.

To include about here table 3 and figure 2

4.4 Comparison of survey accident indices with industrial reports provided by Network Rail

Finally, we have checked the correspondence of the accident information provided by our survey participants, with more object data reported by Network Rail, a relevant UK government agency, whose annual safety reports are published and consultable on line at their institutional website (http://www.networkrail.co.uk/). We did this by creating a specific *accident reporting index* based on the answers provided by our research participants. For every accident they experienced in the workplace in the past twelve months, they had to indicate if the event was properly reported and recorded in the safety systems of their company (Probst & Graso, 2013). They were required to provide this indication for every accident event which caused a damage to people and/or to the company property.

Overall, in our research sample of maintenance workers the statistical mean of the accident reporting index (.57) appears to be comparable (and in the same order) of the normalized accident statistics reported by Network Rail in their annual report for 2015-16 (LTIFR - Lost Time Injuries Frequency Rate: .49), the year to which our research participants referred the information on their personal experiences of accidents in the workplace. In the light of this we concluded that the accident information provided by our research sample appears aligned with the more objective statistics from the general rail industry sector, and it may be considerable as a rough portion of the overall industrial sector. Table 4 presents a comparison summary of the statistical means of all the self-report accident indices (Probst & Graso, 2013) which were assessed with our survey, and the normalized injury accident statistics provided by Network Rail.

To include about here table 4

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5. General discussion

This validation research was developed by an interdisciplinary research team composed of academics and industrial managers, and inclusive of experts from different university fields, such as ergonomics and human factors, occupational and organizational psychology, management and organization sciences. To clarify the dimension of the multilevel safety climate scale (MSC; Zohar & Luria, 2005) in the rail industrial sector, we completed a systematic cross-validation with multiple steps. Better understanding of these dimensions for rail infrastructure workers is important because employees work in a safety-critical environment with competing demands where safety climate has a potentially strong impact on safety outcomes.

In the first research step, we used exploratory factor analysis with half of the research sample data. This strategy allowed us to identify a set of latent factors underlying the item measures which define the MSC questionnaire. In line with the initial proposal of this model, the "organizational safety climate" measure (OSC) appeared to be associated with a single latent factor (see Zohar & Luria, 2005). However, in accordance with another stream of subsequent studies (e.g., Johnson, 2007), the original "group safety climate" measure appeared to consist of a more complex pattern of latent factors. Two distinct latent factors appeared to represent perceptions of distinct supervision safety behaviours (Griffin & Hu, 2013). We verified a first latent factor defined by content items related to supervisor safety communication (SSC); acts undertaken by team safety leaders with their workmates. Examples of these items were: *"(Our supervisor/line manager) frequently talks about safety issues throughout the work week"*, *"(He) spends time helping us learn to see problems before they arise"*, *"(He) discusses how to improve safety with us"*. We also verified a second latent factor defined by a different set of items focused on contents associated with supervisor safety monitoring (SSM) actions, including items such as: *"(Our supervisor/line manager) makes sure we follow all the safety rules (not just the most important), "(He) frequently checks to see if we are all obeying the safety rules", "(He) insists that we obey safety rules when working with all the equipment".*

In the second research step, we used a confirmatory factor analysis approach on the second half of the sample data. This allowed us to verify the suitability of the latent factor structure emerging from the earlier research step. This involved testing the model fit with the data from the second half of the rail worker sample. In addition, we developed a set of statistical comparisons with alternative measurement models which were defined in light of existing research studies. Results confirmed that the proposed structure was suitable and better than alternative factor solutions based on existing literature: a) a more parsimonious two-factor solution, as in the original MSC measurement model by Zohar and Luria (2005); b) a more complex four factor-configuration, combining Johnson's (2007) findings with the original MSC model.

A third research step was focused on analysing a set of statistical associations *(nomological network)* of the MSC questionnaire with related constructs of theoretical relevance for safety, health and risk management in the workplace. Our findings show strong internal correlations among the three measures of OSC, SSC and SSM. In addition, we found that OSC, SSC and SSM measures presented specific correlation profiles with the other constructs included in this analysis. The OSC measure presented systematically higher correlation values with the measures associated with the managerial variables (safety priority; safety systems), distinct sources of social support (peer support; support for organizational change), individual difference factors (reporting attitudes; risk orientation), accident experience indices (accident exposure; accident damage). By contrast, SSC and SSM presented the highest correlations with safety related work conduct considered in our study, safety compliance and safety participation.

Overall, in accordance with the original conceptualizations of safety climate (Griffin & Curcuruto, 2016; Griffin & Neal., 2000; Zohar 1980) these findings seem to suggest that, at least in the context of the railway industry, the OSC factor might be more directly associated with the creation of a safer organizational context, including all its physical, technological, social, cultural and managerial components. Additionally, the two supervision related factors of safety climate (SSC and SSM), were more highly correlated with the behavioural variables included in our research. In a longitudinal study, Neal and Griffin (2006) showed that safety compliance and safety participation can have a lagged effect on subsequent accident frequency, demonstrating the importance of employees' behaviours in organisational safety outcomes. Therefore, we can tentatively propose that, together the OSC factor at the organizational level, and SSC and SSM factors at the group level, as identified present research may provide a complementary contribution to the prevention of accidents in rail work settings, and in the creation of more secure and reliable organizations.

Further insight can also be garnered by comparing our two supervisor related safety climate factors, SSC and SSM. On one hand, the SSC measure appeared to be more strongly associated with variables related to social support and participation in the organizational environment (supervisor support; peer support; support for organisational change; safety participation behaviour). On the other hand, the SSM measure was found to be more highly correlated with elements associated with operational safety priorities, organizational safety systems, reporting attitudes, safety compliance behaviour, and risk orientation (negatively).

5.1 Research contributions to the safety climate literature

The current study makes important contributions to the literature, organizations, and safety professional communities in several ways. The results suggest some important differences in how safety climate is perceived at the organisational versus the more local team level. At the organisational level, a more holistic safety climate is perceived by employees. This perception is more closely linked to the overall implementation of policies, procedures, practices related to safety. At the team level, supervisor behaviours are more important and employees perceive more specific aspects of these behaviours. Researchers should consider the specific level at which they aim to assess safety climate and expect more complexity a the team level.

The separate factors of safety communication and safety monitoring at the team level also provide useful insights for researchers and managers. This distinction between these two aspect of climate is consistent with the important role played by monitoring in safety leadership (Griffin & Hu, 2013). Monitoring is often overlooked in the general leadership literature but is particularly important in a safety context (Griffin & Talati, 2014). It is important to understand how both aspects of safety climate are developed in a positive way.

Overall, these findings will help to investigate gaps in our understanding of how safety climate emerges and how it is influenced (Zohar, 2010). The shortened versions of SSC and SSM scales identified in the current study allow researchers and practitioners to incorporate additional constructs into their survey instruments which could potentially explain the emergence or changes in safety climate. In other words, the use of distinct scales for SSC and SSM at the safety climate group level has the potential to increase the chances of expanding our understanding of the relationships between safety climate and other constructs. Second, the shortened SSC and SSM scales identified in the current study are expected to broaden the usage of safety climate assessment in field settings while retaining acceptable levels of scale information. For example, a company would more likely be able to incorporate the shortened SSC and SSM scales into their existing employee assessments (e.g., employee opinion surveys) and, thus, increase understanding of safety climate in their organization.

5.2. Practical implications for management and interventions in the rail industry.

Our research results provide a factor structure that can be practically used to assess safety climate and compare groups within the rail industry. A current practical issue experienced in the rail industry, it is the relative lack of validated and theory driven measurement tools that can support the investigation and understanding of the rail employees' perception of the state of safety in their industry (Morgan et al., 2016). One of the consequence of this, it is the proliferation and usage of safety climate measurement tools that may be not updated with the state of the art of safety literature (Griffin & Curcuruto, 2016). For example, this can create difficulties for the correct interpretation of research findings, especially when the measurement tools are not effectively aligned with the conceptual definitions of safety climate constructs. Furthermore, it may become hard to compare and benchmark findings in the rail industry if validated measurement tools are not consistently used across the companies. We sincerely hope that our validation findings on Zohar and Luria's MSC scale can provide a diagnostic support to railway safety regulators, industrial managers and safety consultants, toward a more consistent, standardized, and theory-driven approach to assessment of safety climate in the rail maintenance industry.

In addition, our findings on the nomological network described in this article can also offer practical advantages to researchers, managers and practitioners, for instance, to identify where and how intervention program might build a stronger safety climate and support safety behaviours. For example, our correlation findings showed that safety monitoring supervision is more strongly positively associated with safety compliance behaviour, with antecedent variables like safety priority and safety systems, and negatively associated with employees' risk orientations. On the other hand, our findings reveal that safety communication supervision is more highly related with safety participation, and with a different set of antecedent variables like perceived supervisor support, perceived peer support, perceived support to change. Overall, these distinct correlation patterns could provide specific indications about how to design appropriate intervention strategies to improve the supervision skills of the team leaders, and/or the safety related work conducts in the rail maintenance context. On the one hand, organizational programs focused on improving supervisors' safety communication skills can be more efficient when they are associated with concurrent interventions which aim to sustain a collaborative atmosphere in the working groups. Or, again, when safety communication programs are combined with interventions which are aimed to facilitate the expression of suggestions for changes and innovations in the workplace, which can eventually support the organization to improve, the current status of the working conditions. On the other hand, interventions intended to improve the monitoring competences of team supervisors, could be better designed in order to reflect the organizational safety priorities and safety systems. Fo examples, this could affect employees' motivations not only to comply with safety standards and work procedures, but also to make a better usage of the safety systems which are already in place (e.g. risk reporting systems), supporting the organization to monitor and correct risks and hazards in the workplace, and creating a better awareness of the risks present in the work operations. If properly combined, these integrated intervention strategies can sustain the improvement of the observable safety compliance and safety participation behaviours, which have are considered two proximal predictors of safety performance and accident prevention at group level (Neal & Griffin, 2006). Finally, rail industries and regulators can be certainly interested to support a regular and systematic collection of anonymous information on the constructs included in our nomological network model, so that interventions have validity data and can be evaluated more effectively.

5.3. *Study limitations and future research avenues*

Beside its contribution to safety research literature and safety promotion in the rail industry sector, the present study is not without limitations. First, we only collected self-report data on safety outcomes to validate our scales, as directly provided by the survey participants. Future studies can consider collecting more objective indicators measured at the individual level (e.g., supervisor rates of workers' safety behaviours; objective workers' compensation data) or at the group level of analysis (e.g. objective near-miss records; accident and/or injury rates), to be associated to the participants' responses on safety conduct and/or accident outcomes. This could help to establish a better criterion-related validity of the SSC (supervision safety communication) and SSM (supervision safety monitoring) of short scales that we have obtained at the group level of analysis of safety climate. Furthermore, future studies could analyse the potential role of supervision safety communication and supervision safety monitoring as two distinct mediators of the effects of organizational safety climate on safety behaviours. For instance, the two supervision factors may distinctively influence classes of safety behaviours (Griffin & Hu, 2013), and in certain conditions specific effects could be expected on safety compliance behaviour rather than safety participation. Finally, future studies could attempt to test and replicate the three-factor structure of MSC scale in other industrial contexts. If the research findings described in the article will be confirmed, it will be also possible to benchmark the status of safety management in the rail industry with other realities from other industrial sectors.

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Table 1. MSC: Items and factor loading with the original 32 items (EFA) (N = 264)

Item content description	F1	F2	F3
Top management in this plant–company . . .			
OSC11 - Uses any available information to improve existing safety rules	.86		
OSC12 - Listens carefully to workers' ideas about improving safety	.85		
OSC13 - Considers safety when setting production speed and schedules	.82		
OSC16 - Gives safety personnel the power they need to do their job	.80		
OSC06 - Quickly corrects any safety hazard (even if it's costly)	.78		
OSC01 - Reacts quickly to solve the problem when told about safety hazards	.78		
OSC04 - Provides all the equipment needed to do the job safely	.77		
OSC05 - Is strict about working safely when work falls behind schedule	.75		
OSC14 - Provides workers with a lot of information on safety issues.	.74		
OSC08 - Considers a person's safety behaviour when moving people	.73		
OSC10 - Invests a lot of time and money in safety training for workers	.71		
OSC03 - Tries to continually improve safety levels in each department	.70		
OSC02 - Insists on thorough and regular safety audits and inspections	.69		
OSC15 - Regularly holds safety-awareness events	.65		
OSC07 - Provides detailed safety reports to workers	.64		
OSC09 - Requires each manager to help improve safety in his/her department	.62		
My direct supervisor . . .			
GSC10 - Frequently talks about safety issues throughout the work week		.85	
GSC08 - Spends time helping us learn to see problems before they arise		.81	
GSC07 - Says a "good word" to workers who pay special attention to safety		.77	
GSC01 - Discusses how to improve safety with us		.74	
GSC02 - Uses explanations (not just compliance) to get us to act safely		.68	
GSC12 - Reminds workers who need reminders to work safely		.64	.27
GSC09 - Is strict about safety at the end of the shift, when we want to go home		.55	.31
GSC04 - Emphasizes safety procedures when we are working under pressure		.53	.35
GSC05 - Makes sure we receive all the equipment needed to do the job safely		.48	.27
GSC13 - Frequently tells us about the hazards in our work		.44	.38
GSC14 - Makes sure we follow all the safety rules *(not just the most important)*			.84
GSC15 - Insists that we obey safety rules when working with all the equipment			.82
GSC11 - Refuses to ignore safety rules when work falls behind schedule		.33	.76
GSC16 - Frequently checks to see if we are all obeying the safety rules			.71
GSC06 - Insists we wear our personal protective equipment			.65
GSC03 - Is strict about working safely when we are tired or stressed		.24	.34

Legend: OSC = Organizational Safety Climate; GSC = Group Safety Climate

Note: Factor load less than .20 are not displayed in the table

Table 2. MSC: Comparison of measurement models with 27 items (CFA) (N = 264)

Model	N. Factors	Factor model Description	χ2	Df	CFI	RMSEA	AIC	BIC
Factor model emerged from EFA	*Three*	A single factor of Organizational Safety Climate (16 items), as in the original version by Zohar and Luria (2005). Two factors at the group level: I) Supervisor Safety Communication (6 items) II) Supervisor Safety Monitoring (5 items)	947.2	320	.94	.06	1069.3	1318.2
First order model	*One*	Test of method bias effect potentially associated with self-report measures: all items loading to only a single "method factor"	2600.4	324	.76	.13	2712.4	3221.6
Alternative model 1: based on the original MSC measure model by Zohar and Luria (2005)	*Two*	The original two factor structure proposed by Zohar and Luria (2005): I) A single factor of Organizational Safety Climate (16 items) II) A single factor of Group Safety Climate (11 items)	1210.5	323	.91	.08	1326.5	1563.3
Alternative model 2: based on Johnson's contribution (2007) at the group level	*Four*	Combining Johnson's proposal (2007) with the original model proposed by Zohar and Luria (2005): - A single factor of Organizational Safety Climate (16 items), as in the original version by Zohar and Luria (2005). - Three factors at the group level, based on Johnson (2007): a) Supervisor Caring Behaviour (4 items), b) Supervisor Compliance Behaviour (4 items), c) Supervisor Coaching Behaviour (3 items)	1011.8	317	.93	.07	1087.1	1394.9

Table 3. Nomological network of MSC (N = 528): Correlation links with other safety, risk and health related validated measures

	M	Sd	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Organizational safety climate	3.76	.74	*(.95)*													
2. Supervisor safety communication	3.61	.92	.66	*(.93)*												
3. Supervisor safety monitoring	3.9	.76	.58	.71	*(.87)*											
4. Safety priority	3.14	.52	.46	.34	.39	*(.80)*										
5. Safety systems	3.26	.45	.49	.33	.45	.63	*(.82)*									
6. Perceived supervisor support	3.54	.90	.51.	.64	.50	.30	.33	*(.87)*								
7. Perceived peer support	3.82	.74	.46	.45	.39	.28	.34	.65	*(.81)*							
8. Perceived support for change	3.3	.91	.56	.54	.43	.36	.39	.67	. 57	*(.77)*						
9. Risk orientation	2.51	1.17	-.31	-.21	-.29	-.38	-.36	-.19	-.13	-.19	*(.80)*					
10. Reporting attitudes	5.43	1.15	.49	.35	.41	.52	.49	.32	.24	.34	-.43	*(.76)*				
11. Safety compliance behaviour	4.48	.60	.41	.31	.43	.42	.56	.30	.27	.30	-.39	.41	*(.94)*			
12. Safety participation behaviour	3.99	.75	.36	.37	.34	.26	.44	.23	.21	.29	-.31	.35	.53	*(.89)*		
13. 'Accident exposure' index	2.05	2.64	-.33	-.20	-.24	-.37	-.30	-.19	-.14	-.17	.25	-.39	-.27	-.23	*(.82*	
14. 'Accident damage' index	.34	1.01	-.22	-.13	-.16	-.29	-.25	-.14	-.11	-.13	.20	-.37	-.22	-.18	.54	*(.74)*

Note: all correlations are significant at p <.01. Cronbach alpha indices for each scale are reported in the diagonal

Table 4. Comparison of self-report accident indices* (Probst & Graso, 2013) and objective normalized accident statistics reported by Network Rail** (2015/16)

Self-report accident indices measured with the survey (N = 528)			Normalized accident statistics reported by Network Rail
Accident Exposure Index *(Statistical Mean)*	Accident Damage Index *(Statistical Mean)*	Accident Reporting Index *(Statistical Mean)*	LTIFR *(Lost Time Injury Frequency Rate)*
2.05	.34	.57	.49

Note.

* The self-report accident indices were provided by the participants to our survey research. The survey was administrated at the begin of the second half of 2016. The self-report accident refereed to the relevant work experiences in the former 12 months that preceded they survey. The self-report indices were then compared with the normalized accident statistics provided by Network Rail.

**Network Rail is a UK public agency, answerable to Government via the Department for Transport (DfT). Its annual accident reports are consultable on-line at: http://www.networkrail.co.uk

Figure 1: Research model: Original MSC factor model (Zohar & Luria, 2005) and research hypotheses in the overall nomological network

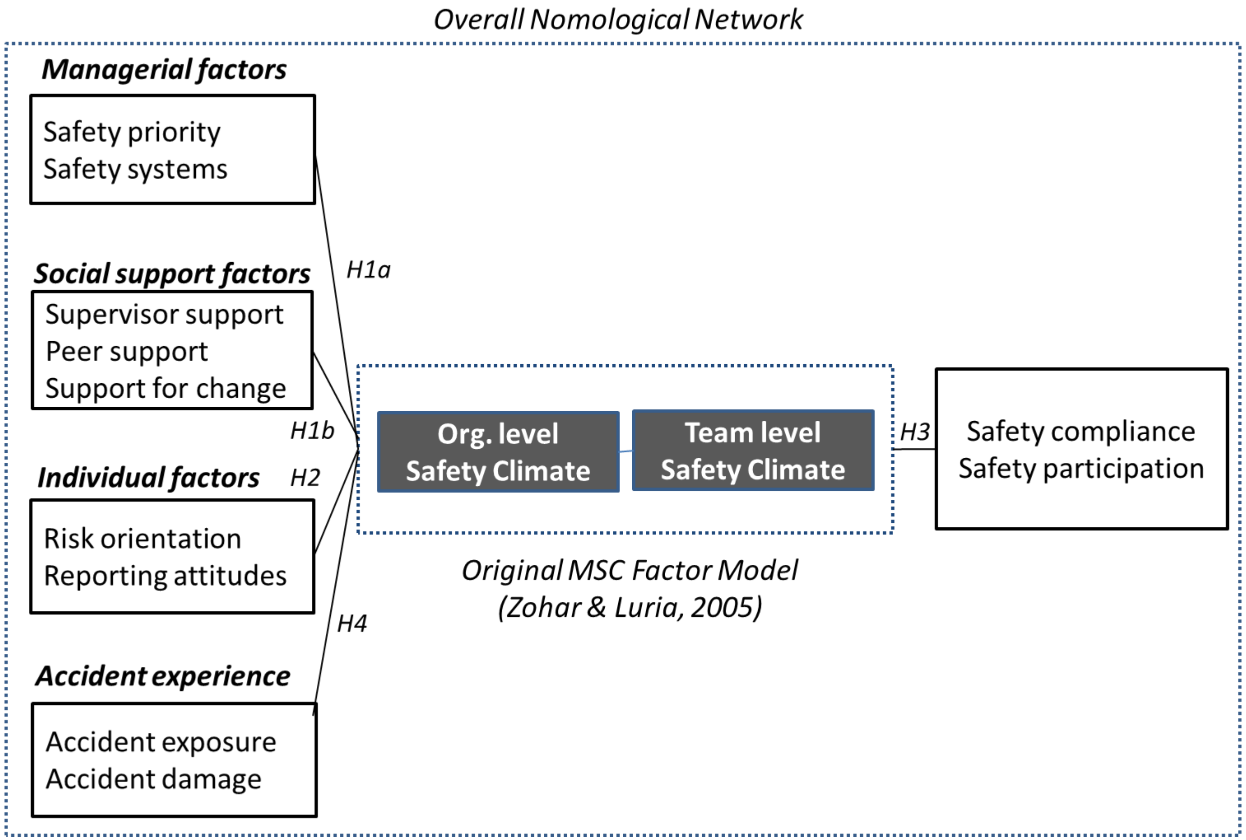
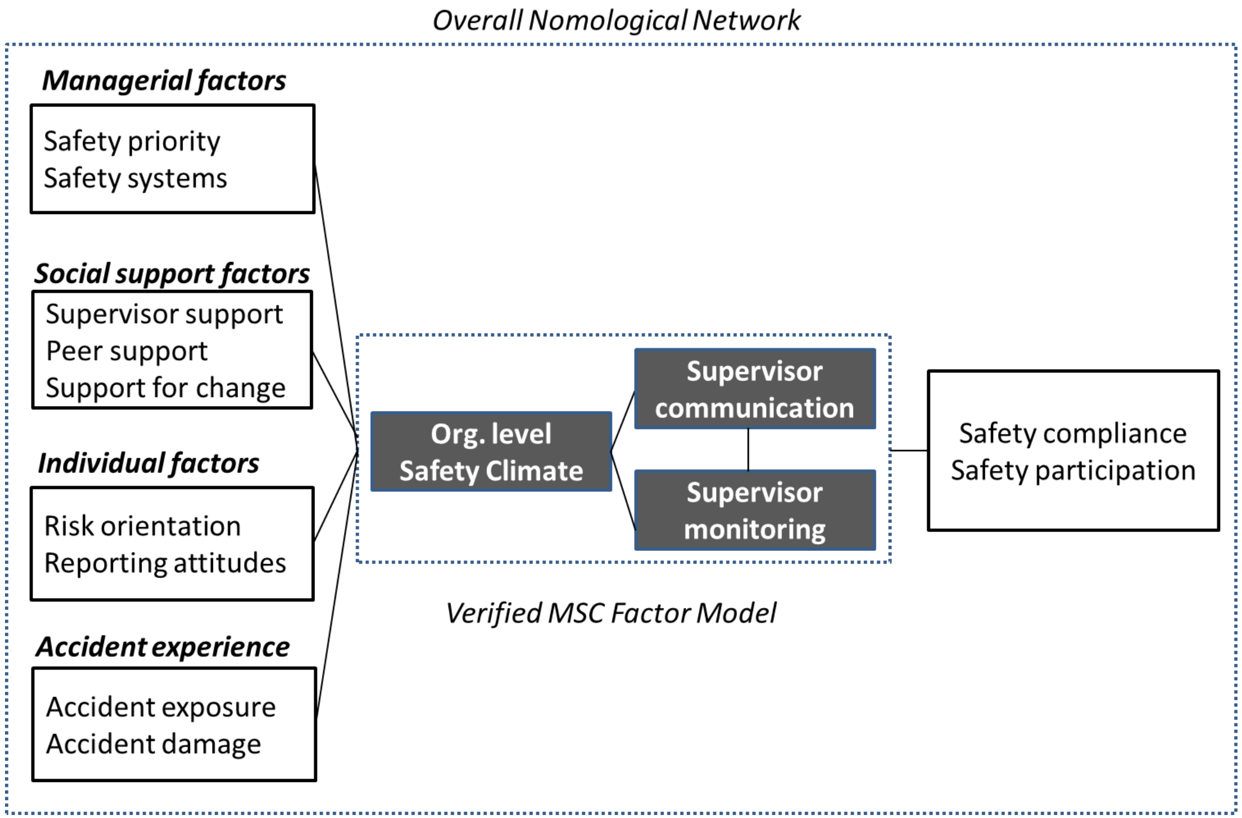


Figure 2: Verified MSC factor model in the research sample (N = 528) from the rail maintenance industry



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All the authors contributed to the writing of the manuscript, and are reported in alphabetical order. JM, MC and RK originally conceptualized the study and chose the theoretical framework. The introduction was written by MC, RK and JM. The review of safety climate literature was developed together by MC, RK, JM and MG. RK and MC wrote the methods sections. MC and MG analysed the data, formalizing and interpreting the results. MC and MG developed the general discussion. MC and MG coordinated the final revision stage of the manuscript. All the authors contributed to revise and improve the manuscript several times. Financial support for this research was provided by the UK government Knowledge Transfer Partnership (KTP) initiative.