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Changes in safety climate and accidents at two identical manufacturing plants

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Abstract

This study aimed at examining if between-plant differences in safety climate are reflected in corresponding differences in accident rates, and if subsequent changes in safety climate are paralleled by changes in accident rates. The study population was all production workers at two identical manufacturing plants under the same corporation. Safety climate was assessed by questionnaires and safety audits at two points in time with a 12-month interval. At baseline Plant B scored lower than Plant A on five out of six dimensions of safety climate, and had double the rate of self-reported injuries and an almost 30% higher incidence of lost-time-injuries (LTIs). Prior to the present study, Plant A had participated in a comprehensive work environment improvement project. During the study period, knowledge and experiences acquired from this intervention were actively transferred from Plant A to Plant B. At follow-up accident rates were reduced at both plants and the only significant between-plant difference was commitment to the workplace. The study demonstrates a relationship between changes in both questionnaire- and audit-based measures of safety climate and rates of self-reported injuries and LTIs.
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Keyword: Safety climate; Occupational accidents; Self-reported injuries

1. Introduction

There is currently a keen interest in safety culture and safety climate in the accident research literature. However, both climate and culture are generally poorly defined and operationalized concepts (Guldenmund, 2000; Mearns and Flin, 1999). Dov Zohar, who originally coined the term safety climate (Zohar, 1980), defines safety climate as employees' shared perceptions of management's commitment and performance with regards to safety policies, procedures and practices (Zohar, 2000). Whereas safety climate is a psychological construct referring to shared perceptions, safety culture is generally taken to refer to the basic values and beliefs regarding safety in the organization, and is considered to be a more persistent construct that is harder to influence

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directly (Guldenmund, 2000; Mearns and Flin, 1999). Relationships and differences between the two concepts remain unclear however. While they can be differentiated to a certain extent in theory, in practice, the means by which they have been operationalized often makes it impossible to distinguish them from each other. The distinction between climate and culture is in practice often more a question of interpretation than operationalization (Mearns and Flin, 1999). The distinction has also been grounded in methodological issues, where climate usually is assessed through quantitative measures, i.e. questionnaires, while culture is assessed via qualitative interviews and anthropological methods (Guldenmund, 2000; Mearns and Flin, 1999). In the present study the term safety climate will be used, although it could be argued that some of the measures also reflect parts of safety culture. Since the current study focuses on changes in safety perceptions and performance during a relatively short period of time (one year), it seems most feasible that these changes reflect changes in safety climate rather than culture. The study also relies primarily on quantitative measures, which is more typical of practices in the climate rather than the culture literature.

Although consensus on definition and measurement issues is lacking, there is some agreement about the main dimensions of safety climate. Research into the factors determining the safety of industrial organizations clearly shows the importance of managerial factors (Flin, 2003), and in a review of the literature, the most typically assessed dimensions of safety climate were also found to relate to management (Flin et al., 2000). Alongside management's commitment to safety worker involvement has also been identified as an important factor in safety climate (Dedobbeleer and Beland, 1991).

1.1. Objective of the present study

The present study took place at two "twin" plants from the same company manufacturing identical products, meaning that many conditions were identical, i.e. same production system, same organizational structure, same top management, same health and safety management system, and same organizational policies. This provided a unique opportunity to examine between-plant differences of importance for accident rates. There were however two major differences between the plants. During the $3\frac{1}{2}$ years prior to the study Plant A was involved in a comprehensive work environment project based on worker involvement and focused among other things on safety related issues such as the correct use of personal protection equipment (Rasmussen et al., 2006). Secondly, as an off spin of this project organizational restructuring of the workforce into self-governing teams was initiated at Plant A prior to the start of the project.

The present study aims at examining, via two cross-sectional analyses, if between-plant differences in a measure of safety climate are reflected in corresponding differences in accident rates, and further, to examine if subsequent changes in safety climate occurring in connection with a natural intervention at one of the plants are paralleled by corresponding changes in accident rates. Four hypotheses are tested:

Hypothesis 1. Despite being twin factories there will be differences in safety climate at the two plants, because of the preceding work environment project at Plant A. The effect of the preceding project should be that the safety climate is better at Plant A than at Plant B at the outset.

Hypothesis 2. Differences in safety climate between the two plants will be mirrored by differences in incident rates at baseline, i.e. the better safety climate at Plant A is mirrored by lower accident rates compared with Plant B.

Hypothesis 3. During the study period, a natural intervention occurred as the company actively tried to harmonize safety practices between the two plants by transferring knowledge from Plant A to Plant B regarding lessons learned from the previous work environment project, as well as the introduction of self-governing work teams at Plant B. It is proposed that this natural intervention will lead to a convergence in safety climate at the two plants at $T1$.

Hypothesis 4. Conversely this convergence in safety climate at $T1$ will be mirrored by changes in accident rates at $T1$, i.e. at the end of the study period there will be a convergence of the accident rates at the two plants.

2. Materials and methods

2.1. Study population and design

The study population was all production workers at two identical medium sized manufacturing plants under the same corporation. The plants manufactured blades for wind turbines. The blades varied in size from 30 to 40 m. The work was mainly manual work, with manual handling of the different components used, e.g. lanes of Pre-Preg (fiberglass pre-impregnated with epoxy resin and hardener). The main hazards include cuts from knives used to remove surplus materials and trips and falls relating to working at different levels (in and around the moulds). During the first weeks of employment workers at both plants attended a one week introductory course where one day was focused on safety and they were introduced to company policies, materials and hazards, and correct working procedures.

The project was a longitudinal study with data collection happening twice exactly one year apart. The first round of measurements was performed in September 2003 ($T0$), while the second round was performed one year later in September 2004 ($T1$). There was no formal intervention initiated by the research team between the measurement points. At baseline the number of employees at Plant A was 442, gradually increasing to 570 at $T1$. At Plant B there was a workforce of 388 at baseline and 341 at $T1$. Each plant had 15–20 supervisors and 1 plant manager, while they shared the same company top management.

The fluctuations in number of employees is explained by the fact that this type of industry is generally characterised by large fluctuations in manpower requirements, as they depend heavily on political decisions and priorities both nationally and internationally. These fluctuations are often more dramatic than those that occurred during the study period. E.g. during the previously mentioned work environment study that took place at Plant A prior to the current study, the number of employees varied from 620 at baseline to 940 two years later and downsized to 480 at the end of the $3\frac{1}{2}$ year study period (Rasmussen et al., 2006). These fluctuations of course pose a challenge to safety, as large numbers of new employees are taken in at the plants in short periods of time. However, at the same time it is something the company is used to, and therefore has set up different initiatives (e.g. the one-day safety course for new employees) to compensate for.

2.2. Accident data

Data on reported occupational injuries with more than one day of absence (Lost Time Incidents or LTIs) was collected from the plants' own identical accident reporting systems from one year prior to baseline ($T-1$) and until 1/2 a year after the study ($T1\frac{1}{2}$). Accident rates were calculated as the number of LTIs per one million hours worked in the previous 6 months. Self-reported injuries were collected via questionnaires at $T0$ and $T1$ in which participants were asked how many times, if any, they had experienced each of nine different types of minor injuries (eight specific types e.g. a cut or bruise, and "other") during the last 12 months. The participants were instructed to report any injury, which resulted in the need to stop working for even a short a period of time and therefore including both major and minor injuries. The number of self-reported injuries was calculated as the total number of accidents reported in the questionnaire.

2.3. Safety audit

The plants were both OHSAS18001-certified. It has been shown that safety policies and programmes have a high correlation with safety climate (DeJoy et al., 2004). Therefore, we investigated how well this occupational health and safety management system (that in theory was identical at the two plants) was implemented in practice at the plants, as an alternative measure of safety climate. We conducted audits of the system at both plants at $T0$ and $T1$. Audits were performed by a member of the research team who is formally trained in auditing, and were based on the principles and procedures of the OHSAS 18001 system and the ISO 19011 guidelines on management systems auditing. The auditing was based on checking activities against procedures and rules defining activities (roles and responsibilities, functions and activities to be performed, etc.). The auditor checked the level of compliance with system requirements through interviews and paper records. The audit consisted of 43 individual checkpoints where the plants had to document compliance with the audit criteria (sample checkpoint: "Is there a registration system for near misses?"). Each checkpoint was coded as "OK" if the plant could document its compliance in a satisfactory way, and "not OK" if this was not the case. If they insisted that they did live up to the checkpoint, but could not document this in a satisfactory way, the checkpoint was coded as "not documented".

2.4. Questionnaire data

The study used the Danish Safety Culture Questionnaire (DSCQ). This is a newly developed questionnaire that incorporates leadership, organizational and worker factors. Initially it contained 138 items covering 13 theoretically derived dimensions of safety climate (e.g. employee participation in safety, management commitment and communication and risk behaviour). Through confirmatory factor analysis and structural equation modelling the questionnaire was reduced to 21 items covering six factors at the end of the study. For further information on the development of the questionnaire and the specific items see Mikkelsen and Nielsen (in preparation).

The six factors included two leadership factors (Immediate supervisor general leadership and Immediate supervisor safety leadership), an organizational factor (Safety instruction) and three worker factors (Convenience violations, Safety oversights and Commitment to the workplace).

Immediate supervisor general leadership is measured with five items covering general aspects of leadership. Four of the items are taken from the Multifactor Leadership Questionnaire form 5× (Avolio et al., 1999). Sample item: My immediate supervisor uses methods of leadership that are satisfying. *Immediate supervisor safety leadership* is measured with three items covering the immediate supervisor's commitment to safety. Sample item: My immediate supervisor intervenes immediately if safety regulations are broken. *Safety instruction* is measured with three items covering the adequacy of safety training. Sample item: I have been shown how to perform my work safely at my current place of work. *Convenience violations* is measured with three items taken from the general unsafe behaviour factor from the Offshore Safety Questionnaire (Mearns et al., 2003). Sample item: I ignore safety regulations to get the job done. *Safety oversights* is measured with three items covering reasons not to bring up safety issues with supervisors. Sample item: It is of no use to bring up safety issues. *Commitment to the workplace* was measured using four items from the Copenhagen Psychosocial Questionnaire (Kristensen et al., 2005). Sample item: Do you feel that your place of work is of great personal importance to you?

A five-point Likert scale was used for all items, and all reported scores are un-standardized means. Chronbach α ranged from 0.73 to 0.89 for the six factors at the four measurements (two measurements at both plants).

Questionnaires were filled out at information meetings during work hours. The rate of participation at Plant A at baseline was 87.8% ($n = 388$) and 78.0% at follow up ($n = 443$). Of the 432 workers who were employed at both $T0$ and $T1$, 67.0% ($n = 290$) answered the questionnaire on both occasions. The corresponding figures in company B were 93.8% ($n = 364$) at $T0$, 86.0% ($n = 293$) at $T1$ and 70.0% at both measurements ($n = 227$ of 326). All questionnaire data reported here are from the workers who participated in both measurements.

2.5. Natural intervention

No formal intervention took place at either plant during the study period. However, prior to the current study, Plant A participated in a planned and systematic work environment intervention conducted by some of the present authors (Rasmussen et al., 2006). Subsequent to this the company decided to transfer the implementation of this intervention from Plant A to Plant B. This was carried out by the plants work environment department and constitutes a natural intervention (in the sense that it was not planned, initiated or controlled by the researchers). The knowledge transfer from the work environment project occurred in two ways. The corporate work environment department had been involved in the project at Plant A, and they introduced the same procedures in Plant B. Specifically, they implemented new safety instructions for chemical and physical hazards including new guidelines for safe behaviour and use of personal protective equipment (e.g. use of cut resistant gloves when using knives). The safety instruction and guidelines were aimed at eliminating the primary safety related work environment problems at Plant A (e.g. cuts from knives). Although they were originally identified at Plant A, the identical nature of the work conducted at the two plants made the same issues relevant at Plant B. Secondly, the team of researchers who had conducted the work environment project at Plant A held a seminar for the safety committee at Plant B focused on creating a more proactive safety organization through redefinition of the role of safety representatives and first line supervisors. Among other things the aim of the seminar was to improve managements' commitment to safety, which is recognized as probably the single most important factor for success in any area of occupational safety (Flin, 2003).

Furthermore, as another component of the natural intervention, self-governing work teams, which were already in place at Plant A, were also introduced at Plant B. The introduction of self-governing work teams was inspired by the previous work environment project, but was a corporate-wide decision that happened partially with the help of external consultants and initiated primarily for organizational and productivity reasons. Safety-wise it had the added benefit of involving workers in safety, which is another important factor in safety climate (Dedobbeleer and Beland, 1991), as one member of each of the new teams was explicitly put in charge of the teams' safety.

2.6. Statistical analysis

Related and independent sample *t*-tests were used to identify differences within and between the two plants at $T0$ and $T1$. *t*-tests were performed using SPSS for Windows version 13.0. Incident rates were analyzed for trend with Poisson regression using STATA SE version 8.0.

3. Results

Measurement invariance of the six safety climate dimensions at $T0$ and $T1$ has previous been established using a multi-sample confirmative factor analysis (Mikkelsen and Nielsen, in preparation). Therefore in this paper, the changes in the safety climate dimensions are analyzed simply by using observed mean sum scores.

Hypothesis 1 stated that the safety climate at Plant A should be better than the safety climate at Plant B at $T0$. From Table 1 it can be seen that Plant A performed significantly better than Plant B in both leadership factors and worker factors at $T0$ (although not significantly for Convenience violations ($p = 0.07$)). There were no differences between the plants in safety instruction. Likewise, the safety audit showed that at $T0$ there were seven checkpoints where Plant A received a "not-OK" (16%), five due to lack of documentation. Plant B received "not-OK" 13 times (30%), 10 due to lack of documentation. The data therefore seem to support Hypothesis 1.

Hypothesis 2 stated that the difference in safety climate between the two plants at the outset should be mirrored by accident rates at the outset. To test this, the nine different types of self-reported injuries for the preceding year were added together for each person. Fig. 1 shows the mean number of self-reported injuries per worker at $T0$ and $T1$ in the two plants. Although there is no significant difference between the plants ($p = 0.11$), there were almost twice as many self-reported injuries per worker per year at Plant B (2.29) than at Plant A (1.19) at $T0$. The LTI data from the plants' own accident reporting systems showed a similar difference (Fig. 2). Plant B reported more LTIs than Plant A at $T0$, although there was a downward trend for both plants for the year leading up to $T0$. One year before the study period started ($T - 1$) Plant B had almost 50% more LTIs than Plant A, while the difference between the two plants at $T0$ was 30%. Again there was no statistical significant difference between the plants but taken together these data seems to support Hypothesis 2.

Hypothesis 3 stated that because of knowledge transfer between the plants their safety climate scores should converge by the end of the study period. The safety audit findings showed this trend as both plants improved and ended at almost the same level at $T1$. Plant A improved marginally and received five "not-OK" (12%), three due to lack of documentation, and Plant B received "not-OK" six times (14%), all due to lack of documentation. The questionnaire data, however, showed a mixed picture. As shown in Table 1, there was only one significant difference between the two plants in the safety climate measures at $T1$. This was the commitment to the workplace factor, which is a psychosocial factor measuring how attached the employees feel towards their workplace. The only other factor where the difference approaches significance at $T1$ is immediate supervisor general leadership ($p = 0.10$). All other differences between the plants have disappeared. On the sur-

Table 1
Questionnaire measures of safety climate dimensions

	N	*T*0	*T*1	Diff. *T*0 − *T*1	Diff. A − B *T*0	Diff. A − B *T*1
Leadership factors						
Immediate supervisor general leadership						
Plant A	273	3.68	3.60	−0.08	0.23***	0.13*
Plant B	217	3.45	3.47	0.03	–	–
Immediate supervisor safety leadership						
Plant A	284	3.68	3.56	−0.12*	0.26***	−0.01
Plant B	224	3.42	3.57	0.15*	–	–
Organizational factor						
Safety instructions						
Plant A	277	3.79	3.78	−0.01	−0.02	−0.08
Plant B	209	3.81	3.86	0.04	–	–
Worker factors						
Convenience violations						
Plant A	284	3.30	3.17	−0.13*	0.14*	−0.06
Plant B	225	3.15	3.23	0.08	–	–
Safety oversights						
Plant A	285	4.00	3.92	−0.08	0.18***	0.02
Plant B	226	3.82	3.91	0.08	–	–
Commitment to the workplace						
Plant A	285	3.61	3.46	−0.14**	0.35***	0.31***
Plant B	218	3.26	3.16	−0.10	–	–

All scores are observed means. Scale 1–5, 5 best.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

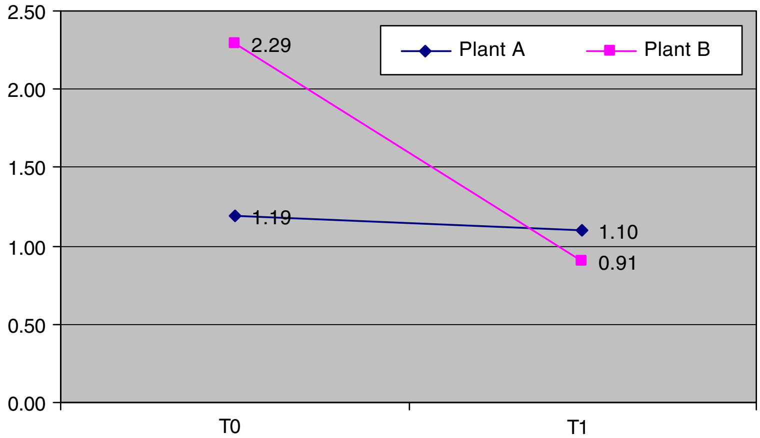

Fig. 1. Mean number of self-reported injuries per participant per year.

face this seems to support Hypothesis 3. However, an inspection of the results shows that the convergence of the safety climate scores at the two plants is generally due both to a decrease in the scores for Plant A, and an increase in the scores for Plant B. So although the data support Hypothesis 3 in as much as a convergence of safety climate appeared, this convergence was not solely due to improvements at Plant B, but also reflected a decline in safety climate scores at Plant A.

Hypothesis 4 stated that the convergence in safety climate should be mirrored by a convergence of the accident rates. As can be seen from Fig. 1 there was no difference in the mean number of self-reported injuries at Plant A from *T*0 to *T*1, but there was a significant difference for Plant B ($p = 0.03$), going from almost double

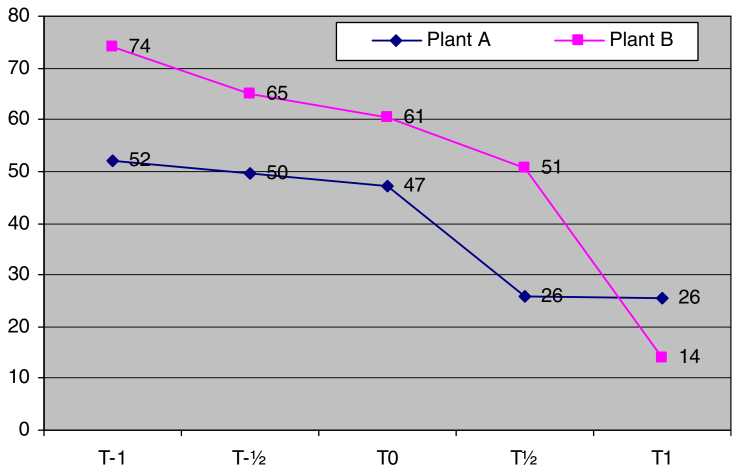

Fig. 2. Reported LTI's per million working hour.

the number of injuries of Plant A at $T0$ to just below Plant A at $T1$. The LTI data from the plants' own accident reporting system shows a downward trend for both plants from $T0$ to $T1$ (Fig. 2). For Plant A the downward trend is not statistically significant ($\chi^2 = 2.74$, $p = 0.10$). However, the downward trend in the study period was much more pronounced for Plant B, and reaches significance ($\chi^2 = 7.55$, $p < 0.01$). Where Plant A had the fewest incidents at $T0$, Plant B had almost 50% fewer LTI's than Plant A at $T1$. Nonetheless there was no statistically significant difference between the LTI-rates at $T1$. Taken together these data seem to support Hypothesis 4.

4. Discussion

The significance of safety climate for the occurrence of occupational accidents has only rarely been studied. The limited existing research has occurred in industrial, military and off-shore settings, and has not been able to clearly demonstrate an association between safety climate on the one hand, and accidents on the other (Cooper and Phillips, 2004; Griffin and Neal, 2000; Mearns et al., 2003).

The main result of the present study is the discovery of a relation between a questionnaire-based measure of safety climate and both self-reported and company reported accidents. At the twin plants, significant differences in dimensions of safety climate at baseline corresponded with differences in accident rates, i.e. Plant B had higher accident rates and also scored lower on almost all safety climate scales than Plant A. At Plant A, which scored highest on 5 out of 6 measures of safety climate at baseline, a comprehensive work environment project had been conducted during the previous $3\frac{1}{2}$ years. During the study period the company actively attempted to harmonize safety practices between the two plants, by transferring knowledge and improvements from the successful project at Plant A to Plant B. One year later at the end of the study period accident rates, self-reported injuries and questionnaire and audit-based measures of safety climate converged at the two plants. This harmonization of safety practices between the plants provides a plausible explanation for the observed convergence of safety climate and accident rates at the two plants.

This result is in line with prior research, which has shown a relationship between safety climate and self-reported injuries and reported accidents. Zohar (2000) found that safety climate predicted micro-accident records during a 5-months recording period in 53 workgroups at a manufacturing plant. Likewise Mearns et al. (2003) found partial support for the hypothesis that safety climate predicts accidents, both self-reported and those contained in the companies' own accident reporting systems, in several off-shore oil installations.

Strengths of the present study include the use of two plants that in many respects were identical at baseline, but in terms of safety climate and accident rates were markedly different, and a follow-up design that could assess changes connected with the transfer of safety practices from one plant to the other. This increases both the internal and external validity of the study, as well as an interpretation of the findings in terms of connections between safety climate and accidents. The adoption of a multi-method approach is also considered a main strength.

A weakness of the study is the validity of the main accident and injury outcome measures. A Danish study has estimated that only 50% of all LTIs are reported in Denmark, although employers are obliged by law to report them (The Danish Work Environment Authorities, 1996). This is both due to lack of knowledge and administrative short-comings in smaller companies, but may also be due to a tendency during the last 5–10 years for many companies to adopt a low accident rate as a performance target. As a means of reaching such a target, companies have introduced procedures that may 'artificially' reduce LTI figures, e.g. transferring injured workers to less demanding work to avoid sick leave, or introducing reward systems that discourage LTI reporting by employees. The difference in LTI-rates between the plants in the present study at *T*0 might therefore be explained by a higher level of underreporting at Plant A, which was then transferred to Plant B as a safety practice. However, neither before nor during the study period did the plants use different reporting or rewarding practices and there is no data indicating that any differences in the level of reporting existed between the plants. It is also worth noting that as the manufacturing process and products are identical at the two plants the higher number of LTIs (and self-reported injuries) at Plant B cannot be due to more hazardous work tasks.

The second accident outcome measure used is self-reported injuries in the last 12 months. A 12-month reference period is frequently used in accident surveys to obtain an adequate number of accidents for analysis, however a shorter recall period is desirable to provide more accurate estimates (Landon and Hendricks, 1995). Studies have shown that accidents are under-reported by up to 43% due to recall bias when using a 12-months reference period, and a recall period between 2 weeks and a maximum of 3 months, depending on the severity of the accidents, is recommended to minimize this bias (Harel et al., 1994; Landon and Hendricks, 1995). However, the main purpose of the self-reported injuries in the present study is not to give the exact number of accidents, but to show the pattern and change in self-reported injuries between the two plants. There is no apparent reason to assume that the recall bias should differ between the employees at the two plants, as the data was collected in the same way. It can therefore be assumed that the general pattern found in the incidence of self-reported injuries between the two plants holds true.

Another weakness is the lack of a good measure for safety behaviour, which could be considered a mediating variable between safety climate and accidents. Previous research in this area has not been consistent. Zohar is one of the few researchers who has found empirical pathways between performance on measures of safety climate, safety behaviour and accident rates (Zohar, 2002; Zohar and Luria, 2003, 2004). On the other hand, Cooper and Phillips (2004), using a safety climate measure based on Zohars original measure (Zohar, 1980) and direct observations of safety behaviour, as well as accident registration via the company's own registration system, found no relationship between changes in safety behaviour and changes in safety climate or changes in accidents rates The authors conclude that the hypothesised links between safety climate, safety behaviour and accidents are not as clear-cut as is often assumed (Cooper and Phillips, 2004). As the present study does not incorporate a measure of safety behaviour it cannot shed any further light on this issue.

Three of the four measures used (safety audit, self-reported injuries and LTIs) showed that Plant A improved marginally from *T*0 to *T*1, whereas Plant B improved a lot to end up at approximately the same level as Plant A. However a slightly different pattern is seen regarding the scores on the DSCQ. Here the convergence of the safety climate scores is a result of not only Plant B getting better but also Plant A getting somewhat worse. Although the decline in the scores at Plant A are generally pretty small and only approaches significance this still warrants some attention, as this pattern resembles the statistical phenomenon of regression toward the mean. As stated in the methods section, the DSCQ was developed by reducing 138 items to 21, through confirmatory factor analysis and structural equation modelling. A concern could be that in this process the items with the most extreme difference between Plant A and B were selected at *T*0 and therefore the convergence at *T*1 is a result of regression towards the mean. To investigate this further all items used at *T*0 were studied. As stated, 138 items were used at *T*0, and out of these there was a significant difference ($p < 0.05$) between the scores at Plant A and B on 107 (77.5%). In 105 of the cases Plant A scored better than B. So it is clear that there was a marked difference in favour of Plant A at *T*0, and if the items used in the DSCQ did not reflect this, they would not be representative of the data. Actually the DSCQ items seems to be quite representative of the data, as 15 out of the 21 DSCQ items (71.4%) showed a significant difference between the plants at $T0$ – all in favour of Plant A. So it does not seem likely that there has been a selection bias favouring differences between the two plants in the process of selecting items for the DSCQ. It therefore seems reasonable to conclude that the changes in safety climate scores seen at the two plants are not due to regression toward the mean.

It is also the case that a true intervention design would allow more clear-cut conclusions about causal pathways. Nevertheless, the company's own efforts to transfer knowledge and practices from Plant A to Plant B represent a natural intervention, but since this was not under the control of the research team, sound data concerning the precise initiatives undertaken is lacking.

Management commitment to safety is usually regarded as the most important dimension of safety climate. One of the curious findings of the present study was the decrease in the number of LTIs at Plant A at $T1$, when the measure of immediate supervisor safety leadership (i.e. immediate supervisors commitment to safety) shows a borderline significant decrease ($p = 0.07$). One might expect that a decrease in management commitment would be associated with higher accident rates and not lower. However this might be accounted for by looking at the temporal relationship between the concepts. The safety climate measure is a here-and-now measure of the state of the safety climate at the time conducted, whereas the LTI's at $T1$ is a time-lagged index. It reflects the accumulation of accidents in the 6 months prior to $T1$. The underlying causal assumption when using these types of measures is that the accidents create – or at least influences – safety climate. Although it could be argued that this holds true, it would be more in line with previous research to look at safety climate as an antecedents of safety behaviour and the occurrence of accidents (Griffin and Neal, 2000; Neal et al., 2000; Neal and Griffin, 2004; Zohar, 2000; Zohar and Luria, 2003). Hence the safety climate scores at $T1$ should be compared to the LTI-rates for $T1\frac{1}{2}$ (the 6 months after $T1$). These data were also collected and showed a marked (but not statistical significant) increase in LTI-rates for both plants (from 26/mio work-hours to 47 for Plant A and from 14 to 36 for Plant B). This argument can be further extended by taking a general look at the relationship between safety climate scores and LTI performance in the following period. If a six month reference period is chosen this means that DSCQ scores at $T0$ and $T1$ should be compared with LTI performance at $T\frac{1}{2}$ and $T1\frac{1}{2}$, respectively. This shows that Plant A had better DSCQ score at $T0$ than at $T1$, and likewise the LTI-rate at Plant A at $T\frac{1}{2}$ was lower than the LTI-rate at $T1\frac{1}{2}$. (26/mio hours worked compared to 47). The same holds true for Plant B, where the DSCQ score was improved from $T0$ (LTI = 51 at $T\frac{1}{2}$) to $T1$ (LTI = 36 at $T1\frac{1}{2}$). However the present data is not well suited for this type of analysis and does not allow any conclusion to be drawn on the causal relationship of the measured dimensions. This could however be an avenue for future research.

5. Conclusion

In conclusion, the present study has demonstrated a relationship between changes in both questionnaire-based and audit-based measures of safety climate and rates of self-reported injuries and LTIs. We have not been able to shed light on all elements of the hypothesised chain of connections, leading from safety climate over safety behaviour to accidents, because of a lack of a well-functioning measure for behaviour. An interpretation of the uncovered relationships as being causal is not possible, but is strengthened by the fact that other relevant conditions at the two plants studied are identical. Furthermore, the study shows that a knowledge transfer from one plant to another following an intervention at the first plant, appears capable of improving safety climate thereby also reducing the accident rates.

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