

DEVELOPING A PROCESS SAFETY CLIMATE TOOL: THE LONG AND WINDING ROAD[†]

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Market research identified a gap in the market for a tool that would enable the perceptions of a workforce on process safety to be collected within an organisation. Following on from the successful launch of the Health and Safety Laboratory's (HSL) Safety Climate Tool in 2010, human factors specialists at HSL have been working on the development of a process specific safety climate tool.

This paper will cover the journey to date of developing a process safety climate tool and will describe the following elements:

- The appetite of industry for a safety culture tool aimed specifically at major hazards
- Key topics identified from the literature and market research
- The challenge of developing a tool with a valid/ reliable question set
- The relationship between HSL's SCT and PSCT

1. INTRODUCTION

1.1 WHAT IS SAFETY CULTURE?

Organisational climate is based on an aggregation of employees' perceptions of their experiences within an organisation (Dawson et al., 2008). Safety climate, as a term was initially used by Zohar (1980) to describe attitudes towards safety, and was derived from earlier work on organisational climates. Typically safety climate is explored through questionnaires exploring attitudes and perceptions regarding safety; it is a statistical construction of perceptions held in an organisation regarding safety and is a way to summarise these (Rousseau, 1988). Flin et al. (2000), in a review of academic papers on the issues, stated that the terms safety culture and safety climate are used interchangeably to refer to similar concepts.

HSC (1993) defined safety culture as:

“the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine commitment to, and the style and proficiency of, an organisation's health and safety management. Organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures.” (pp 23)

The development of good safety culture is recognised as central to achieving good health and safety within an organisation.

1.2 WHAT IS PROCESS SAFETY?

Process safety is described by the Centre for Chemical and Process Safety (2010) as a blend of engineering and management skills focused on preventing catastrophic accidents, particularly explosions, fires and toxic releases, associated with the use of chemicals and petroleum products.

More simply when an organisation is managing a major hazard site or carrying out an activity that requires regulating under Control of major accident hazards (COMAH) regulations (1999) then they should be managing the associated risks.

1.3 INDUSTRY DEMAND FOR A SAFETY CULTURE TOOL AIMED SPECIFICALLY AT MAJOR HAZARDS
The Health and Safety Laboratory (HSL) Safety Climate Tool (SCT) was launched in January 2010. The SCT is a survey tool developed by researchers at HSL and based on a tool developed and sold by HSE in the 1990s. It has 40 items that cover 8 factors.

The SCT has been developed into a software tool that also has the functionality to include demographic and verbatim (open ended) questions to allow users to explore responses from areas and/or specific groups within their organisation.

Using this tool as a method of measuring safety climate enables discussions between different levels and/or sites within an organisation so as to understand workers perceptions relating to conventional health and safety issues. It also allows organisations to prioritise issues that need to be addressed and dedicate the necessary resources.

To date, over 125 organisations have purchased the tool. HSL are currently investigating the feasibility of offering a benchmarking service to organisations and as part of this have collated a database of over 30,000 responses from 42 organisations within the UK across a range of sectors.

Following a number of industrial incidents (e.g. Deepwater Horizon, Buncefield), there had been an increased focus on organisational safety culture and more specifically the culture that exists around managing major accident hazards. The Baker Panel Report which followed BP's Texas City accident urged companies to “...regularly and thoroughly evaluate their safety culture” and provided a

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Figure 1. The HSL Safety Climate Tool

suite of questions as an aid to facilitate discussions between workforce and managers specifically within BP US refineries (Baker et al., 2007). This message was further echoed by the Process Safety Leadership Group (PSLG) who advocates that organisations should “develop a programme for the promotion of process safety... to support the maintenance of a positive process safety culture” (PSLG 2007).

Given the highly hazardous and often complex practices in process safety related industries, it was considered that this industry may require a climate tool that is more tailored to process safety (i.e. major accident hazards) than that offered by the SCT. This would help provide insight into workers’ perceptions specifically related to process safety.

The need for a tool that is targeted towards process safety was also supported by market research, carried out by HSL Scientists, with representatives from six major hazard organisations. Representatives from these organisations stated that there was a need for a tool to collect information from the individuals who are carrying out activities within their organisations. There was also a desire to be able to gauge what process safety messages are and/or are not getting through to workers.

Market research showed that there was an expectation of more technical questions in a Process Safety focused climate tool in comparison to the existing SCT, which was designed to be more relevant across industries. Topic areas identified through the market research that were considered to be of interest were:

- Hazard awareness,
- Permits to work,
- Training and Competence,
- Leadership,
- Emergency planning and response,
- Communication and Shift Work,
- Managing Change,
- Managing Alarms,
- Maintenance of Equipment,
- Supervisory involvement,
- Fatigue and Staffing.

However, it is worth noting that there is substantial overlap between the themes, with leadership, worker involvement, training and competence being common to process safety and occupational health and safety.

2. DEVELOPING ITEMS FOR THE PROCESS SAFETY CLIMATE TOOL

There were three stages to developing a process safety focussed question set: exploration of tool content, tool piloting and statistical analysis, and further piloting for validation.

2.1 EXPLORING THE LITERATURE AND EXPERT VIEWS TO DEVELOP TOOL CONTENT

The initial stage in developing the tool involved a review of the literature relating to major process safety incidents and the characteristics of high reliability organisations, as well as a brainstorming meeting and unstructured interviews with process safety specialists. This provided an evidence base for the inclusion of topics within the tool.

The topic areas identified included:

- Training effectiveness and competence,
- Alarm management,
- Permit to work,
- Maintenance of equipment,
- Management of change,
- Reporting and investigating,
- Resources,
- Communication during shift handover,
- Contractor competence,
- Procedures: usability and violation,
- Management support and commitment,
- Ageing plant.

A more detailed discussion of the topic areas and their evidence base is discussed in greater detail in Butler et al.’s (2010) paper.

In total, 72 items were created covering the above twelve topic areas. An example for the ‘Maintenance of equipment’ topic is: “Repairs of faulty equipment are prioritised appropriately”. The statements were rated on a 5-point Likert scale ranging from strongly agree to strongly disagree. A sixth option of “non-applicable” was also added to reflect the perception that not all the individuals would be aware of the issues.

2.2 FIRST ROUND OF PILOTING

The next stage of the tool development involved piloting the items in relevant organisations.

Interviews and discussion groups were held with representatives from four major hazard organisations in order to assess the face and content validity of the 72 items. Written, rather than face-to-face feedback about the tool, was received from one of the four organisations. This involved checking item clarity as well as the relevance and understanding of the terminology used, particularly terms, such as ‘process

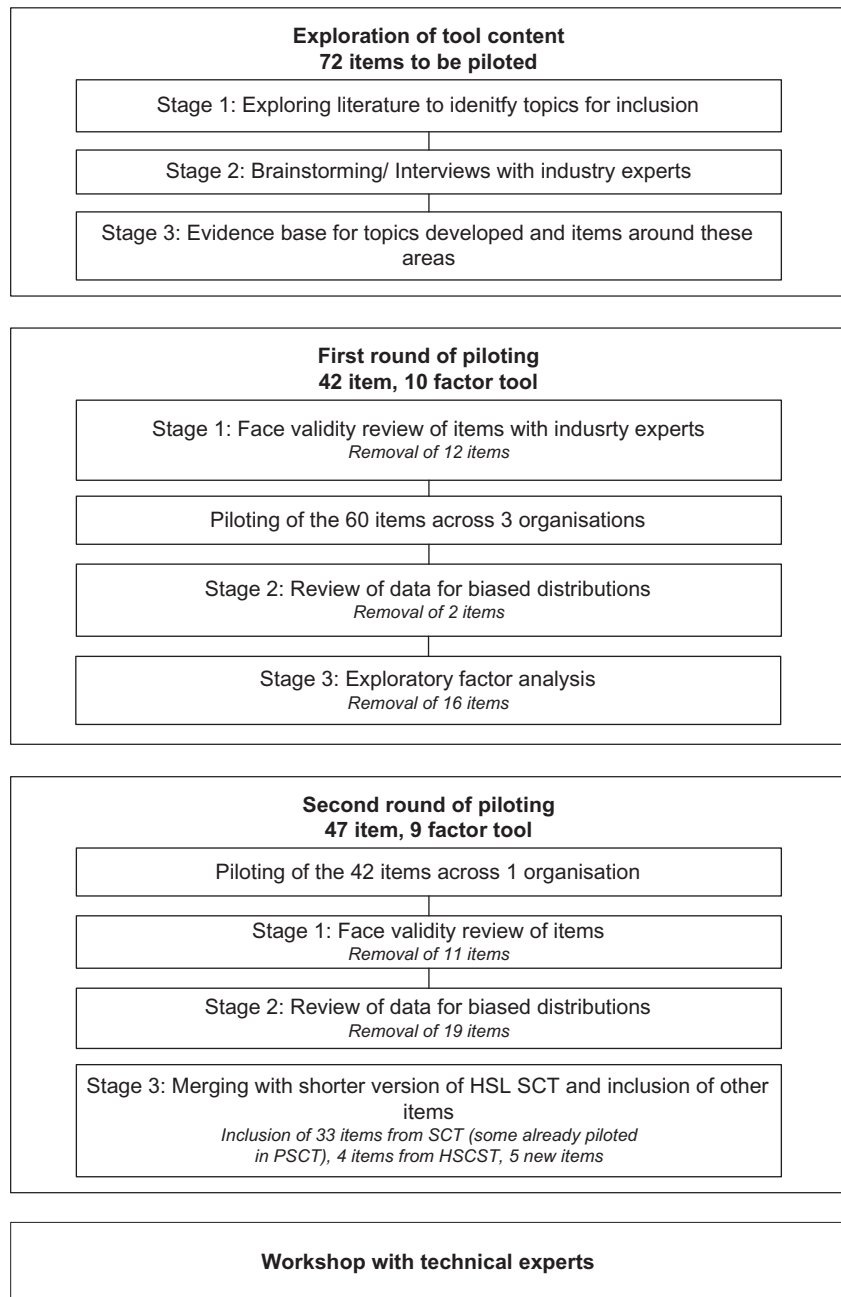


Figure 2. Overview of method for developing items for PSCT

safety’, ‘managers’, ‘supervisors’. Representatives were also asked to provide feedback on the length of the tool.

In total 12 items were removed during this process to remove repetitiveness between the items, and a lack of clarity of a number of items. A number of changes were also made to improve the items’ clarity. For example the statement, ‘The plant’s fitness for service is getting worse’ was changed to ‘The condition of this plant has deteriorated’.

Following the removal of 12 items, the revised tool that consisted of 60 items was then administered across

three of the original four organisations that had assisted with the content and face validity.

A total of 258 responses were received. The first step in the statistical analyses involved screening the data for distributional errors and outliers (i.e. cases that could have an undue influence on the analysis). In particular, the scores for each item of the PSCT were examined to check whether they were normally distributed. At this point two items which had a high proportion of “non applicable” responses were removed. In addition the response options

had the sixth “non applicable” option removed leaving a five point scale, consistent with the SCT.

A Principal Component Analysis (PCA) was carried out in order to identify the underlying factor structure of the PSCT. This was similar to the process used by Sugden et al. (2009) in the development of the HSL SCT.

The basic assumption for including items in PCA is that they contribute something to that analysis, as the procedure works by pooling shared variance. Therefore any items with inadequate loadings onto any factors would be excluded (i.e. loadings of less than 0.5). A number of items were removed at this point and additionally several other items were removed in order to improve the reliability of the individual factors. Interestingly, some of these were statements that had already been identified as marginal for inclusion at earlier stages.

Prior to the analysis the Kaiser-Meyer-Olkin measure of sampling adequacy was used to confirm the appropriate approach. A KMO score of 0.95 was achieved, suggesting that the data was suitable for a Principal Components Analysis (Field, 2000).

The PCA identified ten factors comprising a total of 42 items. The ten factors were as follows:

2.3 SECOND ROUND OF PILOTING

The next stage of piloting involved collecting additional data for validation of the items and the factor structure developed using the pilot data. This would involve repeating the process of reviewing the data for face validity, distributional biases and statistically analysing the factor structure.

The researchers deemed it to be very important to repeat this piloting process due to the relatively low number of responses collected in the first round of piloting. In the literature there are varying views regarding the minimum sample size required for a PCA depending on the number of items. Kass and Tinsley (1979) recommend having between 5 to 10 subjects per variable/item, whilst Comrey and Lee (1992) consider sample sizes of 200 as fair and 300 as good. Similarly, Tabachnic and Fidell (1996) note that it is comforting to have at least 300 cases. In the first round of piloting the sample size was 258 that was

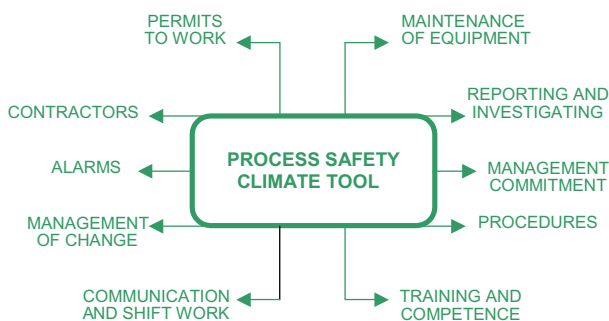


Figure 3. Factor structure of the Process Safety Climate Tool

below what is recommended by some authors, however still acceptable according to Comrey and Lee (1992). Collecting further data would also enable regression analysis to be carried out to enable exploration of the tool’s predictive validity and would ensure the sample size is sufficient.

The revised PSCT containing 42 items, which loaded onto 10 factors, was then piloted at a further two organisations. 121 responses were collected from this second round of piloting and these results were then analysed along with the data for the three organisations, which was obtained in the first pilots, creating a data pool of 379 responses.

A review of the distributions across the 42 items still found there to be issues with skewed responses on a total of 19 items. For these items over 70% of respondents were all responding as either agreeing or disagreeing to any item. Interestingly the skewness was usually always positive – implying the workforce’s perception was that organisations were doing well on the topic areas. However the skewness may not be due to actual performance and could relate to wider language issues and understanding of the concept of process safety. For example researchers found when talking to workforce representatives in a process safety focussed organisation, following process safety training, these individuals still found it hard to understand ‘process safety’ or to distinguish between that and conventional health and safety. When Sugden et al. (2009) were revising the HSL SCT; items were excluded if the responses were skewed, as the ability to be able to discriminate between performers was essential. It was therefore decided that the items making up the draft version of a process safety climate tool (PSCT) required a major overhaul.

Researchers decided to return to the validated SCT and to consider if any relevant items from this could be used and reworded to be more major accident specific. A number of the items in the draft PSCT were in fact very similar to those used within the SCT and were therefore dropped in favour of the already existing and validated SCT items. Additionally a number of items on ‘Permit to Work’ which had been excluded during the revision of the SCT (Sugden et al. 2009) could now be included in the revised draft.

The result of this stage created a draft of the tool with 47 items and 9 factors.

2.4 WORKSHOP WITH INDUSTRY EXPERTS

Following the second piloting phase, it was decided to repeat a review for content validity with industry experts from the Health and Safety Executive (HSE) and Scientists from HSL.

The workshop was attended by eight participants and they were asked to:

- Complete a draft survey,
- Discuss ‘what is process safety?’ and,
- Take part in an activity to group the items against factors.

The aim of this workshop was to ascertain expert evaluation of the relevance of topics and items.

The workshop sparked a great amount of debate and attendees identified differing issues influenced by their own experience of working with different major hazard industries.

When completing the draft survey and in subsequent discussions workshop participants found it difficult to clearly differentiate and define the distinction between personal and process safety. There was agreement that a significant amount of rewording of the items was required. But differences in the terminology used both within and between industries added to the difficulty in reaching consensus within the group. Furthermore, a SCT item states "Management always act quickly over health and safety concerns" and the suggested alternative to this for inclusion in the PSCT would be "Management always act quickly over process safety concerns". However discussions highlighted that although it may be possible for management to act quickly over general health and safety issues it may not be the same in organisations dealing with major accident hazards. Any changes made that affect a 'process' could entail a detailed or lengthy review and planning period to ensure all parties (e.g. appropriate technical specialists, drawing office, engineers commissioning the work) are consulted, and this may not happen 'quickly'.

Another item that was discussed in the workshop was "Accidents that happen here are always reported". This item was derived from the HSL SCT and was considered to work well in relation to conventional health and safety. However feedback from the workshop identified this may not be appropriate in a survey looking at process safety. In major hazard industries any process related accident has to be reported and is also more likely to be due to the potential of a process related event. This example also demonstrates why the pilot data may have been skewed, as the workforce would assume all incidents would be reported.

The discussions highlighted a common question of who the survey is aimed at. Workshop participants felt a number of the items could not be 'answered' by all levels of workforce due to their individual experience.

The conclusion from the workshop was that there was still a substantial amount of work required on the process safety climate tool. Some of the main areas for debate in the expert panel were the use of the term "process safety" in some items and that some of the newly included SCT items changed the emphasis back towards a conventional health and safety focus, whereas previously there had been concern over using the term "process safety" within individual items, where those items with skewed biases incorporated the phrase 'process safety'.

3. THE CHALLENGE OF DEVELOPING A TOOL WITH A VALID AND RELIABLE QUESTION SET

The intent of the Process Safety Climate tool was similar to that of the HSL SCT. It was envisaged that a tool would be developed that would enable organisations to identify workers' perceptions about organisational practices with regard to process safety. The tool would be used across an

organisation's workforce from frontline operators to management (Butler et al., 2010) and would provide a way for companies to identify opportunities for improvement.

However, as the tool has evolved, questions have arisen as to whether process safety climate can in fact be measured in this way using a survey. The terminology used in the items is particularly important as it can either aid understanding or could possibly create a tool that is not applicable across all levels of workforce within an organisation. For the HSL SCT it was intended to make the tool generic and applicable across all industry types and the items contained within the survey reflected this. In the case of a process safety climate tool the intended audience is more specific as it is designed to be used in organisations within the major hazard industries.

All the difficulties experienced in the item development, piloting loops, and the discussions with industry experts raise the question 'what do the workforce view process safety as?' This then causes subsequent difficulties with identifying the correct terminology to be used in any survey trying to measure perceptions of the workforce on major accident hazards. Do the workforce on major hazard sites differentiate between conventional safety and process safety? Or is it just the same as keeping it safe in their day-to-day jobs? Process safety is integral to the job of individuals working on major hazards sites and is linked with the reliability of operations, and is part of the activities that generate revenue for organisations. Process safety events are lower frequency than the 'slips and trips' type events of conventional health and safety and therefore individuals could consider they have less personal ownership for these types of events. This lack of personal ownership of hazards, and the ability to make any changes may mean that a workforce assumes (based on their knowledge of the hazards) that management will be proactively managing the risks. This would therefore create skewed responses to any items on this topic.

The data collected in the piloting stages were often positively skewed, therefore not allowing for any discrimination between those doing better and worse in certain areas. This may raise concerns as to whether the survey is 'tapping' into the right elements or whether attitudinal surveys are the most appropriate way of measuring process safety. There are currently no other validated tools to measure process safety climate, although the tool designed by BP U.S. Refineries Independent Safety Review Panel does offer a way to measure process safety climate. This audit tool covers a number of the same topic areas but it is not a survey aimed at the entire workforce.

The development of the process safety climate tool to date has been based on the assumption that this tool would be similar to the HSL SCT, allowing organisations to obtain a snapshot of the workers' attitudes on a range of issues related to process safety. Based on the aforementioned development difficulties and findings, a substantial amount of work still needs to be completed to clarify some of the findings and identify the most appropriate way forward.

4. CONCLUSIONS

The researchers are currently reviewing and considering the implications of the development work so far. There are a number of key questions that need exploring and clarifying:

- How are statements provided? Who responds? Who is the survey designed to be completed by? All levels of the workforce?
- How can language be 'major hazard specific' without using the term 'process safety'? What is the appropriate terminology?
- Is process safety inherently any different to personal safety to those actually doing the job?

The above points need to be reconsidered before further development work can be appropriately planned and carried out.

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REFERENCES

The B.P. U.S. Refineries Independent Safety Review Panel, 2007, *The report of the B.P Refineries Independent Safety Review Panel*, http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/SP/STAGING/local_assets/assets/pdfs/Baker_panel_report.pdf (accessed 19th November 2008)

Butler, C., Lekka, C. and Sugden, C., 2010, Development of a process safety climate tool. *Mary Kay O'Connor Process Safety Centre International Symposium*, Beyond Compliance, Making Safety Second Nature, 26–28 October 2010, Texas, USA.

Centre for Chemical and Process Safety, 2010, What is process safety? <http://www.aiche.org/ccps/Students/GetSmart.aspx#1>

HSE, 2006, *A Guide to Control of Major Accident Hazards regulations 1999 (as amended)*, HSE Books.

Comrey, A. L. and Lee, H. B., 1992, *A first course in factor analysis*. Hillsdale, NJ: Erlbaum.

Field, A., 2000, *Discovering statistics using SPSS for Windows*. London: Sage.

Flin, R., Mearns, K., O'Connor, P. and Bryden, R., 2000, Measuring safety climate: identifying the common features. *Safety Science*, 34 (1–3): 177–192.

HSC, 1993, *ACSNI study group on human factors. Third report Organising for Safety*. HSE Books.

HSE, 1991, *Successful health and safety management*, HMSO.

Kass, R. A. and Tinsley, H. E. A., 1979, *Factor analysis*, *Journal of Leisure Research*, 11: 120–138.

Process Safety Leadership Group (PSLG), 2007, *Principles of Process Safety Leadership*, <http://www.hse.gov.uk/comah/buncefield/pslgprinciples.pdf>

Rousseau, D.M., 1988, The construction of climate in organisational research, In *International Review of Industrial and Organisational Psychology*, Eds. C.L. Cooper and I. Robertson, John Wiley and Sons, Chichester.

Sugden, C., Marshall, M., Binch, S. and Bottomley D., 2009, The development of HSL's Safety Climate Tool – a revision of the Health and Safety Climate Survey Tool. In *Contemporary Ergonomics 2009*. Ed. P. Bust, Taylor & Francis: London. 245–252.

Tabachnick, B. G., and Fidell, L. S., 1996, *Using multivariate statistics (3rd edition)*, New York: HarperCollins College.

Zohar, D., 1980, Safety Climate in Industrial Organisations: Theoretical and Applied Implications, *Journal of Applied Psychology*, 65: 96–102.