Mapping safety culture onto processes and practices: the Safety Culture Stack approach

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Future Sky Safety is a Joint Research Programme on Safety, initiated by EREA, the association of European Research Establishments in Aeronautics. The Programme contains two streams of activities: 1) coordination of the safety research programmes of the EREA institutes and 2) collaborative research projects on European safety priorities.

This deliverable is produced by the Project P5: Resolving the Organisational Accident. One of P5's aims is to ensure that safety culture can map onto processes and practices in an organisation. The Safety Culture Stack approach has achieved this via the collaborative safety efforts of fifteen organisations located at a single airport.

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Acronyms

Acronym	Definition
ANSP	Air Navigation Service Provider
ATM	Air Traffic Management
CAA	Civil Aviation Authority
EASA	The European Aviation Safety Agency
EU	The European Union
LSE	London School of Economics and Political Science

EXECUTIVE SUMMARY

Problem Area

Safety culture is seen as essential for safety, but it is also seen as something that is to an extent intangible, its effects on operational safety and risk indirect and diffuse. This leads to a state of affairs wherein even those convinced about safety culture find it hard to 'sell' it to others, and those who are less convinced find it easier to ignore in practice.

In aviation, safety culture in Air Traffic Management (ATM) has led the way in terms of developing a tailored approach to safety culture surveys now serving more than 30 countries in Europe, and creating a community of safety culture practice amongst around 20 ANSPs via an annual safety culture regional workshop in Europe. Future Sky Safety Project P5, Resolving the Organisational Accident, has attempted to spread this approach to other aviation sectors, namely airlines, airframe manufacturers and airports, and has already shown that this is feasible via several large and high profile surveys.

What remains however is to show the practical connection with safety at work, to *ground* safety culture and make it more practical, to show that it matters and can make a real difference, whether to pilots, controllers, ground handlers, or their managers. This has been the aim of the final task in the Safety Culture work package, and has resulted in the 'Safety Culture Stack' approach which has been validated at an airport.

Description of Work

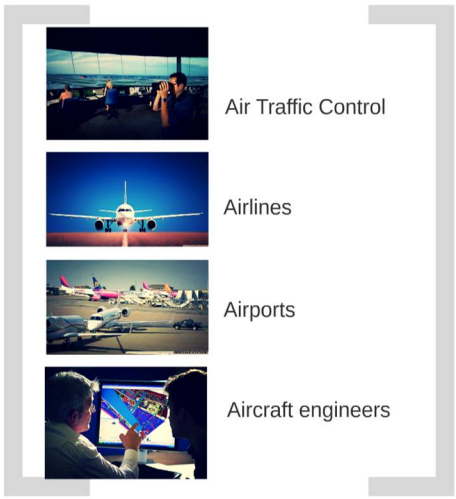
The initial idea for the Safety Culture Stack came from the ATM safety culture work. It was noticed regularly that an Air Navigation Service Provider (ANSP), when recounting their key risks, would often mention certain risks over which they had limited control, because risk management depended on other aviation partners, whether the airport, ground handlers, particular airline practices, or military operations and organisations. These shared risks were effectively safety 'blind spots', since it appeared to an extent that the other organisations were not necessarily aware of the risk they were creating or 'exporting' to the ANSP. At the time such stakeholders were outside the remit of the ATM safety culture programme, which was run by EUROCONTROL, who are primarily focused on air traffic management.

The Future Sky Safety programme, via Project P5, enabled a higher-level evaluation of safety culture, by considering all aviation players. First, the foundation was set by checking if other stakeholder types could utilise the same safety culture approach, and the EUROCONTROL survey was adapted and tested in particular on airlines and airframe manufacturers. These surveys showed that the safety culture issues are not so different between the different aviation segments. The next step was to try to bring such stakeholder partners together. This was achieved by a set of focused and coordinated independent surveys at a single airport, involving the airport authority, an airline, an ANSP, a ground handling service, fire services and a de-icer service. Each of these entities underwent a safety culture survey. Six of the organisations then met, and compared their results at a high level. The organisations decided they should

work together to help each other, and to share and evolve harmonised best practices. The resultant collaborative group of organisations has been called a 'Stack', because they can be viewed as a vertical arrangement from ground operations upwards, as shown in the diagram below.

Results & Conclusions

In 2017 four Safety Culture Stack workshops were held, and currently fifteen organisations are working together in what has been called the Safety Culture Stack approach. This has already led to harmonised ground handling procedures to reduce operational variability and to enhance safety on the ground. A shared safety dashboard is being developed, as well as an 'App' to share key safety insights rapidly across staff at the airport location. In total the work programme of the Safety Culture Stack has nine goals aimed at enhancing operational safety. The Safety Culture Stack represents 'safety culture in action', and has made an effective bridge between safety culture theory and operational safety processes and practices.



The Safety Culture Stack represents an evolution of the safety culture approach. Often, after several surveys over a period of years in an organisation, safety culture can be seen as 'losing its edge', particularly where the organisation has been implementing ever-improving safety culture practices. The question then becomes 'what next?' The Safety Culture Stack can inject new life into the process. Furthermore, with respect to resolving the organisational accident, accidents are not always down to a single organisation. This is particularly so at an airport, where operational safety depends on synchronised and safe operations between multiple organisations – joined up safety – creating a 'safety chain'. In such systems, any organisation is only as safe as the weakest link in that chain. In such a system, it is no longer enough for an organisation to say 'we're safe, if another organisation isn't that's not our problem.' Rather, if one organisation can see how to help another improve its safety and safety culture, it should do so. Passengers and other air transport users should expect no less. A more collaborative and practical approach to safety culture will help aviation maintain its hard-won reputation as the safest form of air transport, in Europe and beyond.

Applicability

The Safety Culture Stack approach has been demonstrated at a single airport location. The next stage will be to see it migrate to other airports or aviation sectors.

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1 INTRODUCTION

1.1. The Programme

Future Sky Safety[1] is an EU-funded transport research programme in the field of European aviation safety, with an estimated initial budget of about € 28 million, which brings together 33 European partners to develop new tools and new approaches to aeronautics safety, over a four-year period starting in January 2015.

Future Sky Safety contributes to the EC Work Programme Topic MG.1.4-2014 Coordinated research and innovation actions, targeting the highest levels of safety for European aviation in Call/Area Mobility for Growth – Aviation of Horizon 2020 Societal Challenge Smart, Green and Integrated Transport. Future Sky Safety addresses the Safety challenges of the ACARE Strategic Research and Innovation Agenda.

Future Sky Safety will also help coordinate the research and innovation agendas of several countries and institutions, as well as create synergies with other EU initiatives in the field (e.g. SESAR, Clean Sky 2). Future Sky Safety is set up with four years duration, and started on the 1st of January 2015.

Future Sky Safety, established under coordination of EREA, is built on European safety priorities around four main themes, each consisting of a small set of Projects:

- Theme 1 (New solutions for today's accidents) aims for breakthrough research with the purpose of enabling a direct, specific, significant risk reduction in the medium term.
- Theme 2 (Strengthening the capability to manage risk) conducts research on processes and technologies to enable the aviation system actors to achieve near-total control over the safety risk in the air transport system.
- Theme 3 (Building ultra-resilient systems and operators) conducts research on the improvement of Systems and the Human Operator with the specific aim to improve safety performance under unanticipated circumstances.
- Theme 4 (Building ultra-resilient vehicles) aims at reducing the effect of external hazards on the aerial vehicle integrity, as well as improving the safety of the cabin environment

1.2. Project context

The objective of Project P5 "Resolving the organisational accident" (FSS P5) is to reduce the likelihood of organisational accidents in aviation via development and implementation of a Safe Performance System. P5 answers to Future Sky Safety Theme 3, which aims at strengthening the resilience to deal with current and new risks of the humans and the organizations operating the air transport system.

In order to achieve this objective, four research directions (work packages 1 through 4) are followed supplemented with an integration work package (WP5) to reduce the likelihood of organisational accidents in aviation:

[1] See https://www.futuresky-safety.eu/ accessed 15JAN2016.

- WP1 - Safety intelligence. Researching the contributions to safety in aviation organizations by top and middle management. Additionally to research how to improve Safety Intelligence by identifying best practices for the design and use of Safety Dashboards.
- WP2 - Safety mindfulness. Developing and implementing a model able to improve the organizational mindfulness –i.e. creating a purposeful flow of relevant and useful information that actively supports, from the one side, operational people's capability to remain mindful of safety when carrying out their activities, and from the other, the managers to remain 'in the loop' and collect useful data to ensure continuity of improvement process.
- WP3 - Safety culture. Extending the safety culture analysis and improvement approach developed for ATM to other sectors in the air transport system.
- WP4 - Agile response. Developing an agile response capability that addresses events focusing on sudden crises but also exploring aspects of the continuum towards slower developing risks with longer-term dynamics.
- WP5 – Safe Performance System. This final WP integrates the foregoing into typical Safety Management Systems frameworks, lending them an organisational risk management capability to help reduce the likelihood of accidents.

Extending safety culture in the air transport system is the subject of Work Package 3 and this deliverable.

1.3. Research objectives

This study has four objectives:

1. Apply a safety culture measurement tool used in the ATM and Airline industry to systematically investigate safety culture across the interconnected parts of the aviation system (the 'stack')
2. Profile, at the questionnaire-item and dimension level, broad safety culture trends amongst the different partners of the stack
3. Identify variations between partners that might indicate potential weaknesses in the safety culture stack
4. Utilise these data to open a 'stack-wide' discussion on safety culture, whereby they are used to identify potential areas for learning and improvement amongst all partners, impacting on processes and procedures in a practical way.

1.4. Research context and approach

The context

The aviation industry in Europe is constantly evolving due to a combination of global economic changes, changing customer demands, and increases in airlines with alternate business models (Jorens, Gillis et al. 2015). Yet, it remains very safe: the European Aviation Safety Agency (EASA) report that in European Commercial Aviation, an average of 1.3 accidents (with 64.2 fatalities) has occurred per year since 2005 (EASA 2016). This is against a backdrop of 800 million passengers travel per year in the European Union alone, with fewer than 0.5 fatal accidents per million flight departures in Europe.

Developments in technology and airframes, automation, standardisation, safety protocols, regulation, air crew training, working directives, the external environment, and professional standards have contributed to this. Also crucial, however, has been an industry-wide culture of safety, whereby due to the low frequency of accidents and near-misses, and the non-linear relationship between profitability and safety (Masden, 2011), *safety culture* has become a key indicator for assessing safety practices and susceptibility to safety problems within aviation organisations.

Yet, there is a requirement for researchers and practitioners to constantly evaluate whether the methodologies and theorisations of safety culture are ideal for detecting potential problems in the aviation system, and also for identifying and sharing best practices. In particular, safety culture investigations have tended to be 'siloed', where they investigate the state of safety culture within a given industry (e.g. airlines) or organisation (e.g. a single airline).

This does not take into account the inter-dependencies between the different parts of the aviation system. For example, the reliance upon an airline of a safe and effective air traffic control system. The importance of the air traffic control system for safe and efficient operations within the airport, and in particular ground handling. Indeed, within an organisation, for example an airline, there are important safety-related inter-dependencies between different functions (e.g. rostering and pilots).

In effect, it might be argued that safety culture in the aviation system is only as strong as the organisation with the weakest safety culture. Furthermore, perhaps staff in some organisations (e.g. Air Navigation Service Providers (ANSPs)) have insights about the safety culture of the organisations they interact with (e.g. airlines) that are unobserved and valuable. Indeed, the safety culture of one organisation (e.g. an airline) might have implications for the organisations they sub-contract work to (e.g. ground handling companies), with cost pressures or institutional routines creating safety issues for those organisations.

At present, little research has investigated this issue in the aviation sector (or indeed any sector). In this report, we describe the application of a psychometrically established tool for measuring safety culture at a single juncture in the aviation system: an airport, and the airlines, air traffic management services, and sub-contracted companies operating out of that airport. We term this a 'safety culture stack', as it includes most of the various operational components associated with delivering safe air transport. We apply the same safety culture measurement tool to all components of the stack, and examine the resulting trends from the survey data. The purpose is simply to establish what safety culture 'looks like' at a stack level, and the variations between organisations. We then examine and report on the process of bringing together stakeholders in order to discuss the 'safety culture stack' results. The purpose is to develop a new way of conducting safety culture analyses, whereby data is explored in a systematic and collaborative way with stakeholders, whereby common challenges and problems can be addressed collectively.

Safety culture: definition and background

Safety culture is a sub-facet of organisational culture (Reason 1997, Clarke 1999, Cooper 2000). It is made up of safety-related norms (or basic assumptions), values, and practices shared by groups (Guldenmund

2000). Simply, it comprises how people feel (psychological aspects), what they do (behavioural aspects) and how the organisation operates (situational aspects) in relation to safety (Cooper 2000). The concept rose to prominence after the Chernobyl nuclear disaster where it became apparent that the organisation's poor safety culture contributed to the preventable tragedy (International Atomic Energy Agency 1986). Discussions on safety culture often refer to the topic of safety climate, with the terms being used interchangeably. This reflects a long-standing, if not terribly useful, debate on the differences between the two (Zohar 1980). Most commonly, safety climate is considered to be a temporary snapshot of the current safety culture made up of perceptions and feelings (likened to mood), while safety culture is more stable (and compared to personality) and relevant to group activities and organisational histories (Cox and Flin 1998). Safety climate focuses on managerial prioritisation of safety (Zohar 2010), whereas safety culture focuses on the safety-related values and practices that more widely permeate the organisation (Reader, Noort et al. 2015). In this study, we focus on the topics covered by safety climate (management commitment to safety), and also a range of enduring practices that reflect safety culture (e.g. incident reporting practices, relationships, cooperation with colleagues). Thus, our focus is on safety culture, with the concepts measured within safety climate being subsumed within this theoretical framework.

Safety culture research is common across most high-risk industries. For example, construction (Chinda and Mohamed 2008), offshore environments (Cox and Cheyne 2000), healthcare (Halligan and Zecevic 2011), nuclear power (Lee & Harrison, 2000), aviation (O'Connor, O'Dea et al. 2011), air traffic management (Mearns, Kirwan et al. 2013), shipping (Havold 2005), and rail (Clarke 1998). Many methods exist to measure safety culture (e.g. interviews, focus groups, observations), however surveys are most often used (Huber 1991, Reason 1997, Conchie, Donald et al. 2006). Surveys typically involve organisational members responding to questionnaire items that relate to a number of 'latent dimensions': for example Just Culture and incident reporting, collaboration and involvement, fatigue, the support given by an organisation (e.g., resources) to improve safety, and communication on safety (Reader, Noort et al. 2015).

Where responses to such dimensions are assessed as shared and positive across an organisation, safety culture is conceptualized as 'strong', and to be a positive indicator of safety. Conversely, negative, opposite or fragmented perceptions tend to indicate a 'weak' safety culture, where responders view safety-related values and practices within the organisation (e.g. on attitudes and behaviours for working when sick or fatigued) as problematic.

Research shows that organisations with a poor safety culture are more prone to accidents, while those with a strong safety culture are more resilient (Clarke 2006). However, this finding has not been demonstrated in the aviation industry, primarily due to very low rate of incident occurrence (e.g. compared to healthcare). Nonetheless, safety culture measurement has become a widely used method to gather insight on (e.g. strengths, weaknesses, areas for improvement) the safety practices of employees and managers and organisational safety management strategies.

Safety culture in the aviation industry

Safety culture is a concept deeply embedded within the aviation industry (e.g. airlines, manufacturers, air traffic control). This is due to the recognition that threats to safety will always exist, and that where they

manifest they have the potential to be catastrophic (Gill and Shergill 2004). In particular, safety culture issues have been established as a major causal factor in aviation accidents (Aarons 2011) , and are now integral to advanced safety management systems. These are "a proactive and integrated approach to managing safety including the necessary organisational structures, accountabilities, policies and procedures" (Civial Aviation Authority 2015). Safety management systems comprise safety policy and objectives, safety risk management, safety assurance, and safety promotion: they are most effective when "built on a foundation of a positive safety culture" (CAA, 2014, p4). Thus, various tools for measuring safety culture exist across the aviation industry: in Air Traffic Control (Mearns, Kirwan et al. 2013), aircraft maintenance (McDonald, Corrigan et al. 2000, Kim and Song 2016), ground handling (Ek and Akselsson 2007), and for cabin crews (Kao, Stewart et al. 2009). Indeed, due to the high standards established for managing safety in the aviation industry, it has become a model upon which safety management strategies are emulated in other sectors (Kapur, Parand et al. 2016).

In terms of taking a system-wide approach (stack) to measure safety culture in the aviation industry, to our knowledge, this is the first study to have done this. Various surveys and psychometric models have been developed to examine different components of the system. For example, Reader and colleagues (2015) have outlined a measurement model for assessing safety culture in European Air Traffic Management. In the airline industry, various bespoke models have been developed to measure safety culture in pilots (O'Connor, O'Dea et al. 2011), or engineers and ground crews (Gill et al., 2004).

However, to date, a systems approach to measuring safety culture has not been adopted within the aviation industry. In the current study, we utilise a safety culture questionnaire widely applied in the ATM industry (Reader et al., 2015), and adapted to airlines (Reader et al., 2016), to measure safety culture across the aviation system.

Specifically, EUROCONTROL (the European Organisation for the Safety of Air Navigation) has instituted a pan-European approach to safety culture measurement in ATM. In partnership with the University of Aberdeen (2006-2011) and the London School of Economics (2012-present), a psychometrically tested measurement tool has been developed for measuring safety culture in European ATM. The survey tool is part of a wide toolkit (e.g. focus groups, observations) used to measure safety culture in European ANSPs (e.g. with air traffic controllers, engineers, and managers). These data are used to monitor potential problems in an ANSP's safety culture (e.g. comparing data to industry norms), to identify strengths and opportunities for improvement, and to evaluate the impact of organisational change (e.g. over time).

To date, over 30 ANSPs have participated in the programme (with some being surveyed multiple times), with data being gathered from over 20,000 respondents. The programme has received very positive recognition from the ATM sector (as evidence by changes in industry practices and conferences on safety culture) and the scientific community, and is currently one of the largest safety culture programmes in the world. In terms of academic safety culture research, the work has shown that i) safety culture can be reliably measured across different countries, ii) ANSPs vary considerably in their safety culture, with factors such as national environments explaining this, iii) management and controllers can develop quite

divergent beliefs around safety culture in an ANSP, and iv) safety culture can be meaningfully benchmarked and used to stimulate inter-organisational learning across the industry in Europe.

In 2016 this approach was adapted to measuring safety culture in airlines, and was tailored (in partnership with the European Cockpit Association) to airline pilots. A total of 7,239 (14% of the population) commercial pilots in Europe completed the survey. The results found that perceptions of safety culture were generally positive. However, significant differences in pilot' assessments of safety culture were revealed, depending on factors such as the type of airlines they work for, or the type of contracts they work to. Pilots working on atypical contracts, and those working for low cost and cargo airlines, had more negative perceptions of safety culture than their colleagues working under more secure forms of employment and for network carrier airlines. In particular, this was in relation to management commitment to safety, staffing and equipment, fatigue and perceived organisational support.

In the current study, we apply the safety culture measurement tool developed for ATM, and then airlines, to a single airport, and the airlines, ATM, and contract services operating out of the airport (termed the 'stack').

1.5. Structure of the document

Section 2 describes methods for safety culture measurement to systematically investigate safety culture across the interconnected parts of the aviation system (the 'stack').

Section 3 provides the results of the Safety Culture Stack approach, via a collaborative safety effort of fifteen organisations located at a single airport.

Section 4 discusses the results and the limitations of this study.

Conclusions and recommendations are provided in Section 5.

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2 METHODS

2.1. Safety culture measurement

The study utilised the EUROCONTROL safety culture survey, which has been used extensively and has been psychometrically validated in European Air Traffic Management. The questionnaire is part of a larger toolkit that is used to measure, understand, and improve safety culture in ATM. The purpose is to measure staff (e.g. operational, management, engineers) assessments and beliefs on safety culture within their Air Navigation Service Provider (ANSP). The survey items underlying the tool were developed through a literature review and qualitative investigation (interviews, focus groups, incident analyses). Data from the survey is used to structure workshops and interviews on safety culture (e.g. to understand specific safety problems), and a prototype version of the questionnaire was tested in four ANSPs in 2008. A larger investigation, with 17 ANSPs and data from nearly 6500 participants was used to establish a measurement model for assessing safety culture across Europe.

The tool was then iterated for commercial pilots working in European aviation (e.g. adapting items relating to work in ATM to pilots), with each question being reviewed, amended where appropriate, and tested with a small sample of respondents (Reader et al., 2016). For the current study, this version of the tool was used for airlines within the stack (with some amendments), and then through further discussions with the other organisations in the study (e.g. ATM, airports, ground handlers, fire services, de-icing services) the tool was tailored for those organisations. For the final survey, either the same questionnaire items were used for each participant (e.g., like-for-like survey items were used (e.g. *My direct manager is committed to safety*), or items were made specific to particular industries (e.g. *pilots in this company…, people in this organisation…).*

The final survey comprised a total of 50 items covering eight safety culture dimensions: *Management Commitment to Safety; Collaboration & Involvement; Just Culture & Incident Reporting; Communication & Learning; Colleague Commitment to Safety; Risk Handling; Procedures & Training; Fatigue.* Furthermore, basic demographic questions were collected. These included: participant role; tenure; contract-type,

Table 1 Questionnaire items & dimensions

DEMOGRAPHICS ➢ What is your primary role? ➢ How long have you been working in your company? ➢ Are you a full-time or part-time employee?
MANAGEMENT COMMITMENT TO SAFETY ➢ My direct manager is committed to safety ➢ My direct manager takes action on the safety issues we raise ➢ My direct manager would always support me if I had a concern about safety ➢ Employees have a high degree of trust in management with regard to safety ➢ Senior management takes appropriate action on the safety issues that we raise

COLLABORATION & INVOLVEMENT

- My involvement in safety engagement activities (e.g. safety meetings) is sufficient
- People who raise safety issues are seen as troublemaker (R)
- There are people who I do not want to work with because of their negative attitudes to safety (R)
- Other people in this organisation understand how my job contributes to safety
- We are sufficiently involved in safety risk assessments
- We are sufficiently involved in changes to procedures

JUST CULTURE & REPORTING

- Voicing concerns about safety is encouraged
- People who report safety-related occurrences are treated in a just and fair manner
- We get timely feedback on the safety issues we raise
- If I see unsafe behaviour by any of my colleagues I would talk to them about it
- I am prepared to speak to my direct manager when unsafe situations are developing
- Incidents or occurrences that could affect safety are properly investigated
- I am satisfied with the level of confidentiality of the reporting and investigation process
- A staff member who was involved in an error would be supported by the management of this organisation
- Incident or occurrence reporting leads to safety improvements in this organisation
- A staff member who regularly took unacceptable risks would be disciplined in this organisation.

COMMUNICATION & LEARNING

- Information about safety-related changes within this organisation is clearly communicated to staff
- There is good communication up and down the organisation about safety
- We learn lessons from safety-related incident or occurrence investigations
- There are people who I do not want to work with because of their negative attitudes to safety (R)
- I know what the future plans are for our company
- I read reports of incidents or occurrences that are relevant to our work
- We openly discuss incidents or occurrences in an attempt to learn from them

RISK HANDLING

- Changes to the organisation, systems and procedures are properly assessed for safety risk
- We often have to deviate from procedures
- I often have to take risks that make me feel uncomfortable about safety (R)

COLLEAGUE COMMITMENT TO SAFETY

- My colleagues are committed to safety.
- Everyone I work with in this organisation feels that safety is their personal responsibility.
- I have confidence in the people that I interact with.
- My team works well with the other teams within the organisation.
- I can comfortably challenge my colleagues on safety issues.

STAFF & EQUIPMENT

- We have sufficient staff to do our work safely.
- People in this organisation share safety-related information.
- We have sufficient support from safety specialists.
- We have the equipment needed to do our work safely.

PROCEDURES & TRAINING

- The procedures describe the way in which I actually do my job.
- I receive sufficient safety-related refresher training.
- Adequate training is provided when new systems and procedures are introduced.
- The procedures associated with my work are appropriate.
- I have sufficient training to understand the procedures associated with my work.

FATIGUE

- I have received sufficient training to understand the risk of fatigue.
- The issue of fatigue is taken seriously by this organisation.
- I would feel comfortable reporting fatigue.

(R)=Reverse (negatively) worded item

2.2. Data collection

Six organisations were surveyed during April to June 2016. The organisations all operated out of a single airport, and the participating organisations were: A. Airport; B. Commercial airline; C. Ground Handlers; D. Air Traffic Services; E. Fire services; F. De-icing services.

The survey was electronic, and managed through the 'Qualtrics' survey platform. In each organisation, the survey was distributed via an online link. In total, the six organisations had a total population of 1716. These were A. Airport (n=64); B. Airline (n=1164); C. Ground Handlers (n=400); D. Air Traffic Services (n=35); E. Fire services (n=43); F. De-icing services (n=10). For each company involved, the survey was promoted through newsletters, company emails, and social media.

2.3. Study participants

There were a total of 594 valid responses included in the study and subsequent analyses. This was equivalent to 34.6% of the total population. This is after removal of surveys that did not meet a number of criteria for detecting non-meaningful or fraudulent entries (e.g. partial completion, completion time, lack of sensitivity to negatively worded items, and a number of other criteria).

In terms of responses by organisation, these were as follows: A. Airport (n=57, 64% of population); B. Airline (n=428, 37%); C. Ground Handlers (n=49, 12%); D. Air Traffic Services (n=21, 60%); E. Fire services (n=30, 46%); F. De-icing services (n=9, 90%). Within the sample there were some missing responses (e.g. to a single item). We handled missing variables using pairwise deletion. This means that we identify that these responses are missing and we remove them from the case, but include all other responses from the respondent with the missing data.

2.4. Quantitative analysis

Using the software package SPSS, we checked the normal distribution of survey items. We then ran descriptive statistics comprising frequencies, means, ranges and standard deviations (SD) for all items in the survey. The table below contains an explanation of these terms.

Table 2 Statistical definitions

N (valid): The number of participants who provided a rating for the item.

N (missing): The number of participants who did not provide a rating for the item.

Mean score: This score indicates the general level of agreement for the whole sample, where: 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, 5 = strongly agree.

Reverse scored items (R): These are rescored items of statements that were worded negatively. For example, a response of 'disagree' to these items is a positive response for safety culture.

Standard deviation (SD): This indicates the spread of responses. A large standard deviation indicates a large variation between individuals' responses on the scale. A small standard deviation indicates low variation and higher agreement amongst individuals.

Range: This refers to the difference between the highest and smallest values. It indicates spread of the scores.

Min & Max: Shows the minimum and maximum scores from the scale. The agreement scale used is between 1 to 5, from strongly disagree (1) to strongly agree (5).

P value: The p value refers to the probability that any observed difference between groups is due to chance. We have set the significance level at a very strict level of 0.1%, P<.001 (the standard p value is usually set at P=0.05, 5%). The reason for the stricter significance level is the large size of this study sample, which is more likely to present more significant results.

ANOVA: An Analysis of Variance (ANOVA) is a statistical test of difference for more than two groups. Post hoc tests (e.g. Games-Howell and Sheffe reveal which groups have significant differences or not)

Cronbach's alpha: Cronbach's alpha is a test of a dimension's internal reliability (i.e. how well do the items appear to be measuring the same thing). The higher the alpha (i.e. the closer to 1), the more reliable the measure. We consider alphas above .6 to show an acceptable reliability of the dimension.

Our analysis consisted of the following.

First, we examine the mean responses and standard deviations to all survey items across the entire stack. The purpose is to report on the overall safety culture of the aviation stack.

Second, we examine the top-five and bottom-five items for each organisation within the aviation stack. The purpose is to examine the issues facing each operator, to examine whether these are shared (i.e. focussing on the same items), or disparate. To do this, we identified the items with the most favourable or unfavourable response trends. This is where, regardless of whether a questionnaire item is worded negatively or positively, participants get a response consistent with a positive safety culture. For example, either agreeing or strongly agreeing with the statement: "We have sufficient staff to do our work safely"

Third, we examine the means and standard deviations for each safety culture dimension, for each organisation. Here we examine whether, overall, safety culture is uniform or disparate amongst the organisations within the stack. We conduct a One-Way Analysis of Variance (ANOVAs) to check statistically for significant differences on each safety culture dimension between the participating organisations.

To calculate safety culture dimensions scores, we undertook the following procedure. The scores of each item that related to a dimension were added up and divided by the number of items in that dimension to create a mean score and standard deviation. We then checked inter-item reliability with Cronbach's alpha to see whether responses to the items under the dimension heading are consistent with one another (indicating they are measuring the same construct). Please see Table 1 for questionnaire items grouped by dimensions, and Table 13 for dimension inter-item reliability scores.

Future Sky Safety has received funding from the EU's Horizon 2020 Research and Innovation Programme, under Grant Agreement No. 640597.

3 RESULTS

3.1. Responses

We received a total of 594 valid responses (34.6% of the available sample).

3.2. Demographics

The two tables below present the sample demographics (missing responses not included). The majority of respondents report working for the airline (n=428), then the airport (n=57), then the ground handling firm (n=49), then fire services (n=30), then Air Traffic Control (n=21), the de-icing (n=9). From herein, the identity of the different organizations participating in the study is anonymised.

Table 3: Organisational roles

ORGANISATION DEMOGRAPHICS		n	%
Airline:	Airline Ground Operations - Base/Central Management	28	4.7
	Cabin Services	155	26.1
	Flight Operations	140	23.6
	FSOPA team	14	2.4
	OCC	89	15.0
	Other	2	0.3
Airport:	Airport operations	57	9.6
Ground handling	Ground staff	49	8.2
Air Traffic Management	Air Traffic Controllers	12	2.0
	Other	9	1.5
De-icers	De-icing staff	9	1.5
Fire service	Fire service staff	30	5.1
	Total	594	100.00

Table 4 Participant demographics

DEMOGRAPHICS		n	%
Tenure in company:	<1yr	86	14.5
	1-3yrs	117	19.7
	4-6yrs	78	13.1
	7-10yrs	102	17.2
	11-14yrs	84	14.1
	15yrs+	127	21.4
	Total	86	14.5
Tenure in industry	<1yr	49	8.2
	1-3yrs	76	12.8
	4-6yrs	74	12.5
	7-10yrs	88	14.8
	11-14yrs	69	11.6
	15yrs+	238	40.1
	Total	594	100.0

3.3. Reporting item-by-item

This section reports the descriptive statistics by item for the whole sample, split by sections of the questionnaire.

3.3.1. Q Section B – Descriptive statistics of all respondents by items in section B of survey

Table 5 reports on the mean scores for all items, by all respondents in all organisations, in section B (General) of the safety culture survey.

This section of the survey focuses upon 'general' safety culture issues: for example around whether people feel they can speak-up on safety issues, attitudes towards safety, and future planning. They are designed so that all participants can respond to them.

For all items the full range of response options (1-5) were used. The overall mean score for all section B items was 3.84, and the standard deviation was 1.02. Safety culture researchers tend to utilise the score '3.5' as an ad-hoc indicator of whether a safety culture is positive or problematic. This indicates that, across the entire sample, responses to section B of the survey were generally positive. Additionally, the Standard Deviation shows that there is a lot of variation in these opinions.

Table 5 Survey Section B descriptive data

	Mean	SD
B01 My colleagues are committed to safety.	4.39	0.78
B02 Voicing concerns about safety is encouraged.	4.16	0.99
B03 We have sufficient staff to do our work safely.	3.17	1.29
B04 Everyone I work with in this organisation feels that safety is their personal responsibility.	3.79	0.99
B05 My direct manager is committed to safety.	4.28	0.87
B06 Employees have a high degree of trust in management with regard to safety.	3.52	1.26
B07 I have confidence in the people that I interact with.	3.91	0.82
B08 People who report safety-related occurrences are treated in a just and fair manner.	3.90	1.02
B09 People in this organisation share safety-related information.	3.88	1.02
B10 My direct manager takes action on the safety issues we raise.	4.04	0.93
B11 Information about safety-related changes within this organisation is clearly communicated to staff.	3.90	1.02
B12 We get timely feedback on the safety issues we raise.	3.60	1.10
B13 My involvement in safety engagement activities (e.g. safety meetings) is sufficient.	3.46	1.13
B14 If I see unsafe behaviour by any of my colleagues I would talk to them about it.	4.31	0.76
B15R People who raise safety issues are seen as troublemakers.	3.76	1.18
B16 I am prepared to speak to my direct manager when unsafe situations are developing.	4.35	0.75
B17 There is good communication up and down the organisation about safety.	3.73	1.07
B18 Changes to the organisation, systems and procedures are properly assessed for safety risk.	3.65	1.13
B19 Safety is taken seriously in this organisation.	4.11	1.07
B20 My team works well with the other teams within the organisation.	3.83	0.95
B21 We learn lessons from safety-related incident or occurrence investigations.	4.09	0.92
B22 My direct manager would always support me if I had a concern about safety.	4.15	0.89
B23 We have sufficient support from safety specialists.	3.65	0.98

B24 I have good access to information regarding safety incidents or occurrences within the organisation.	3.55	1.21
B25R There are people who I do not want to work with because of their negative attitudes to safety.	3.56	1.20
B26 I know what the future plans are for our company.	3.37	1.14
B27 Other people in this organisation understand how my job contributes to safety.	3.66	1.06
B28 Senior management takes appropriate action on the safety issues that we raise.	3.67	1.15

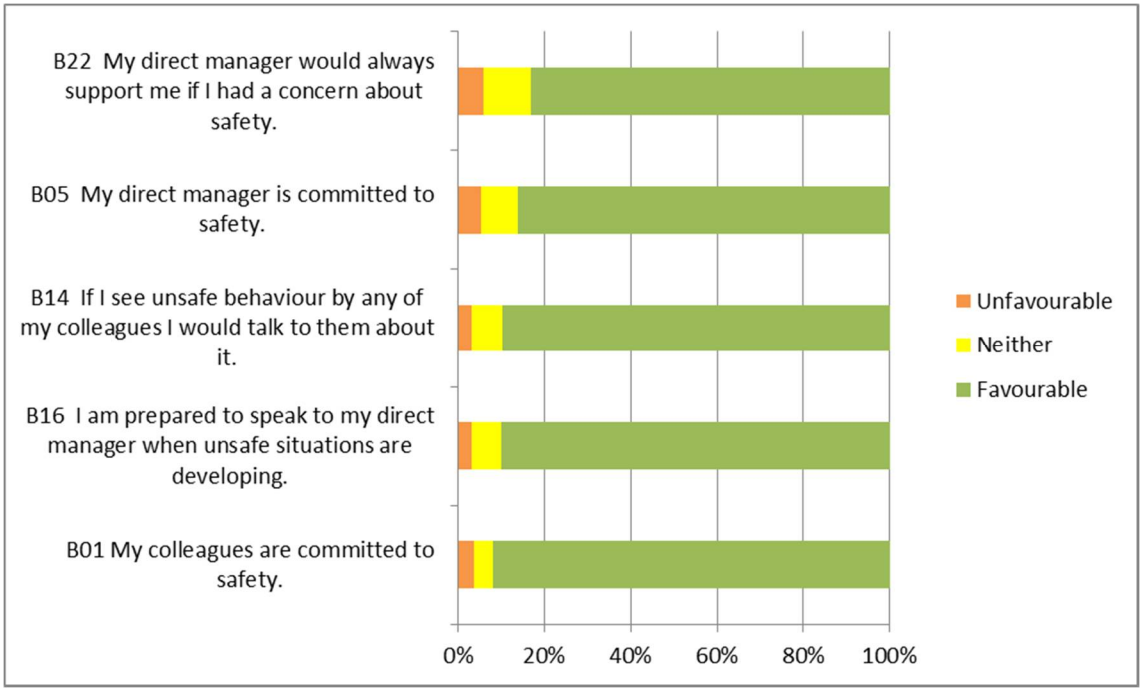
The table below reports on the extent to which respondents gave a 'favourable' or 'unfavourable' response to each survey item in Section B. The most and least favourable responses are reported in the following table.

Table 6 Survey Section B Favourable and Unfavourable responses

	% Unfavourable	% Neither	% Favourable
B01 My colleagues are committed to safety.	3.5%	4.5%	91.9%
B02 Voicing concerns about safety is encouraged.	8.6%	10.5%	80.9%
B03 We have sufficient staff to do our work safely.	33.3%	19.0%	47.6%
B04 Everyone I work with in this organisation feels that safety is their personal responsibility.	11.7%	19.6%	68.8%
B05 My direct manager is committed to safety.	5.2%	8.6%	86.2%
B06 Employees have a high degree of trust in management with regard to safety.	22.3%	18.6%	59.1%
B07 I have confidence in the people that I interact with.	6.2%	18.0%	75.8%
B08 People who report safety-related occurrences are treated in a just and fair manner.	11.7%	14.7%	73.6%
B09 People in this organisation share safety-related information.	11.7%	14.4%	74.0%
B10 My direct manager takes action on the safety issues we raise.	6.4%	16.6%	77.0%
B11 Information about safety-related changes within this organisation is clearly communicated to staff.	11.6%	15.0%	73.4%
B12 We get timely feedback on the safety issues we raise.	15.9%	24.4%	59.7%
B13 My involvement in safety engagement activities (e.g. safety meetings) is sufficient.	20.1%	27.9%	52.0%
B14 If I see unsafe behaviour by any of my colleagues I would talk to them about it.	3.0%	7.3%	89.7%
B15R People who raise safety issues are seen as troublemakers.	16.2%	18.6%	65.1%
B16 I am prepared to speak to my direct manager when unsafe situations are developing.	3.1%	6.9%	90.0%
B17 There is good communication up and down the organisation about safety.	15.3%	17.0%	67.6%
B18 Changes to the organisation, systems and procedures are properly assessed for safety risk.	15.9%	21.6%	62.5%
B19 Safety is taken seriously in this organisation.	10.5%	8.6%	80.9%
B20 My team works well with the other teams within the organisation.	9.8%	18.8%	71.5%
B21 We learn lessons from safety-related incident or occurrence investigations.	6.6%	11.1%	82.3%
B22 My direct manager would always support me if I had a concern about safety.	5.9%	11.0%	83.1%
B23 We have sufficient support from safety specialists.	11.9%	27.7%	60.4%
B24 I have good access to information regarding safety incidents or occurrences within the organisation.	22.1%	17.9%	60.0%
B25R There are people who I do not want to work with because of their negative attitudes to safety.	21.2%	20.7%	58.0%
B26 I know what the future plans are for our company.	22.6%	25.5%	51.9%
B27 Other people in this organisation understand how my job contributes to safety.	15.4%	19.3%	65.3%
B28 Senior management takes appropriate action on the safety issues that we raise.	15.9%	18.8%	65.4%

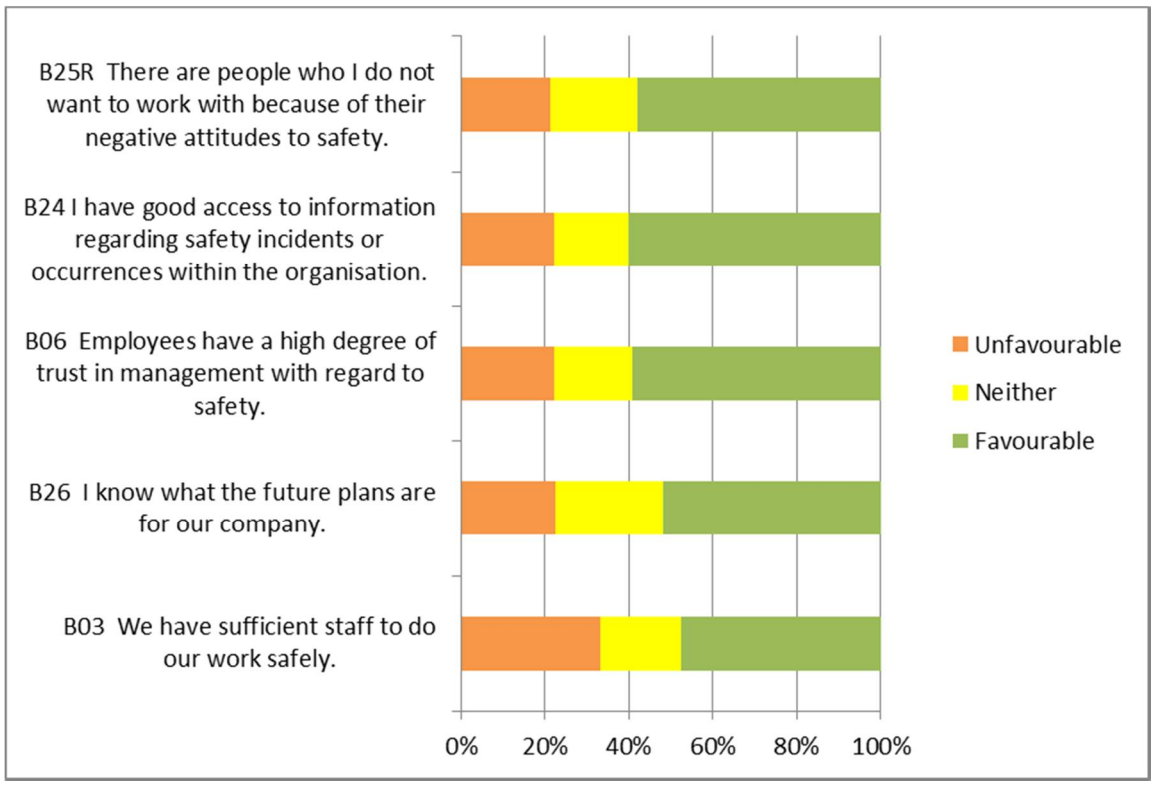
The figure below reports on the five section B items participants responded to most favourably (i.e. agreed with a positive statement on safety culture, and disagreed with a negative statement). This reveals the strongest aspects of safety culture, across the stack, for the general section. For the item B01 "My colleagues are committee to safety", 92% of participants responded favourably to this item. This was followed by the item B16 "I am prepared to speak to my direct manager when unsafe situations are developing" (90%). This indicates respondents feel positively about the safety practices of their colleagues.

Figure 1 Top 5 most favourable responses in section B



The figure below reports on the five section B items participants responded to least favourably (i.e. disagreed with a positive statement on safety culture, and agreed with a negative statement). This reveals the weakest aspects of safety culture, across the stack, for the general section. For the item B03 "We have sufficient staff to do our work safely.", only 48% of participants gave a favourable response. For the item B26, only 52% responded favourably to "I know what the future plans are for our company". This indicates some overall concerns over resourcing and future plans.

Figure 2 Top 5 least favourable responses overall in section B



3.3.2. Q Section B – Top and bottom-items across organisations

To examine the strongest and weakest items with the different organizations constituting the 'stack', we investigated the consistency of response patterns in different organisations to the top and bottom safety culture items. Simply put, to what extent were perceptions of safety culture consistent across the different organisations collaborating to provide aviation services?

The table below shows that, for the top 5 general items, response patterns were fairly consistent across organisations. For example, in response to question B16 "I am prepared to speak to my direct manager when unsafe situations are developing", the mean score for all organisations was above 4.

Table 7 Top-5 general item scores across all organisations

	A.	B.	C.	D.	E.	F.
B01 My colleagues are committed to safety.	4.56	4.39	3.88	4.71	4.37	4.89
B16 I am prepared to speak to my direct manager when unsafe situations are developing.	4.61	4.28	4.33	4.76	4.41	4.78
B14 If I see unsafe behaviour by any of my colleagues I would talk to them about it.	4.47	4.27	4.08	4.57	4.43	5
B05 My direct manager is committed to safety.	4.66	4.26	4.06	4.62	3.70	4.89
B22 My direct manager would always support me if I had a concern about safety.	4.32	4.14	4.04	4.57	3.79	4.78

The table below shows that, for the bottom 5 general items, response patterns were quite variable, with safety culture diverging across the participating organisations. For example, mean responses to B03 "We have sufficient staff to do our work safely" ranged from 4.28 (A) to 1.77 (E). Similarly, for B26, "I know what the future plans are for our company", responses ranged from 4.35 (A), to 2.45 (C).

Table 8 Bottom-5 general item scores across all organisations

	A.	B.	C.	D.	E.	F.
B03 We have sufficient staff to do our work safely.	4.28	3.15	2.69	3.14	1.77	4.22
B26 I know what the future plans are for our company.	4.35	3.35	2.45	3.29	3.21	4.22
B06 Employees have a high degree of trust in management with regard to safety.	4.12	3.45	3.57	4.19	2.43	4.78
B24 I have good access to information regarding safety incidents or occurrences within the organisation.	4.37	3.41	3.43	4.14	3.45	4.89
B25R There are people who I do not want to work with because of their negative attitudes to safety.	3.75	2.43	2.98	3.90	3.76	3.89

3.3.3. Q Section C – Descriptive statistics of all respondents by items in section C

The table below reports on the mean scores for all items, by all respondents, in section C of the safety culture survey (operational). This section refers to questions that are more technical in nature, and describe specific aspects of operational safety work. For all items the full range of response options (1-5) were used. The overall mean score for all section C items was 3.62, and the standard deviation was 1.09. Safety culture researchers tend to utilise the score '3.5' as an ad-hoc indicator of whether a safety culture is positive or problematic. This indicates that, across the entire sample, responses to section C of the survey were generally positive. The Standard Deviation shows a high degree of variation in these opinions.

Table 9 Survey Section C descriptive data

	Mean	SD
C01 Incidents or occurrences that could affect safety are properly investigated.	4.05	0.90
C02 We have the equipment needed to do our work safely.	3.82	1.05
C03 I read reports of incidents or occurrences that are relevant to our work.	3.86	1.01
C04 The procedures describe the way in which I actually do my job.	3.76	1.03

C05 I am satisfied with the level of confidentiality of the reporting and investigation process.	3.86	1.01
C06 I have received sufficient training to understand the risk of fatigue.	3.38	1.28
C07R We often have to deviate from procedures.	3.47	1.14
C08 I receive sufficient safety-related refresher training.	3.50	1.14
C09 A staff member who was involved in an error would be supported by the management of this organisation.	3.45	1.08
C10 Adequate training is provided when new systems and procedures are introduced.	3.18	1.21
C11 We are sufficiently involved in safety risk assessments.	3.26	1.15
C12 Incident or occurrence reporting leads to safety improvements in this organisation.	3.81	0.96
C13R I often have to take risks that make me feel uncomfortable about safety.	3.92	1.11
C14 We are sufficiently involved in changes to procedures.	3.06	1.21
C15 The issue of fatigue is taken seriously by this organisation.	3.11	1.40
C16 We openly discuss incidents or occurrences in an attempt to learn from them.	3.70	1.12
C17 A staff member who regularly took unacceptable risks would be disciplined in this organisation.	3.99	0.95
C18 The procedures associated with my work are appropriate.	3.86	0.89
C19 I have sufficient training to understand the procedures associated with my work.	3.98	0.90
C20 I can comfortably challenge my colleagues on safety issues.	3.95	0.88
C21 I would feel comfortable reporting fatigue.	3.59	1.22
C22 When I am unwell, I do not go into work.	3.14	1.26

The table below reports on the extent to which participants gave a 'favourable' or 'unfavourable' response to each survey item in Section C. The most and least favourable responses are reported on the following pages.

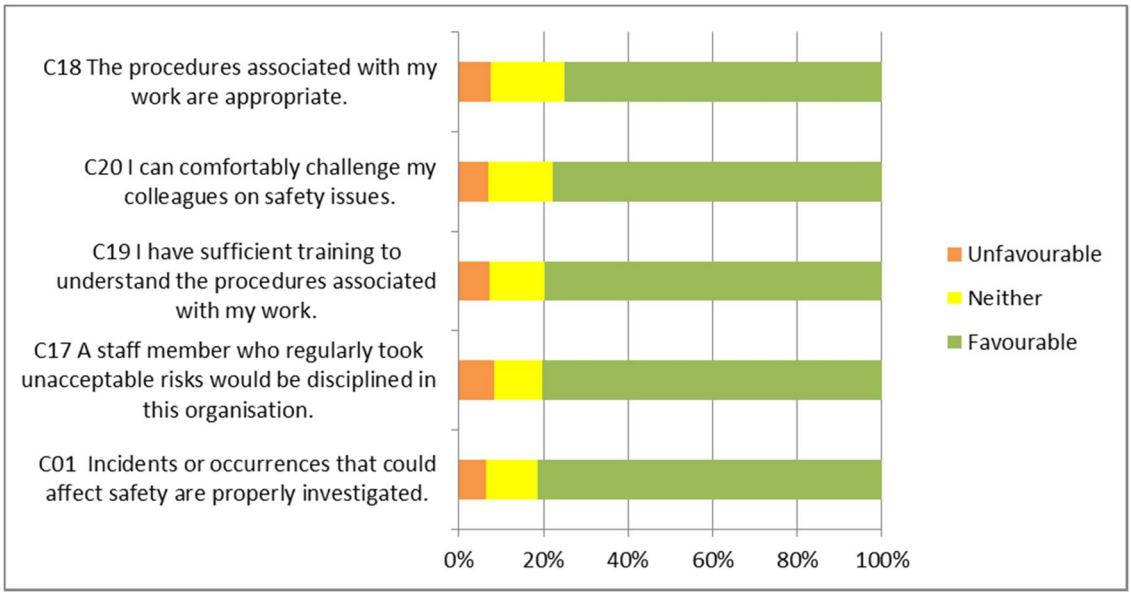
Table 10 Survey Section C Favourable and Unfavourable responses

	% Unfavourable	% Neither	% Favourable
C01 Incidents or occurrences that could affect safety are properly investigated.	6.4%	12.1%	81.5%
C02 We have the equipment needed to do our work safely.	14.4%	12.3%	73.3%
C03 I read reports of incidents or occurrences that are relevant to our work.	11.9%	14.1%	74.0%
C04 The procedures describe the way in which I actually do my job.	13.2%	16.5%	70.3%
C05 I am satisfied with the level of confidentiality of the reporting and investigation process.	10.9%	15.5%	73.6%
C06 I have received sufficient training to understand the risk of fatigue.	27.7%	16.8%	55.5%
C07R We often have to deviate from procedures.	21.3%	24.5%	54.2%
C08 I receive sufficient safety-related refresher training.	20.3%	21.9%	57.8%
C09 A staff member who was involved in an error would be supported by the management of this organisation.	18.4%	26.9%	54.7%
C10 Adequate training is provided when new systems and procedures are introduced.	31.7%	21.5%	46.8%
C11 We are sufficiently involved in safety risk assessments.	26.3%	28.4%	45.4%
C12 Incident or occurrence reporting leads to safety improvements in this organisation.	9.3%	19.8%	70.9%
C13R I often have to take risks that make me feel uncomfortable about safety.	12.7%	17.1%	70.2%
C14 We are sufficiently involved in changes to procedures.	33.8%	25.1%	41.1%
C15 The issue of fatigue is taken seriously by this organisation.	35.1%	19.1%	45.8%
C16 We openly discuss incidents or occurrences in an attempt to learn from them.	17.1%	16.0%	66.9%
C17 A staff member who regularly took unacceptable risks would be disciplined in this organisation.	8.4%	11.4%	80.2%
C18 The procedures associated with my work are appropriate.	7.5%	17.5%	75.0%

C19 I have sufficient training to understand the procedures associated with my work.	7.1%	13.2%	79.6%
C20 I can comfortably challenge my colleagues on safety issues.	7.0%	15.2%	77.8%
C21 I would feel comfortable reporting fatigue.	22.3%	15.5%	62.1%
C22 When I am unwell, I do not go into work.	33.1%	22.4%	44.5%

The figure below reports on the five Section C items that elicited the most favourable responses (i.e. agreed with a positive statement on safety culture, and disagreed with a negative statement). This reveals the strongest aspects of safety culture, across the stack, for the operational section. For the item C01 "Incidents or occurrences that could affect safety are properly investigated", 82% of participants responded favourably to this item. This was followed by the item C17 "A staff member who regularly took unacceptable risks would be disciplined in this organisation" (80%). Participants also reported (80%) feeling "I have sufficient training to understand the procedures associated with my work" (C19).

Figure 3 Top 5 most favourable responses in Section C



The figure below reports on the five Section C items that elicited the least favourable responses (i.e. participants disagreed with a positive statement on safety culture, and agreed with a negative statement). This reveals the weakest aspects of safety culture, across the stack, for the operational section. For the item C15 "The issue of fatigue is taken seriously by this organisation", only 46% of respondents gave a favourable response. For the item C14, only 41% of participants responded favourably to "We are sufficiently involved in changes to procedures". For the item C10, only 47% of participants responded favourably to "Adequate training is provided when new systems and procedures are introduced".

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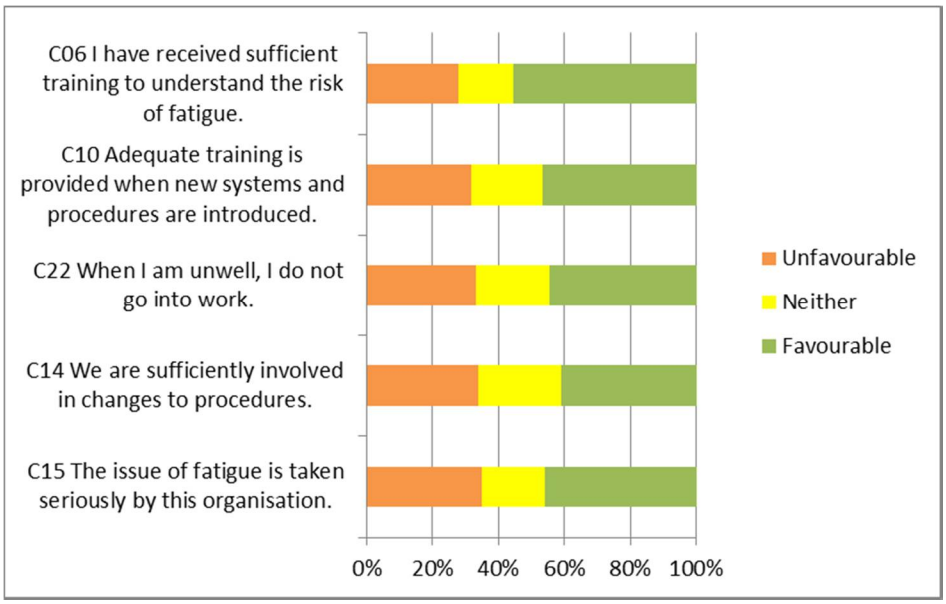
Figure 4 Top 5 least favourable responses in Section C



3.3.4. Q Section C – Top and bottom-items across organisations

To examine the state of safety culture across organizations within the 'stack', we investigated the consistency of response patterns in different organisations to the top and bottom operational safety culture items. This was to establish the extent to which perceptions of safety culture were consistent across the different organisations participating in the study.

The table below shows that for the top 5 operational items response patterns were generally consistent across organisations. An exception was "C18 The procedures associated with my work are appropriate", where company mean scores ranged from 4.5 to 3.07. Similarly, responses to "C01 Incidents or occurrences that could affect safety are properly investigated" varied across organisations.

Table 11 Top-5 operational item scores across all organisations

	A.	B.	C.	D.	E.	F.
C01 Incidents or occurrences that could affect safety are properly investigated.	4.54	4.06	3.55	4.38	3.37	4.63
C17 A staff member who regularly took unacceptable risks would be disciplined in this organisation.	4.09	3.98	3.80	4.05	4.10	4.38
C19 I have sufficient training to understand the procedures associated with my work.	3.93	3.99	3.88	4.33	3.63	4.5
C20 I can comfortably challenge my colleagues on safety issues.	4.16	3.89	3.81	4.43	4.07	4.43
C18 The procedures associated with my work are appropriate.	4	3.9	3.70	4.00	3.07	4.5

The table below shows that, for the bottom 5 operational items, response varied considerably. For example, for question C10 ("Adequate training is provided when new systems and procedures are introduced"), scores ranged from 3.81 (D) to 2.97 (E). Similarly, for questions such as C15, "The issue of fatigue is taken seriously by this organisation", scores varied from 3.75 (F) to 2.70 and 2.67 (C and E).

Table 12 Bottom-5 operational item scores across all organisations

	A.	B.	C.	D.	E.	F.
C15 The issue of fatigue is taken seriously by this organisation.	3.23	3.13	2.70	3.57	2.67	3.75
C14 We are sufficiently involved in changes to procedures.	3.88	2.92	2.93	3.57	2.87	4.13
C22 When I am unwell, I do not go into work.	2.61	3.25	3.02	3.81	2.33	3.5
C10 Adequate training is provided when new systems and procedures are introduced.	3.64	3.08	3.16	3.81	2.97	4.5
C06 I have received sufficient training to understand the risk of fatigue.	3.57	3.34	3.33	3.71	3.27	4.25

3.4. Safety culture dimensions

In this section, we focus on the latent dimensions measured by the safety culture questionnaire items. To recap, groups of individual survey items refer to broader conceptual themes (e.g. Management Commitment to Safety), and we utilise these 'dimensions' to interpret the results of the survey, and to make group comparisons. Please see the Method (section 2.4) for details on how the dimensions are calculated, the items underlying the themes, and the dimensions themselves.

3.4.1. Dimension Descriptive Statistics & Reliability

Groups of survey items were aggregated together (with a mean score being generated) according to the safety culture 'dimension' they relate to (e.g. management commitment to safety). This allows for analysis of the safety culture (rather than responses to a single survey item). Safety culture assessments often attempt to ascertain whether responses to a dimension are positive or not. Although there is no definitive rule for doing this the following interpretation is often used.

If the mean score of a dimension is under 2.5, this is considered to be of concern as it indicates most participants responded negatively to an item (thus indicating opportunities for improvement). If a dimension mean score is between 2.5 to 3.5, this is somewhat open to interpretation as it indicates either conflicting viewpoints, or uncertainty (e.g., participants indicating they 'Neither Agree Nor Disagree' to safety survey items). The implications of this depend on the topic under investigation. A dimension mean score above is 3.5 generally considered positive, as it indicates most participants responded positively to a survey item.

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Prior to analysing the dimension mean scores, we examined the Cronbach Alpha scores for each. All were above 0.6, and eight were above 0.7. This generally indicates good reliability for safety culture dimensions.

Table 13 Safety culture dimension reliability scores

	Alpha
Management Commitment to Safety	0.893
Collaboration & Involvement	0.785
Just Culture & Incident Reporting	0.893
Communication & Learning	0.891
Colleague Commitment to Safety	0.809
Risk Handling	0.608
Procedures & Training	0.851
Fatigue	0.715
Staff & Equipment	0.818

The figure below reports the mean scores for the 9 dimensions included in the survey. It can be seen that the majority of dimension mean scores are above 3.5, indicating a positive response from across the sample. This includes: Management Commitment to Safety (3.94); Just culture and Reporting (3.95); and Colleague Commitment to Safety (3.97). Average dimension responses below 3.5 were for Collaboration and Involvement (3.46), Fatigue (3.36), and Risk Handling (3.06).

Table 14 Mean safety culture dimension scores

	Min	Max	Mean	SD
Management Commitment to Safety	1.00	5.00	3.94	0.86
Collaboration & Involvement	1.00	5.00	3.46	0.80
Just Culture & Incident Reporting	1.00	5.00	3.95	0.68
Communication & Learning	1.00	5.00	3.73	0.84
Colleague Commitment to Safety	1.00	5.00	3.97	0.66
Risk Handling	1.00	5.00	3.06	0.50
Procedures & Training	1.00	5.00	3.66	0.82
Fatigue	1.00	5.00	3.36	1.04
Staff & Equipment	1.00	5.00	3.63	0.88

3.4.2. Safety culture dimension comparisons

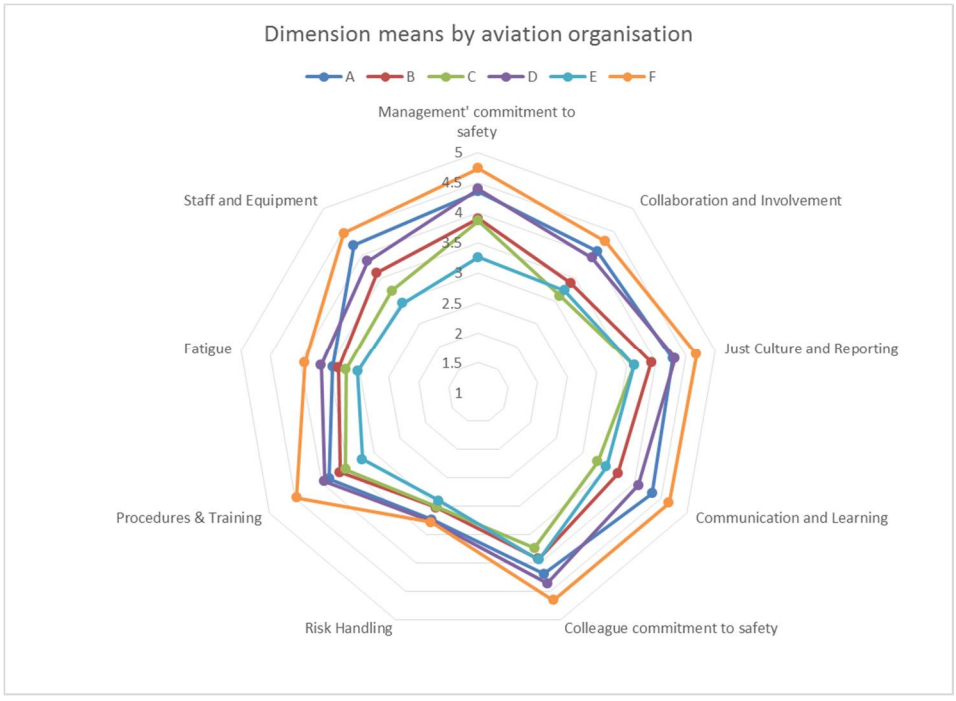
We then examined for the consistency of safety culture dimension scores across the six organisations participating in the study. These are presented in the table below. Considerable variation can be seen across the organisations included in the sample. For example, for dimensions such as Management Commitment to Safety, mean scores vary from 4.39 to 3.26.

Table 15 Safety culture dimension mean scores, by organisation

	A.	B.	C.	D.	E.	F.
Management' commitment to safety	4.35	3.9	3.86	4.39	3.26	4.73
Collaboration and Involvement	4.08	3.39	3.11	3.94	3.23	4.29
Just Culture and Reporting	4.28	3.92	3.63	4.32	3.63	4.68
Communication and Learning	4.34	3.68	3.29	4.07	3.46	4.66
Colleague commitment to safety	4.2	3.93	3.74	4.36	3.95	4.66
Risk Handling	3.24	3.03	3.01	3.27	2.91	3.29
Procedures & Training	3.85	3.65	3.54	3.94	3.22	4.48
Fatigue	3.45	3.36	3.23	3.65	3.03	3.92
Staff and Equipment	4.21	3.61	3.22	3.86	2.95	4.47

The figure below reveals that, generally, organisations were consistent in their safety culture dimension scores. This is to say, where an organisation was positive on one dimension, it tended to be positive on all dimensions. The dimension that, perhaps, bucks this trend was Risk Handling, for which the mean score was below 3.5 for all organisations.

Figure 5 Safety culture dimension mean scores, by organisation



Finally, an analysis of variance (ANOVA) test showed that the differences across organisations for each safety culture dimension were significant, except for the dimension of Fatigue. As can be seen in the table below, where a significant difference was found between organisations, this was at the $p<.001$ level except for Risk Handling.

Table 16 ANOVA overview of significant differences between organisations

		Sum of Squares	df	Mean Square	F	Sig.
Management Commitment to Safety	Between Groups	33.849	5	6.770	9.845	.000
	Within Groups	399.517	581	.688		
	Total	433.366	586			
Collaboration & Involvement	Between Groups	39.970	5	7.994	13.857	.000
	Within Groups	315.552	547	.577		
	Total	355.523	552			
Just Culture & Reporting	Between Groups	20.652	5	4.130	9.576	.000
	Within Groups	232.912	540	.431		
	Total	253.564	545			
Communication & Learning	Between Groups	42.110	5	8.422	13.332	.000
	Within Groups	348.703	552	.632		
	Total	390.813	557			
Colleague Commitment	Between Groups	12.388	5	2.478	5.871	.000
	Within Groups	231.258	548	.422		
	Total	243.646	553			
Risk Handling	Between Groups	4.237	5	.847	3.426	.005
	Within Groups	136.066	550	.247		
	Total	140.303	555			
Procedures & Training	Between Groups	15.548	5	3.110	4.802	.000
	Within Groups	355.506	549	.648		
	Total	371.054	554			
Fatigue	Between Groups	8.646	5	1.729	1.61	.155
	Within Groups	590.684	550	1.074		
	Total	599.331	555			
Staff & Equipment	Between Groups	45.935	5	9.187	13.166	.000
	Within Groups	383.094	549	.698		
	Total	429.029	554			

3.5. Developing the Safety Culture Stack

Following the surveys, a one-day meeting was held with the six participating organisations. Whilst each one had their own report, and so knew their own safety culture strengths and areas for improvement, no organization had seen any other's results. After a brief introduction on the survey, Figure 5 was presented to the group. The representatives of each organization stated that they wished to waive their confidentiality and know which line on the spider-web diagram represented each organization. This was unanimous, and so the two presenters showed them 'who was who'.

A good deal of discussion followed, focusing on who was performing best on each respective element, and why. People wanted to know, for example, what the 'leader' was doing in the area of Just Culture, in practical terms. During the ensuing conversations it became clear that they all had something to learn from each other. There was not necessarily a 'best' safety culture, and furthermore, in certain areas they all shared similar problems. There was also discussion around the size and complexity of the organisations, ranging from fairly small companies to large organisations, and how this factor affected the nature of the measures that could be taken to improve or sustain a positive safety culture.

The conclusion of this pivotal meeting was that the study could not end there, and in fact needed to be the beginning of something larger, and more regular. Therefore, a two-day workshop was planned, in which the six surveyed organisations got together to discuss in more detail where they wished to improve and 'borrow' from each other. Three more workshops were held in 2017, each one attracting a larger cluster of airport organisations, the current membership being 15, including more airlines, more ground handling services, and more airport services (e.g. fueling, catering, cleaning, etc.). Experience from the current stack suggests that a workshop/meeting every three months, on average, maintains momentum and focus of the collaborative safety efforts, and that it may take a year for the membership (i.e. who attends from each organization each time) to stabilize. Although there is a natural tendency to focus initially on safety-relevant organisations (airlines, ATC, ground-handling etc.), the aim of the Stack is to have a broad membership including diverse services.

In terms of early topics for discussion, these need to be a combination of technical issues, such as determining what are the key risks and areas where collaboration could be most useful for collective safety, and more inter-organisational, focusing on creating e.g. a 'brand' and common mission statement and ways of working so that collaboration between legal entities can actually happen. The approach has used a combination of meetings and workshops, the latter leading to collaboration between the different parties, as a means to working together. As an example, an early workshop focused on each organisation stating its top 5 key risk concerns, and then the group (the members were divided into several groups) considering how they could help each other.

Each workshop/meeting was of 1-2 days duration and comprised a plenary session discussing progress on key issues, and a workshop element. The workshops have been jointly run by the head of airport safety and the EUROCONTROL representative from Future Sky Safety (the P5 Project manager). The workshops broke into small groups of different organisations, to ensure that no one is left out, and to ensure that the smaller ones can give their contributions. Early on there was a danger of self-censorship since the 'key risks' are always seen as runway incursion and excursion, or an air crash in the vicinity of the airport. Yet, as pointed out by the airport safety manager, the more likely safety events for the airport (and many others) are for example falls and other occupational accidents. This valid concern for the safety of all staff

at airport helped 'legitimize' the concerns of those services who might otherwise have felt their safety concerns were not as important.

This in turn led to the need to have an overview of all the risks for the airport, and to share these risks amongst the organisations, from slips, trips and falls, to oil and fuel spillages, to ground handling events, to near misses between aircraft on the taxiways and runways. The need to have this shared risk awareness (which would be relevant to any stacks developed elsewhere) was facilitated by four over-arching actions:

(i) **Formal recognition of the 'Stack'** group as a transversal safety function at the airport. This in turn meant having a stable group of organisations and members, a mission statement, and terms of reference for the group (i.e. role definition and scope).

(ii) **Informal recognition of the 'Stack'** was also essential, as otherwise it could be seen as 'simply' another safety management function. Since the central aim of the groups concerned safety culture, the Stack activities needed to outreach to all staff at the airport, whether on the ground or in the air. To this end there has been a degree of 'branding', with the Stack falling under the umbrella of the 'We are Safety' brand, but also involving the development of a video by mid-2018 showing how the different roles at the airport collectively serve safety.

(iii) **A designated safety representative** from each organisation able to interface with the airport 'Stack' group, to share incident and accident data and information. The aim is that safety information can be fast-tracked by an information hub that does not require the usual formal processes, which can take significant amounts of time before information is shared to neighbouring organisations. For example, if one airline or ground handling company sees something of concern, it can be transmitted to others very quickly. Underpinning this sharing of safety information amongst competitive organisations is a safety culture understanding that competition must not be allowed to impede safety. This in turn is seen as good for business, as any incident at an airport ultimately reflects on all the organisations. The actual implementation of this is still in progress.

(iv) **A shared safety dashboard** is under development, where the key safety data for the airport as a whole would be available. Furthermore, in line with item (ii) above, the intent is to have this information available on a mobile phone application, so that any safety observation, which might be relevant to current staff or those on subsequent shifts, whether pilots, cabin crew, air traffic controllers, de-icers, fuellers, catering staff etc., can be shared within minutes and seen by those concerned (e.g. using 'push notifications' that users can self-select).

The other principal activity of this Stack has been a focus on a particular area of safety associated with ground-handling safety, already noted by EASA and the European Commission as an area of increasing safety importance. As with many airports, ground handling procedures are variable depending on both the ground-handling organisation and the airline. This can lead to a very diverse set of procedures at a single airport, which itself can breed error. The Stack has therefore been focusing on the harmonization and clarification of ground-handling procedures, producing a series of one-page summaries to achieve common ground handling activities, and therefore to reduce error and bolster safety. Other future

'stacks' may choose different areas of interest, but it is recommended that one is selected per year to ensure there is focus on a key collaborative operational safety issue.

By the time of writing this report (January 2018) the number of such harmonized procedures in operation at the airport, i.e. used by all ground handling companies, is 21. This activity has helped the Stack group focus its efforts on something very tangible and potentially useful both for safety as well as airport efficiency and on-time-performance. The aim is that each year there is such a focus, arising from the common safety concerns across the Stack membership, or from key results from the safety culture surveys, so that the group is seen as tackling common safety issues, and not merely as a talking shop or as a source of inspiration.

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4 DISCUSSION AND LIMITATIONS

4.1. Discussion

Although there is variability amongst the six organisations who took part in the Stack study, the overall safety culture results for each organization are generally positive. Variability is to be expected, and surveys highlighting where there are weaknesses or areas for improvement are healthy, signifying that the surveys have been honest, paving the way forward for improvement.

What has been compelling about this study is how the organisations have worked together since the surveys, in order to enhance safety culture and operational safety across the airport. The focus on harmonizing and clarifying ground handling procedures has been noticed by other airports and by IATA. The last workshop had fifteen participants, and work is occurring between the workshops (e.g. on harmonizing ground handling procedures and developing a safety risk dashboard) so that the Stack is not simply a 'talking shop'. This is no doubt due in part to the commitment and leadership from certain individuals in the Stack. The work of the Stack so far has already impacted on operational procedures for ground handling, and is likely to deliver more agile and rapid risk awareness sharing processes across organisations at the airport via the Dashboard and the 'App'.

Although the six surveys were the impetus for the Stack, and oriented the collective in terms of where to start and what to focus on, to an extent the surveys were more a springboard than an architectural plan for future activities. This has been discussed inside the Stack, since only six of the fifteen organisations have completed a safety culture survey. Whilst the Stack has the intention of an airport-wide survey in the future, the study suggests that not every organization needs to have completed a survey. However, it is recommended that certain core partners have carried out a survey, to ensure that the activities remain grounded in improving safety culture, rather than for example losing sight of this central aim and instead focusing purely on particular safety issues. The Stack is well aware of this danger, and while it does wish to focus on key operational areas (e.g. ground handling safety), there is a balanced focus on 'softer' but equally important aspects including Just Culture, rewards for safety, shared understanding of each other's roles and job constraints, and awareness of emerging hazards.

The Stack work reported here is an experiment, and clearly it was worked. A further challenge, however, is to see the concept migrate to another airport location. This may go beyond Future Sky Safety's remit, but it is something that the P5 Project will explore during the remainder of the Project and afterwards.

4.2. Limitations

There are several limitations, as follows, which do not manifestly detract from the success of the Stack approach:

- The degree of participation from the six different organisations was variable. Ideally there would have been a higher and more consistent percentage of respondents. The reasons for the low

response rates remains unclear: it could have been due to a lack of engagement, poor communication, concerns over confidentiality, or participants not having time.

- The EUROCONTROL approach normally comprises questionnaire survey followed by confidential workshops with staff and management to gain deeper insights into safety culture. Such workshops were only held with the airline, as to do this for all six organisations was too onerous given the resources available. This limitation was to an extent mitigated via the first Partner meeting and subsequent stack workshops where various representatives participated in the further elucidation of the safety culture issues for their organisations. But for future stacks, particularly where the organisations are large (e.g. airlines), workshops are recommended inside key and large organisations, to ensure that the complexities of their safety culture are understood.
- The Stack has only so far occurred in one location. It may be that its success is due to key individuals rather than a process. However there are other locations where there have already been surveys, and where the Stack approach could be applied to determine how easy it is to transpose these successful results to other locations and national cultures.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The Safety Culture Stack approach has shown the benefits of multiple safety culture surveys in a single airport location followed by collaborative safety culture work. The Stack approach allows organisations to learn from each other and to help overcome safety 'blind-spots' at organisational interfaces. Moreover the approach shows how safety culture, often seen as indirectly relevant to safety, and even as a too-vague concept to be operationally-relevant, can lead to concrete safety changes, enhanced collaboration for safety, and heightened safety awareness across the aviation spectrum.

This study has shown the potential benefits of the Stack, pioneered by organisations located at a single airport. The next step will be to see if the approach can be adopted and adapted by other airports, or conglomerates of aviation organisations.

5.2. Recommendation

It is recommended that other airport hubs consider the Stack approach as a way to enhance their collective safety.

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6 REFERENCES

Aarons, R. N. (2011). " A failed culture of safety." Business & Commercial Aviation **107**(2): 53.

Atak, A. and S. Kingma (2011). "Safety culture in an aircraft maintenance organisation: A view from the inside." Safety Science **49**(2): 268-278.

Chinda, T. and S. Mohamed (2008). "Structural equation model of construction safety culture." Engineering, Construction and Architectural Management **15**(2): 114-131.

Civial Aviation Authority. (2015). "Safety Management Systems - Guidance to Organisations: CAP 795." from http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=6616.

Clarke, S. (1998). "Safety Culture on the UK Railway Network." Work and Stress **12**(3): 285-292.

Clarke, S. (1999). "Perceptions of Organizational Safety: Implications for the Development of Safety Culture." Journal of Organizational Behavior **20**(2): 185-198.

Clarke, S. (2006). "The relationship between safety climate and safety performance: a meta-analytic review." J Occup Health Psychol **11**(4): 315-327.

Cohen, J. (1992). "A power primer." Psychological Bulletin **112**(1): 155-159.

Conchie, S. M., I. J. Donald and P. J. Taylor (2006). "Trust: Missing piece (s) in the safety puzzle." Risk Analysis **26**(5): 1097-1104.

Cooper, M. (2000). "Towards a model of safety culture." Safety Science **36**(2): 111-136.

Cox, S. J. and A. J. T. Cheyne (2000). "Assessing safety culture in offshore environments." Safety Science **34**(1–3): 111-129.

EASA. (2016). "Annual Safety Review 2016." from https://www.easa.europa.eu/system/files/dfu/209735_EASA_ASR_MAIN_REPORT.pdf.

Eisenberger, R., R. Hungtington, S. Hutchison and D. Sowa (1986). "Perceived Organizational Support." Journal of Applied Psychology **71**: 500-507.

Ek, A. and R. Akselsson (2007). "Aviation on the ground: Safety culture in a ground handling company." International Journal of Aviation Psychology **17**(1): 59-76.

Evans, B., A. I. Glendon and P. A. Creed (2007). "Development and initial validation of an Aviation Safety Climate Scale." Journal of Safety Research **38**(6): 675-682.

Field, A. (2013). Discovering statistics using IBM SPSS statistics (4th ed.) London, Sage.

Gao, Y., P. J. Bruce, D. G. Newman and C. B. Zhang (2013). "Safety climate of commercial pilots: The effect of pilot ranks and employment experiences." Journal of Air Transport Management **30**: 17-24.

Gill, G. K. and G. S. Shergill (2004). "Perceptions of safety management and safety culture in the aviation industry in New Zealand." Journal of Air Transport Management **10**(4): 231-237.

Guldenmund, F. W. (2000). "The nature of safety culture: a review of theory and research." Safety Science **34**(1–3): 215-257.

Halligan, M. and A. Zecevic (2011). "Safety culture in healthcare: a review of concepts, dimensions, measures and progress." BMJ Quality & Safety **20**(4): 338-343.

Havold, J. I. (2005). "Safety-culture in a Norwegian shipping company." J Safety Res **36**(5): 441-458.

Huber, G. P. (1991). "Organizational learning: The contributing processes and the literatures." Organization Science **2**(1): 88-115.

International Atomic Energy Agency (1986). Summary Report on the Post-Accident Review Meeting on the Chernobyl Accident. Safety Series 75-INSAG-1,. International Safety Advisory Group. Vienna.

Jorens, Y., D. Gillis, L. Valcke and J. De Coninck (2015). Atypical Employment in Aviation. European Social Dialogue European Commission.

Kao, L.-H., M. Stewart and K.-H. Lee (2009). "Using structural equation modeling to predict cabin safety outcomes among Taiwanese airlines." Transportation Research Part E: Logistics and Transportation Review **45**(2): 357-365.

Kapur, N., A. Parand, T. Soukup, T. Reader and N. Sevdalis (2016). "Aviation and healthcare: a comparative review with implications for patient safety." JRSM Open **7**(1): 2054270415616548.

Kim, C.-Y. and B.-H. Song (2016). "An Empirical Study on Safety Culture in Aviation Maintenance Organization." International Journal of u- and e- Service, Science and Technology **9**(6): 333-344.

McDonald, N., S. Corrigan, C. Daly and S. Cromie (2000). "Safety management systems and safety culture in aircraft maintenance organisations." Safety Science **34**(1–3): 151-176.

Mearns, K., B. Kirwan, T. W. Reader, J. Jackson, R. Kennedy and R. Gordon (2013). "Development of a methodology for understanding and enhancing safety culture in Air Traffic Management." Safety Science **53**: 123-133.

O'Connor, P., A. O'Dea, Q. Kennedy and S. E. Buttrey (2011). "Measuring safety climate in aviation: A review and recommendations for the future." Safety Science **49**(2): 128-138.

Reader, T. W., K. Mearns, C. Lopes and J. Kuha (2016). "Organizational support for the workforce and employee safety citizenship behaviors: A social exchange relationship." Human Relations.

Reader, T. W., M. C. Noort, S. Shorrock and B. Kirwan (2015). "Safety sans Frontieres: An International Safety Culture Model." Risk Analysis **35**(5): 770-789.

Reason, J. (1997). Managing the Risks of Organizational Accidents. Professional Safety. Surrey (UK), Ashgate Publishing Ltd.

Reason, J. T. (1997). Managing the risks of organizational accidents. Aldershot, Ashgate.

Reitchmuth, J. (2008). Topical Report: Airline Business Models. Air Transport and Airport Research.

Sexton, J. B., J. R. Klinect and H. R. L. (2001). The link between safety attitudes and observed performance in flight operations Proceedings of the Eleventh International Symposium on Aviation Psychology., Columbus, OH: Ohio State University.

Zohar, D. (2010). "Thirty years of safety climate research: reflections and future directions." Accid Anal Prev **42**(5): 1517-1522.