Resilience Safety Culture

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Published in:
17th World Congress on Ergonomics 2009

2009

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Safety culture may be seen as the oil necessary for an efficient safety management system. During the work in HILAS SMS task force some weaknesses in the use of safety culture in practice were identified. A work stream was initiated to identify further weaknesses and suggest remedies for them. The objective of this paper is to discuss some of the weaknesses and propose mitigations. A major suggestion is to actively look for 'holes' in the safety culture and mitigate them. The 'holes' could be low-score groups, low-score aspects of safety culture, and critical time-windows. Also the efforts by top management may need to be improved. Also means for feed forward control should be used and further developed as proposed by the new school of resilience engineering. Also when problems with long questionnaires are too big shorter questionnaires could be used complemented by interviews and studies of behaviour and artefacts.

INTRODUCTION

The aviation sector is under extreme pressure. The competition is intense and leaner production is a must for most aviation service providers. At the same time stress on the environment from aviation in terms of carbon emissions has to decrease and although already being ultra-safe compared to most other sectors safety has to be improved.

The HILAS project (Human Integration into the Lifecycle of Aviation Systems – a project supported by the European Commission's 6th Framework Programme) focuses on using Ergonomic/Human Factor knowledge and methodology in addressing key issues for performance including performance for safety in the aviation sector, mainly in flight operations and maintenance.

In order to improve safety in the aviation sector the International Civil Aviation Organisation (ICAO) has introduced requirements on aviation service providers to implement a Safety Management System (SMS). To guide the service providers and the national civil aviation authorities ICAO has published a Safety Management Manual (SMM) (ICAO, 2008). The SMM presents four core components in the ICAO SMS framework: Safety policy and objectives, safety risk management, safety assurance and safety promotion. The SMM also promotes an organisational culture that fosters safe practices and encourages the process of active and effective safety reporting. In this paper we call this culture the safety culture, seeing it as the oil keeping the SMS working including the continuous improvement of the SMS itself.

"An SMS is defined as a systematic approach to managing safety, including the necessary organisational structures, accountabilities, policies and procedures" (ICAO, 2008, 6.5.3). However we cannot identify for certain what are the best procedures for taking safety and cost efficiency into consideration. Also, what the best procedures are dependent on preconditions such as equipment, tools for safety, organisation and business. Since these conditions change a continuous improvement process for safety management and one's safety management system is very important. This is just as important when one's safety level is already perceived as satisfactory.

A well documented safety management system is not sufficient for safety. A good safety culture fostering the best use of the safety management system and its continuous improvement is also needed. An efficient, in terms of cost efficiency, adoption of tools and techniques for fostering safety culture is of course also important for a sector under economic pressure.

In order to comply with the very high requirements on safety (improve safety in a sector where safety already is very high) new concepts for safety management may be needed. Resilience Engineering (see below), a concept under development stressing feed forward control as a complement to feedback control, may be such a concept.

A HILAS taskforce mainly focusing on developing processes and procedures for the successful implementation of an SMS is also exploring this issue of developing tools and techniques for fostering a good safety culture in practice. Weaknesses in the current conceptualisation of safety culture and utilisation of it as a concept in practice are identified. Improvements are developed and trials are planned. The objective is to develop a toolbox with tools to support the more efficient fostering of safety culture building on current knowledge from the scientific literature on safety culture and resilience.

Thus objective of this paper is to discuss parts of the toolbox to support the more efficient fostering of safety culture in the aviation sector.

METHOD

To commence a literature review was made on safety culture, safety management in aviation and resilience engineering. The focus was on important aspects of safety culture, on weaknesses in its use in practice and on ideas for improvements. Secondly, a series of SMS workshops in a large European airline were held with key safety and operational staff to identify elements for improvement in their adoption of ICAO safety management system.

Some of the identified elements for improvements were:

1. Organisational learning
2. Decision making
3. The investigation process for learning for safety
4. Fatigue risk management
5. Safety culture including resilience aspects

Procedures for the different elements are at different stages of development, implementation and validation. This paper focuses on point number five – safety culture including resilience aspects, hereafter referred to as a resilience safety culture. The work on the other elements will be reported elsewhere.

In this series of workshops also problems and weaknesses in the work with safety culture were identified and improvements/tools were developed.

Finally five validation workshops were held with a cross section of European aviation companies representing airlines, maintenance organisations, original equipment manufacturers and Ergonomic/Human Factor research institutes.

The following sections will:

- briefly discuss safety culture and resilience engineering as a basis for the paper
- present some identified common weaknesses in the work with safety culture in practice and some ideas for improvements
- identify key issues concerning safety culture, some issues from the school of resilience engineering and the state of the art of the framework for implementation, measurement and continuous improvement of a resilience safety culture.

SAFETY CULTURE

About the definition

There are several review articles on safety culture (e.g. Cooper, 2000; Flin et al., 2000; Gadd & Collins, 2002; Guldenmund, 2000; Sun et al, nd). Many of these cite safety culture as the most important factor in the ability of an organisation to implement a safety management system (Reason, 1997). Also a special issue of Safety Science was fully devoted to safety culture with an editorial by Hale (2000). These articles include several different definitions of safety culture. Mainly based on Cooper (2000) and HSE (2005) we define safety culture in this paper as values about safety shared in an organisation expressing itself in three groups of aspects: psychological aspects (the safety climate including attitudes; how people feel), behavioural aspects (what people do), and situational aspects (artefacts such as the SMS; what the organisation has). Here we also make use of Bandura's model of reciprocal determinism stating that these three groups of aspects influence each other bi-directionally (Bandura 1977 a; b; 1986).

The safety climate of an organisation (peoples' perception of their company's commitment to safety) is usually measured with questionnaires. In this case the questions, the items, are often grouped into aspects. The number of aspects varies between different authors. In this paper we shortly discuss Reason's four subcultures (aspects) (Reason, 1997) and the importance of management commitment and behaviour.

ICAO stresses the importance of an "organisational culture that fosters safe practices and encourages the process of active and effective safety reporting, through whichever means or building blocks it might be achieved" (ICAO, 2008). The definition of safety culture we have and how we work with safety culture is not in opposition with the organisational culture that ICAO is advocating.

Reason's approach

Reason (1997) stresses four aspects (or subcultures) of a safety culture:

1. a learning culture,
2. a reporting culture
3. a just culture and
4. a flexible culture

Together they create an informed culture.

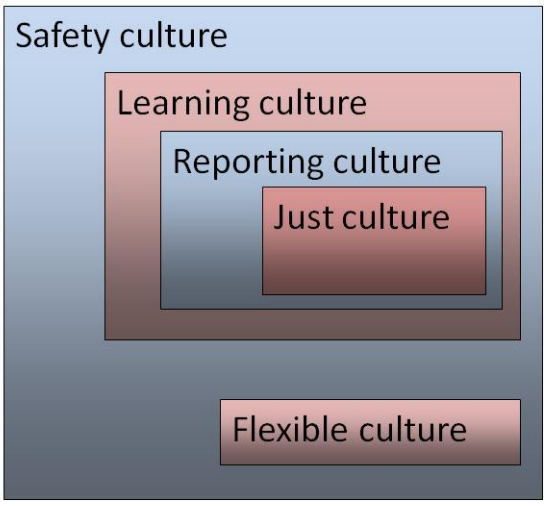

Figure 1. Safety culture and Reason's subcultures

Figure 1 illustrates how these aspects may be related

to each other within a safety culture, leaving place also for other aspects.

A learning culture. Concerning learning our focus is on organisational learning (Koornneef, 2000; Koornneef & Hale, 2004a; Koornneef et al., 2008) and learning from all relevant sources, e.g. accidents, incidents, other disturbances, observations of unsafe acts and unsafe conditions, flight data monitoring, internal and external safety audits, investigations, risk analyses and research. In HILAS, organisational learning (Koornneef & Hale, 2004a; Koornneef et al., 2008) and organisational memory (Koornneef & Hale, 2004b) has been a central focus. Also the importance of learning between flight operations and maintenance and shared learning between operators has been stressed (Koornneef 2008; Ward, 2009). The last step in learning is implementation and use of improvements, a step that obviously closes the learning loop. This should be stressed as an expression of the safety culture in any safety culture investigation.

What is learnt is of course important as well (Koornneef, 2004a). As mentioned above, work in HILAS is also ongoing concerning the investigation process. Proactivity is a focus, meaning an emphasis on an active search for system weaknesses, latent conditions and insufficient barriers including gaps in the prevailing theory of action between espoused theories and theories-in-use (Argyris & Schön, 1974, Koornneef 2004a). A theory-of-action takes two different forms, that of an 'espoused theory' that is explicitly advanced to explain or justify a given pattern of activity, and, simultaneously, that of a 'theory-in-use' which is manifest only in action and may not be articulated or articulable. 'Espoused theory' is explicit and overt and 'theory-in-use' is implicit and tacit.

Theories-in-use govern actual behaviour and tend to be tacit structures. Their relation to action "is like the relation of grammar-in-use to speech; they contain assumptions about self, others and environment - these assumptions constitute a microcosm of science in everyday life" (Argyris & Schön, 1974, p.30). The words one uses to convey what one does or what one would like others to think one does, can then be called 'espoused theory'. Its importance here is that in a change situations for example senior management can put the need for change high in their espoused theory (i.e. what they talk of doing), but their theory-in-use (i.e. the basis of their actions) can stay the same.

For analysis good reporting is needed.

A reporting culture. A reporting culture includes a just culture – see below – and expresses itself mainly as creating good reporting of incidents and near incidents regarding both quantity and quality of reports. It is also expressed as willingness to report by all employees and as ability of the organisation to bring about

1. a just culture
2. motivation for reporting
3. user-friendly forms for reporting (templates)
4. good training and instructions for reporting with usable content
5. feedback to those reporting, showing
   a. that reports are used for improvement and how they are used
   b. appreciation to groups with good reporting
6. a regular follow-up that reporting is functioning

In aircraft maintenance in particular voluntary reporting on errors or mistakes made has always been problematic. At a recent meeting labelled Europe's First Annual Error Management Best Practice Symposium (2008), a number of organisations were of the opinion that a successful error management system will generate one or two internal reports per person per annum and this includes near misses and issues which overlap into the Health and Safety arena. Maintenance tends to suffer from much lower voluntary error reporting culture than flight operations (Nisula & Ward, 2008). Part of this issue can be explained in terms of a continued reliance on error theories in maintenance to explain accidents and a slow movement towards a just culture. In a recent survey of 53 European aviation maintenance organisations most organisations admitted to still having to work on a 'no-blame' culture and felt they were a long way away from a 'just culture' (Ward, 2008).

A just culture. A just culture in an organisation is a culture where nobody in the organisation is punished or mistreated in any way for actions, omissions or decisions taken by him /her that are commensurate with his /her experience and training taking the context of the action into consideration. However, gross negligence, wilful violations and destructive acts are not tolerated.

This definition leaves, however, a grey zone between what is culpable and not. In order to enhance the willingness to report the procedure for drawing the line between what is culpable and not is important. Trust is crucial. Thus it should be explicit to each person who exactly is drawing the line (Dekker, 2007, p 84). Furthermore special actions should be taken in order to protect the reporter's identity and to keep sensitive information to a small group. It may be wise to exclude managers from this small group in order to avoid unconscious mistreatment. In any instance where sensitive information reaches managers they must be committed not to misuse it. When applicable an agreement between the aviation company and relevant Union(s) should be signed clarifying procedures and actors.

For a just culture it is important that everybody understand that 'to err is human'. We need to move beyond this being our 'espoused theory' to our 'theory in use'.

A framework for development and maturation of safety culture

Parker, Lawrie & Hudson (2006) have developed a framework for development and maturation of organisational safety culture. The framework is based on Westrum's classification of culture based on how safety-related information is handled (Westrum, 1992). Westrum's levels of culture are: pathological, bureaucratic and generative, each shortly described.

Parker et al. (2006) build on this and use five levels: pathological, reactive, calculative, proactive and generative. They also extended the number of aspects to eighteen (e.g. Incident and accident reporting, investigation and analysis; Hazard and unsafe act reports; contractor management; What are the rewards of good safety performance; Commitment level of workforce and level of care for colleagues). An organisation can use it as a guideline for development of their safety culture and for following that development.

The role of management

There are many studies stressing the importance of safety-related attitudes and behaviour among management (e.g. Clarke, 1998; 1999; Flin, 2003; Griffits, 1985; Zohar, 1980). Particularly the perception by staff of management's attitudes and behaviour is important (Clarke, 1998; 1999). An understanding, however, of the processes relating to management behaviours, their perception by the work-force and any resulting impact on work-force behaviours is rather less well established (Corrigan, 2002). What is obvious however is that management should be central to any efforts to improve the safety culture and to any efforts to maintain a good safety culture.

Other aspects

As mentioned above, often several other aspects or dimensions are used in safety culture investigations. A learning culture, where learning for safety is the focus, could be seen as a particularly important aspect of safety culture. This is because if such a learning culture has been in place for a sufficiently long time other aspects important for safety should have reached a high standard. However, since we should count on shortcomings in existing culture that may express themselves in shortcomings in other aspects and since it is important to identify these aspects for mitigation purposes additional aspects should be measured. Different published questionnaires use different aspects – often constructs defined using factor analysis

A good safety culture should also express itself in an active search for gaps between what the managers and management system say or write (espoused theory) and what happens in practice (theory-in-use). A good safety culture should also express itself in ways and means of decreasing these possible gaps.

RESILIENCE ENGINEERING

An essential aspect of a system's resilience.is its enhanced sensitivity to detect weak surprise signals from operational performance data and trigger organisational learning (Weick & Sutcliffe, 2007).

The concept 'resilience engineering' is in a phase of development as evident from recent conferences and books (Hollnagel et al., 2006; 2008). There is no single agreed upon definition of resilience used in the system safety context, but there are several variants. Here we cite a definition suggested by Wreathall (2006): "Resilience is the ability of an organisation (system) to keep, or recover quickly to, a stable state, allowing it to continue operations during and after a major mishap or in the presence of continuous significant stresses". Resilience engineering then attempts to control processes in terms of safety and not only risks and to keep the system within safety limits. If this fails then the objective is to control the system back to normal safe functions. In control theory terms this means to focus on feed forward control in addition to feedback control (learning from accidents and incidents) – see Figure 2 (end of paper).

For feed forward control of complex socio-technical systems it is important to have a model of the key processes showing the expected behaviour of the total process when disturbed by internal and external variations. Within the HILAS project research on such models has taken place. Key processes in maintenance and flight operations have been modelled using a tool developed in the TATEM and HILAS projects called the 'Operational Process Model' (Bunderath, McDonald, Grommes & Morrison, 2008). Other interesting models of complex socio-technical systems to learn from are STAMP (Systems-Theoretic Accident Model and Processes) by Leveson (2004) and FRAM (Functional Resonance Accident Model) by Hollnagel (2004). In this paper we focus on methods to anticipate or to support the early detection of stress on the system. These methods could increase the level of safety significantly and support organisations developing a readiness to mitigate. The methods are meant to complement models of complex socio-technical systems fed by a multitude of relevant information.

Ek and Arvidsson (2009) have a similar approach when developing a tool for proactive identification of factors that can affect safety in air traffic control, i.e. leading safety performance factors to be used for feed forward control.

SOME IDENTIFIED COMMON WEAKNESSES IN WORKING WITH SAFETY CULTURE AND PROPOSED MITIGATION

In Table 1 some weaknesses in working with safety culture identified as common are listed together with proposed mitigation.

Hole in the culture 1 – low-score groups

Culture is the attitudes and values shared by everybody in the organisation (see definition of safety culture above). Many of the major accidents reported in literature have evolved from a poor safety culture embracing the whole organisation concerned, e.g. the Chernobyl disaster (IAEA, 1991), the Columbia accident (NASA, 2003), the Clapham Junction railway disaster (Hidden, 1989) and the Herald of Free Enterprise disaster (e.g. Kletz, 2001). However accidents could also have their origin in small subgroups not sharing the attitudes and values of the majority of employees in an organisation with an otherwise good safety culture. Such

subgroups may not be detected from mean values from analysis of questionnaires. Not even standard deviations may reveal small subgroups. Outliers may be dangerous.

Table 1. Weaknesses in working with safety culture.

Common weaknesses	Proposed mitigation
Sometimes focus is only on one aspect, often just culture	Focus on all aspects considered as important for safety
Low-score groups	Focused search for low-score groups
Low-score aspects or items	Focused search for low-score aspects and items
Time-windows when forces towards the design envelope exceed the counter-forces	Identification of hazardous time-windows is • on the agenda of management and safety groups • focused in questionnaires and interviews Frequent investigations
Questionnaire results may be very much influenced by temporary stress on the organisation, e.g. ongoing conflict	Feedback of results to different groups are also used to identify temporary stress
Long questionnaires, especially when competing with other questionnaires, may give low response rate and hasty answers	Short questionnaires, interviews and study of artefacts
The construct dilemmas • Constructs may not be feasible with short questionnaires • Dimensions (constructs) may not correspond to characteristics suitable for mitigation • Items (questions), judged as important for safety may fit in more than one constructs or in none, are discarded	Focus on items and on characteristics useful when planning mitigation
Resilience aspects not considered	Resilience aspects considered
Management commitment and communication	Short course including self-test against a framework on how safety information is handled using the levels pathological, reactive, calculative, proactive and generative. Communication supported by • process models • balanced scorecard style annual reports • cost-benefit thinking in the learning-for-safety process
Gaps between what is said and written and what is practice	Focus on identification and mitigation

By analysing questionnaires to explicitly look for low-score subgroups, by explicitly looking for them in interviews and observations the probability of detecting low-score subgroups is increased. An adequate programme for fostering an improvement in the safety culture in such groups then has to be developed. Also more proactive activities should be applied to prevent low-score subgroups manifesting in the first instance such as stressing the requirement on safe behaviour in selection and recruitment, job introduction training, Ergonomic/Human Factor introduction training, promotion, annual performance appraisals and in clear signals from managements. In a study in one HILAS organisation exploring 'Risk in the Process' the place where people felt 'Ergonomics/Human Factors' could best be addressed in their role was through their individual performance appraisal process (cited in Ward, 2009).

Hole in the culture 2 – low-score items and characteristics

Weaknesses in safety culture could express themselves in different ways. A safety culture questionnaire includes questions (items) often belonging to different characteristics, aspects or dimensions (e.g. perceptions of management's attitudes and behaviours in relation to safety, safety arrangements, procedures, training and work pressure). By looking for low-score items or low-score aspects in subgroups weaknesses could be identified. After a careful investigation of the reasons behind the low scores decisions about risk mitigation could be taken. Good questions and sense-making aspects may make risk mitigation easier and less expensive as they can be focused.

Hole in the culture 3 – time windows when forces towards the safety border may exceed the counter forces. Some resilience aspects.

Using Rasmussen's design envelope metaphor (Rasmussen, 1997) safety culture can be seen as a counterforce against migration towards and beyond the limit for safe operation (see Figure 3). Examples of centrifugal forces for migration could be targets for a higher efficiency or for making the job more comfortable. Therefore a company should have a good safety culture avoiding the system to migrate beyond the envelope – the margin for safety. However during extreme environmental stress on the organisation and its members the centrifugal forces could be very strong instantaneously. Also the motivation for safe work and work for safety could decrease drastically.

Some proposals against this kind of threats are:

- Develop and sign agreements with employees and where applicable with unions stating that safety should not be compromised under any circumstances including conflicting requests from either managers or employees. For example often times maintenance staff can be 'pushed' to perform tasks without the proper safety equipment in place when the aircraft is due for immediate release to service.

- In line with the basic ideas behind resilience engineering develop skill for anticipation or early detection of internal or external stressors with the potential to compromise safety; for example using threat and error management techniques to anticipate potential threats (Helmreich, Klinect, & Wilhelm, 2001).
- Also in line with resilience engineering ideas develop routines for fast response counteracting the stress and its potential effects on safety.

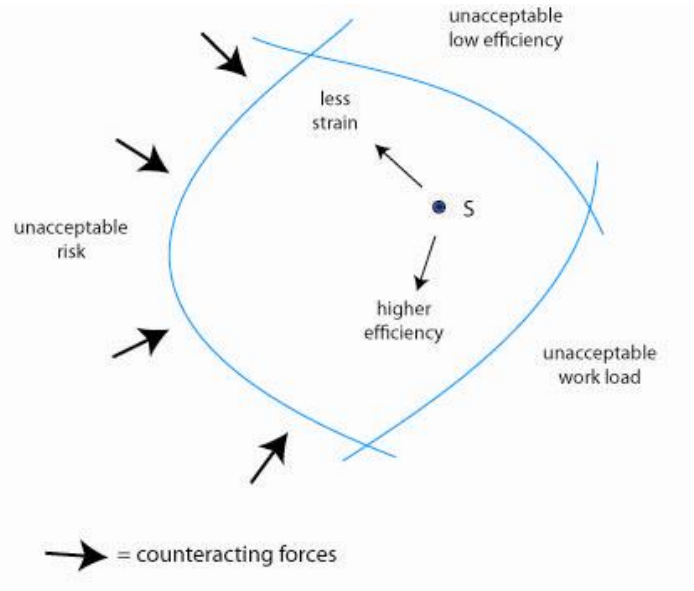

Figure 3. The design envelope. Forces changing work procedures or artefacts to make work more comfortable or more efficient mean that the working point of the system 'S' migrates towards the design envelope – the margin for safety. Counterforces, for example the safety culture, can counteract this migration. After Rasmussen (1997)

For early anticipation of potential stress on the organisation the board, the management group and safety groups should as a regular action point in their meeting agendas discuss possible temporal threats. Depending on the fora they could for instance discuss the possibilities of and the necessary control of

- risks for conflicts between employer and employees, e.g. on salaries or on working conditions,
- foreseeable generation shifts on important posts,
- downsizing
- fast expansion, with the possibilities that key personnel would not have time for their ordinary safety critical tasks
- implementation of new technology or a new organisation

Also safety culture investigations could be performed several times per year in form of questionnaires and interviews. The questionnaires and the interviews should include questions for early detection of conflicts or other kinds of discontent in the organisation.

A questionnaire to one sixth of the personnel six times per year for a larger company is proposed.

Traditional safety culture questionnaires may constitute a problem due to the number of questions in some cases

Traditional safety culture investigations often include questionnaires containing many questions, e.g. around 100 or more. Employees often do not like long questionnaires, which may result in a low response rate and hasty answers making the investigation not so useful. Furthermore many person-hours are consumed by the employees making employers, but also employees, wonder if time for safety could be spent more efficiently. Therefore shorter questionnaires complemented by interviews (around 25 easy to answer questions) and observations of behaviour and studies of artefacts are being trialled. Together these methods should reflect the safety culture as it is expressed in items and aspects judged as important for safety. A drawback from a scientific point of view is that the low number of questions does not allow the formation of several constructs. Instead focus needs to be on individual items sometimes pooled into aspects making sense in practice and for risk mitigation if found necessary.

A problem noticed in questionnaire investigations on safety culture is that the result is very sensitive to ongoing or recent stress on the employees. It is therefore important to discuss the interpretation of the results in different groups when giving feedback.

SOME OTHER KEY POINTS

Two more issues identified as being important for the safety and the safety culture, namely management's role and communication will be briefly discussed here.

Management's role for the safety culture is of paramount importance. Therefore a short course for top management is under development including a number of 'commandments' for managers and a self-test on how safety information is requested and used.

Communication is stressed as an important aspect in safety culture by many authors. Misunderstanding, no information and wrong information is often a cause for incidents and accidents. Above we have indicated the importance of good communication between managers and employees. The importance of reporting and receiving safety information well is important for learning. As a result in HILAS communication platforms between different departments in the organisation, between the organisation and other organisations involved in the business are being developed.

CONCLUSIONS

In this paper we have pointed at some areas identified as important for safety and in particular conceptualising and fostering safety culture in organisations. These have been developed out of extensive literature reviews in the area and the

workshops held within the European airline and further validation workshops held with a cross section of European aviation companies representing airlines, maintenance organisations, original equipment manufacturers and Ergonomic/Human Factor research institutes. These concepts are still in development and for some of them tools are now in a trial phase for validation and further development.

Implications to date of this work on safety culture for the companies involved in the research have been to re-examine management commitment to safety, particularly in these challenging times, explore means of transmitting that commitment to all staff, critiquing the 'assumed' use of safety culture surveys, exploring ways to better understand their safety culture and to look at plugging any possible 'holes' in safety culture.

The hope is that companies recognising similar problems or possibilities for improvement of their routines could pick up some of the ideas and adapt them for their needs and visions.

ACKNOWLEDGEMENT

We would like to acknowledge the EU Commission funding for the HILAS project under the 6th Framework Programme and all of the industrial and research partners who are currently iteratively developing and trialling the HILAS tools and methodologies. A special thanks also to all of the staff at the airline where the initial workshops took place.

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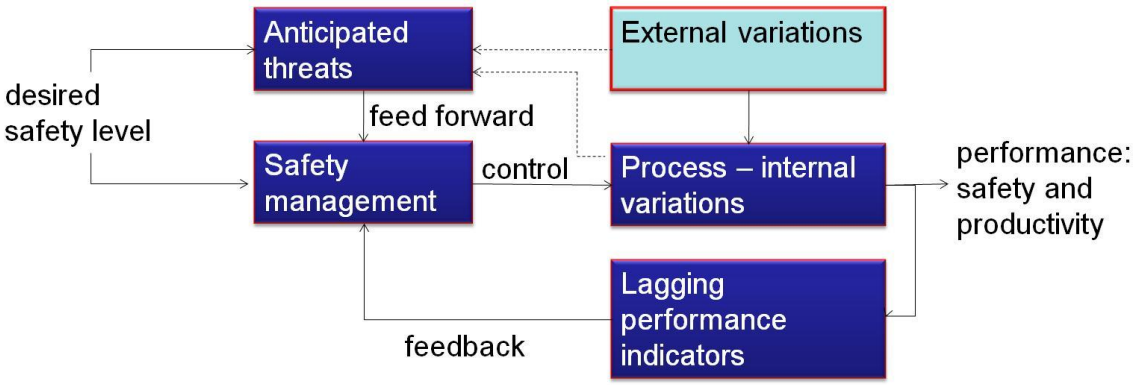

Figure 2. Feedback and feed forward control. The dotted arrows denotes leading indications used in a model to identify anticipated threats and suitable mitigation.