An Aviation Fatigue Risk Management System

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Abstract

Rapid expansion and increased competition in the aviation market has altered the way in which crew rosters are organised. For example, the intensity with which crew are working has increased. These changes have highlighted deficiencies in the primary control for fatigue risk, flight time limitations (FTL). As a corollary, airlines may currently be operating with an elevated level of fatigue risk exposure. Airlines and regulators have a new set of challenges to meet in order to control fatigue risk and obtain effective safety oversight.

In response to these challenges, easyJet have developed a fatigue risk management system (FRMS) and a supporting framework called System Integrated Risk Assessment (SIRA). Both systems are currently being enhanced with the support of an EU-funded project called Human Interaction in the Lifestyle of Aviation Systems (HILAS).

This paper explains the benefits of managing fatigue risk as well as describing the FRMS and SIRA. To illustrate these systems in operation we step through a case study relating to the workload of Training Captains (TCs).

Background

Introduction: easyJet is the second largest Low Cost Carrier (LCC) in Europe and operates 150 jets on 318 routes. The company currently transports over 35 million passengers per year. easyJet is one of the pioneers of low cost travel and since inception has continued to expand at a rate of around 15 to 20% per annum. The success of the company can be largely attributed to its business model which focuses on minimising direct costs and maximising resource utilisation. In the present economic environment, rising fuel costs, airport charges and aircraft costs, mean that the airline has limited room to manoeuvre to minimise costs. Therefore, emphasis is being placed on maximising utilisation of the airline's key resources – aircraft and crew.

The extent to which crew can be utilised is controlled by the United Kingdom CAA via a flight time limitation (FTL) scheme called CAP 371 (ref. 1). CAP 371 stipulates, for example, that crew cannot work more than 900 duty hours per 12 month period. While FTL schemes provide upper limits on the number of hours that can be worked, they are increasingly being criticised for providing inadequate protection from fatigue risk (e.g. ref. 2). Specifically, research at easyJet found that, within the FTL boundary, high crew utilisation led to decrements in crew alertness and performance, increased absenteeism and attrition and an unacceptable risk of fatigue-related accident (ref. 3).

The long-term success of easyJet demands that a more sophisticated approach than simply relying on FTL to provide protection from fatigue. Managers require dynamic information on the company's fatigue risk exposure and a system for managing this risk to as low a level as is reasonably practical. This paper describes a system that has been designed to fill this gap. The paper consists of four sections and the first section provides an overview of the causes and consequences of fatigue in aviation. In the second section we explain why FTL compliance does not provide adequate protection from fatigue and introduce fatigue risk management. easyJet's FRMS and supporting framework, SIRA, are then described. The final section takes the reader through an easyJet case study which demonstrates how the FRMS and SIRA are being used to manage fatigue risk.

The consequences of fatigue: Fatigue has been identified as a contributor to aviation accidents including the crashes of a DC-8 at Guantanamo Bay and Korean Airlines Flight 801 (refs. 4-5). Aviation is not unique in its exposure to fatigue related accidents and research in the medical fraternity suggests that extended duty shifts commonly worked by interns elevate the incidence of medical errors and risk of adverse events (ref. 6).

Fatigue impacts on our ability to work safely by impairing a range of cognitive skills including reaction time, memory, decision making and communication (e.g. ref. 7). On the flight deck, research at easyJet has found an association between fatigue and increased rates of error commission, decreased error detection and increased threat mismanagement (ref. 3). Other published consequences of fatigue for flight crew performance include (summarised from refs. 4, 8-12):

- Degraded judgement and decision making of crew
- Deterioration in the accuracy and timing of actions, reduced (increased?) reaction time
- A change in perception of risk and risk tolerance
- Crew involuntarily lapses into sleep (microsleep events)
- Crew unconsciously accepting lower standards of performance
- A reduction in situational awareness (ability to integrate information into a system model)
- Crew performance becomes increasingly erratic and inconsistent
- Crew attention range narrows and some tasks are forgotten or ignored; cognitive fixation
- An increased number of errors of omission, which leads to an increase in error commissions, when time pressure becomes a factor
- An increase in both number and duration of lapses (forgetting) with increasing fatigue
- Reduced visual perception
- A decline in crew resource management (CRM) behaviours e.g. effective communication and inter-personal interactions; poor communication and coordination

The consequences that fatigue as for performance are not, however, straightforward. Flight crew are highly professional and readily implement a range of countermeasures, such as caffeine consumption and double checking, to promote the safe passage of the flight. A recent simulator study found that rested crew and crew who had returned from a long haul flight and rested crew operated with similar levels of safety (ref. 13). The fatigued crew took longer to make decisions and were more likely to repeat checklists and the researchers suggested that by altering their behaviour this way (consciously or unconsciously) the crew were able to maintain their overall performance. Further operational research is required to explore the countermeasures that crew put in place and the mediating role that they play.

The causes of fatigue: Much of the fatigue associated with commercial aviation stems from the fact that airline business models insist upon the operation of early morning flights, late night flights and long haul flights (figure 1). To fulfil these commercial demands, rosters inevitably include duties which promote fatigue, for example, early duties, long duties, night duties and duties which start and finish in different time zones. The extent to which a roster promotes fatigue is also determined by external influences, such as airport curfews, the local FTL scheme and additional limitations that the company may have imposed.

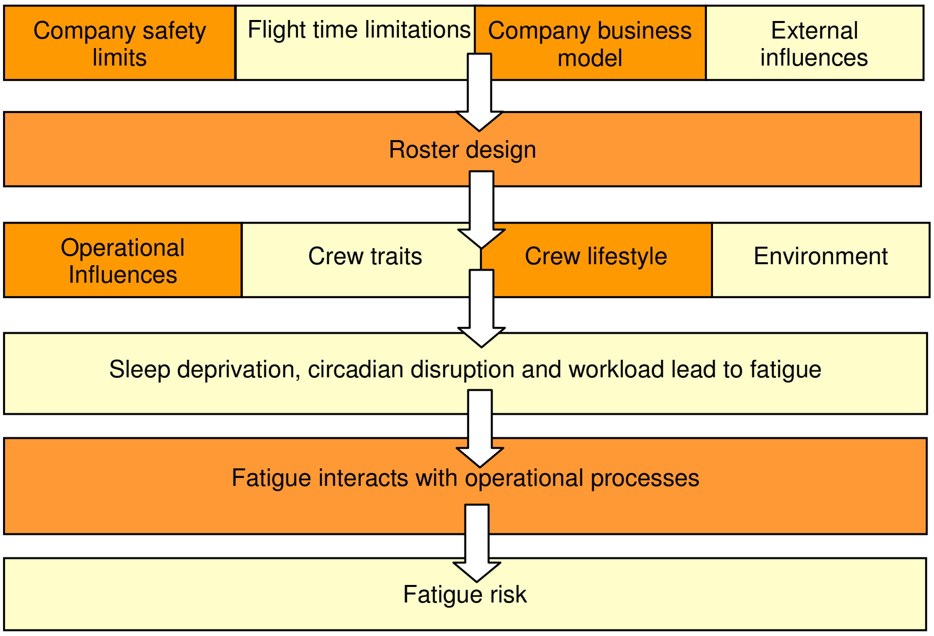

Figure 1 –– The generation of fatigue risk within an airline

Once the roster is established, the level of fatigue associated with an operation is depended on operational and environmental influences and the crew working that roster. Operational influences, such as hassle factors (delays, technical failures, airspace complexities, ramp congestion), and environmental variables including noise and temperature, obviously play an important role. Fatigue levels also vary greatly between individuals, with some of this variability due to trait differences such as age, sleep need and ability to sleep at irregular times. The interaction of hours of work with an individual's lifestyle will also influence fatigue. Lifestyle factors, such as having young children at home, second jobs, social engagements and domestic disharmony, can all affect fatigue levels.

Rosters, operational factors, crew differences and the environment influence fatigue essentially by reducing sleep times, disrupting the body's circadian rhythms and elevating workload. As this paper is written from an operational perspective, we will not discuss the underlying physiological mechanisms by which fatigue is generated. Rather, we will focus on how fatigue translates into fatigue risk.

Fatigue risk is not a simple reflection of how fatigued crew are; rather, it depends on how fatigue interacts with operational processes and in turn threatens the integrity of the operation. For example, a crew member who has not slept well may not pose a risk if the company has a policy for controlled rest, good aircraft maintenance and an experienced crew population. However, the same level of fatigue may pose a significant risk if crew are discouraged from reporting fatigue, not provided with strategies for managing fatigue, aircraft are not well maintained and pilot experience levels are relatively low.

Fatigue Risk Management

The rationale behind fatigue risk management: FTL compliance is the primary strategy used to control fatigue risk in aviation. Recently however, ICAO and civil aviation authorities in the United Kingdom, France, Canada, New Zealand and Australia, plus a range of operators, have recognised that FTLs do not necessarily provide an adequate level of safety. FTL schemes are criticised on the basis that they fail to adequately account for the influence the body's natural 24 hour rhythms (circadian rhythms) in sleep and alertness and are a "one size fits all" approach to a complex risk. FTL neglect the contributors to fatigue outlined in figure 1, such as operational influences, crew traits, crew lifestyle, the environment, workload and operational processes. The consequence of the simplistic nature of FTL schemes is that sometimes unacceptable levels fatigue are allowed and at other times flexibility and productivity are unnecessarily limited.

What is a fatigue risk management system? Regulators who recognise the inadequacies of FTL compliance have begun to recommend, or require, that operators develop elements of an FRMS (e.g. ref 14). The ICAO draft definition of an FRMS is a *"scientifically based, data driven flexible alternative to prescriptive FTL that forms part of an operator's SMS and involves a continuous process of monitoring and managing fatigue" (ref. 15).* The draft ICAO components of an FRMS are listed below:

- A fatigue risk management policy;
- A crew fatigue reporting mechanism with associated feedback;
- Procedures and measures for assessing and monitoring fatigue levels;
- Procedures for investigating, and recording incidents that are attributable wholly or in part to fatigue;
- Processes for evaluating information on fatigue levels and fatigue-related incidents, undertaking interventions, and evaluating the effects of those interventions.
- Competency based education and awareness training programmes (organisational learning);
- A performance audit plan (internal and regulatory).

The benefits of fatigue risk management realised at easyJet: In 2006, when easyJet became the first European airline to implement an FRMS, the key driver behind the system was a desire to prevent accidents. Managers have since come to appreciate that being aware of fatigue risk exposure is in the commercial interests of the business. Knowing operational risk exposure enables managers to ensure that short-term profitability and brand protection are simultaneously considered. A valuable upshot of this forward thinking has been a significant reduction in the company's insurance premium. Insurers and underwriters are increasingly scrutinising what distinguishes a company from regulatory baselines and rewarding the application of proactive risk management strategies (ref.16).

UK managers have another reason for valuing dynamic information about risk, and that is the corporate manslaughter legislation due to soon become effective which states that being unaware of a risk does not preclude managers from accountability (ref. 17).

A final benefit of the FRMS that easyJet is realising is advance compliance with the upcoming ICAO safety management system (SMS) Standard and Recommended Practice (SARP). From January 2009 national regulators will be require that airlines implement an SMS that incorporates management accountability for operational risk. In a similar vein, the strengthening of the European Aviation Safety Agency (EASA) means that national regulatory bodies in the European Union are going to have less oversight that in the future and airlines will need to develop internal governance, or in other words, risk awareness and ownership and a strong internal audit processes (ref. 18).

While the FRMS was initially promoted as safety initiative, the benefits that the FRMS has delivered for safety, strategy and the bottom line mean that the system has now been formally integrated into the company business model.

easyJet's FRMS and SIRA

The FRMS structure: easyJet's FRMS includes all of the ICAO criteria listed in the previous section. As there is guidance on hand on how to meet the criteria we will not discuss them here. One of the challenges we faced when designing the system, about which we could find only limited advice, was how to comprehensively gauge the level of fatigue encountered by crew. Fatigue is complex phenomenon and there is no single measure that can provide an all encompassing indicator of an organisation's level of exposure. To resolve this problem, the FRMS was designed to include a system sensory net that captures the four different layers of data listed below.

1. Continuous data reported monthly or more frequently

- For example, flight data monitoring (FDM), fatigue report forms, software modelling of the fatigue associated with rosters (FAID and SAFE) and additional metrics, such as roster stability figures.

2. Sample data reported regularly, usually quarterly or bi-annually
    - For example, crew surveys, safety walks, FRMS audits

3. Incident/risk driven
    - The results of investigations of incidents or identified risks.

4. In-depth investigation
    - Research projects to improve our understanding of the causes of and countermeasures to fatigue in the operational environment, for example, a Human Factors Monitoring Programme (HFMP).

Figure 2 below illustrates how the data that is collected is reported within and outside the company and, in turn, how this influences strategic development.

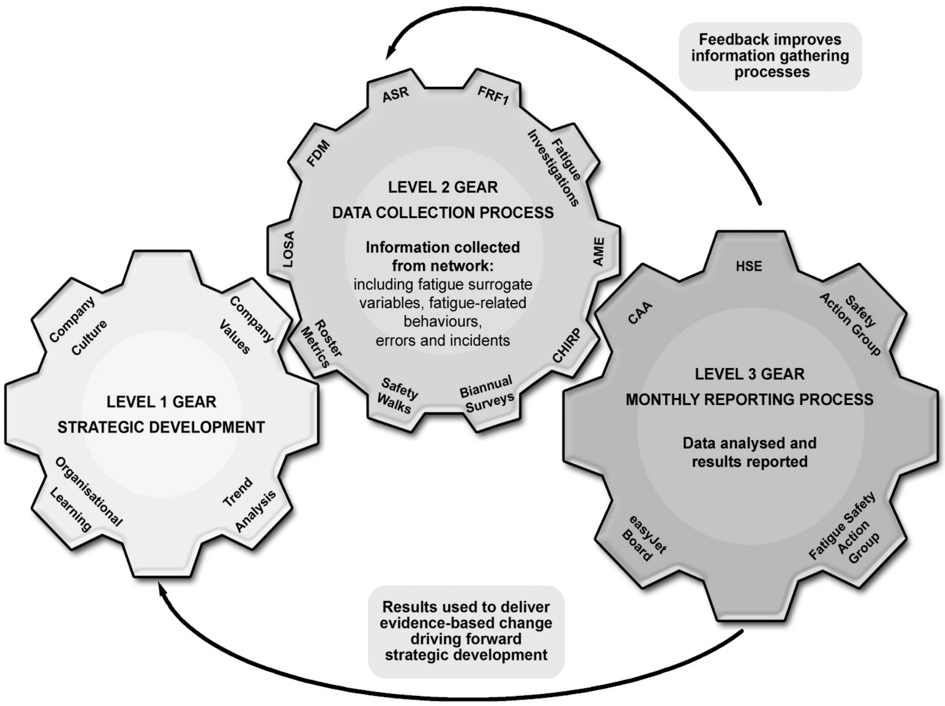

Figure 2 –– The data on fatigue that is collected, reported and influences strategic development

System Integrated Risk Assessment (SIRA): The guidance available regarding the design of an FRMS consistently recommends that the FRMS is linked to and supported by the company's SMS (e.g. ref. 19). Unfortunately, however, there is minimal information available as to how to assess fatigue risk from a systems perspective and how to integrate this information into an SMS. Moreover, airlines tend to have SMSs that are primarily reactive: that is, they respond after incidents have occurred. Reactive analysis of past events provides useful information on how and why an event took place (in order to understand how to prevent re-occurrence), but it is a limited source of evidence of overall system performance. If airlines are to manage fatigue and other risks in a proactive manner they need to apply risk detection tools that provide real time and continuous systems oversight.

In order to link the easyJet FRMS to the company SMS, and to enhance the SMS, we have spent the last few years constructing a risk management framework, known as SIRA (System Integrated Risk Assessment, ref. 20). To develop the capabilities of SIRA further the company is working as a deputy stream leader of an EU Commission funded project called Human Interaction in the Lifecycle of Aviation Systems (HILAS). The aim of HILAS is to develop methodologies and technology that will enable airlines to satisfy future regulatory requirements regarding SMS. The project is developing a 'system life-cycle model' in which knowledge generated about the human aspects of the system is coalesced and transformed into an active resource for the design of more effective operational systems and better, more innovative use of technologies.

Figure 3 shows the latest version of SIRA that the HILAS project is supporting. SIRA starts with a risk radar, or system sensory net, that gathers a wide range of technical, human performance and system data. The data is managed within the company Aviation Quality Database (AQD) and fed into an intelligence process which classifies and analyses causal patterns. In turn, this drives decision-making, intervention design and monitoring of the effectiveness of the intervention. SIRA has a tactical (immediate short-term) and strategic (long-term) cycles and the tactical cycle informs the strategic cycle. Both cycles support organisational learning and include a feedback loop whereby the interventions that are put in place may influence the type of data that is collected by the risk radar.

SIRA considers the 'defence in depth' approach to incident/accident investigation proposed by the Integrated Safety Investigation Methodology (ISIM) of Transportation Safety Board of Canada (ref. 21) and the System of Organisational Learning model (SOL, ref. 22) which considers an organisation's willingness to change operational process and policy. The model also draws from the International Risk Management Standard 4360; widely acknowledged as the industry leading practice for managing organisational risk (ref. 23).

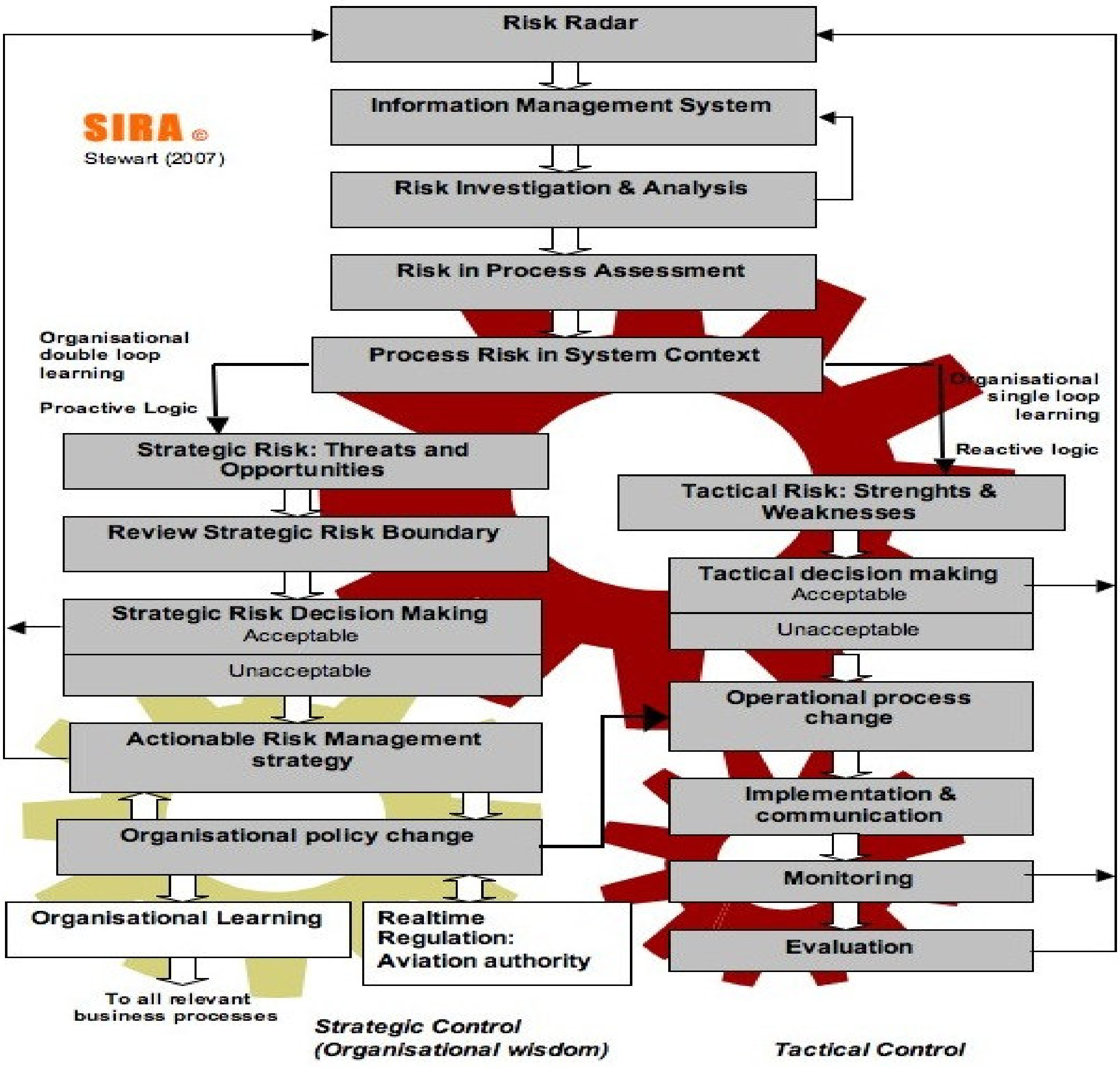

Figure 3 –– SIRA©

Case study

In this final section we step through a case study from 2006/2007 to illustrate how easyJet is working to collect the multi-layered data on fatigue that the FRMS requires and how this information is processed by SIRA. The study concerns the workload and fatigue encountered by Training Captains (TCs), a sub-group of the crew population who fly standard line duties and also perform in-flight and flight simulator training. Please note that the case study does not step through each of the headings shown in figure 3 because at the time a slightly less advanced version of SIRA was in operation.

i. Risk Radar: SIRA's risk radar enables pro-active, evaluative and reactive risk detection and two pro-active detection tools, namely a crew fatigue survey and an exploratory study, found that TCs were exposed to an elevated level of fatigue risk. The survey is completed on a biannual basis and the study was conducted because management were concerned that the FTL scheme does not consider the different types of duties that TCs complete and the possibility that these duties are associated with different levels of workload. To explore the workload of the TCs further, 31 TCs completed a detailed work diary over 15 duty days. The diary collected information on duties, self-assessments of workload (NASA-TLX), commute, experience and demographic variables.

<u>ii. Risk Investigation and Analysis:</u> The fatigue survey found that compared to line crew, TCs reported greater levels of fatigue and more instances of performance impairment due to fatigue. The five most commonly reported contributors to fatigue were all features of the roster and included early start times, long duty days, early to late transitions and vice versa and insufficient rostered rest time (figure 4). To see if these subjective results could be corroborated with objective data we assessed the rosters of representative sample of TCs and line crew across six bases (four large and two regional) over a three month period. The analysis showed that compared to line crew, TCs worked on average 90 minutes longer per duty day, had 30 minutes less rest between duties, encountered more duty transitions from early to late duties, worked more night time simulator training sessions and had travelled more frequently for work.

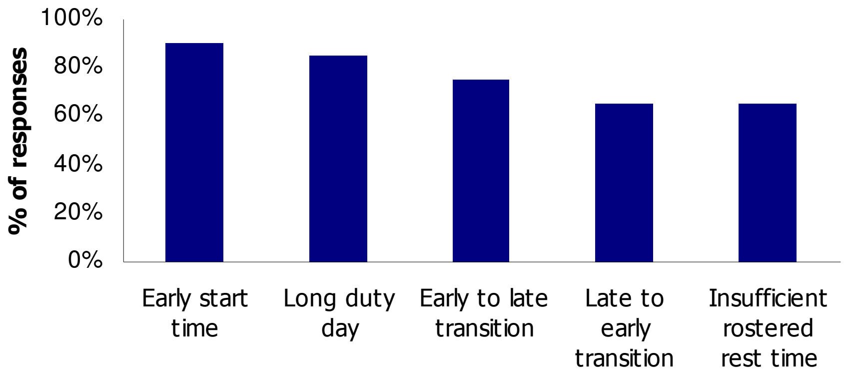

Figure 4 –– The five factors that TCs find most problematic in terms of fatigue

In addition to working a more fatiguing roster, the diary study revealed that TCs were experiencing elevated levels of subjective workload (figure 5). Training in the simulator and on the line had a greater workload than standard line duties and simulator training was more demanding than line training. In fact, the workload associated with simulator training was not significantly different from that associated with flying in bad weather. Simulator duties had the highest subjective workload primarily because they have high temporal demands. TCs need to complete a complex lesson plan in six hours with no option to overrun and extend the lesson. TCs also spend a significant amount of time additional to their rostered hours preparing simulator lesson plans and report writing at the end of simulator sessions.

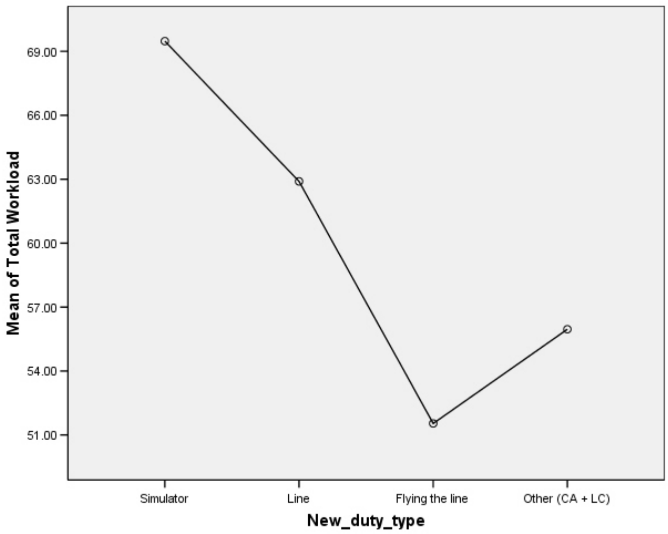

Figure 5 –– Mean workload (NASA-TLX) associated with the different duty types performed by TCs

During the two month period over which the diary study was conducted, TCs submitted a disproportionately high number of fatigue reports forms (n=34) to the company. The most serious fatigue-related incident was reported by a TC who had fallen asleep behind the wheel when driving home from his second consecutive night simulator duty. He crashed his car but thankfully was uninjured. The immediate investigation revealed that the pilot did not live local to the simulator and despite having the option of taking a taxi or staying in a hotel, he elected make the six hour journey in his own car.

iii. Risk in process assessment: The next step within SIRA was to identify the operational processes that were involved in generating fatigue risk for the TC population. The results are listed below:

- Simulator instructor duties were being considered under the regulations that relate to duty hours (non-flying duties i.e. ground duties), rather than the more restrictive block hour regulations (flight time). As a consequence of the classification of simulator hours as duty hours, the following fatigue-promoting practices were permitted:
    - As TCs had artificially low block hour totals, rostering offices could assigned the heavy block hour schedules.
    - Simulator duties could be sandwiched between block hours in a way that would not otherwise be legal.
    - Prior to a simulator duty, there was no requirement for the local night of rest that is required prior to working block hours.
    - Crew could commute on the same day as a simulator duty, which is something that is not allowed on days that include block hours.
- Although additional preparation is required for a training duty, line and training duties were allocated the same amount of time for pre and post flight activities. In practice trainers were reporting earlier for the duty and remaining later post duty to facilitate thorough briefing/debriefing time for crew.
- Many trainers do not live local to the simulator training facilities and need to work out of a variety of different bases. The trainers were financially compensated, and thereby encouraged, to travel in their own cars.

- The roster stability figures in use did not account for the actual number of roster changes being experienced.

iv. Strategic and Tactical Risk Management: The multiple layers of evidence for an elevated fatigue risk amongst TCs was communicated to the company Fatigue Safety Action Group (FSAG) and Safety Review Board (SRB) for tactical and strategic decision making. A number of immediate tactical changes were made to existent processes and some of these are listed below:

- Crew must now have a local night off prior to simulator duties;
- After a simulator duties crew must have days off or be allocated a local night off before working a flying duty, and
- Line training report time has been increased by 15 minutes.

The strategic policy changes that were agreed at company board level included, most importantly, the re-classification of simulator hours from duty hours to block hours. New crew roster stability figures that better reflect crew lifestyle disruption are also under development.

v. Evaluation of monitoring metrics and controls: Residual risk assessment: To evaluate how the tactical and strategic changes to TC rosters actually impacted on TC work rate we analysed three variables - block hours, duty hours and the number of sectors flown. These variables were calculated for June and November 2006, which was prior the introduction of the new rules, and for the same months after the rules were in place. Six TC rosters and six line pilot rosters, matched for home-base, were analysed.

The analysis found that while block hours, duty hours and the number of sectors flown reduced for both TCs and line crew, the work rate amongst TCs declined to a greater extent. For example, block hours declined by 8% for line crew and by 26% for TCs.

References

1. UK Civil Aviation Authority. CAP 371: Avoidance Of Fatigue in Air Crews, 4th Edition, Amdt 1, 2004.
2. Dawson D and McCulloch K. (2005). Managing fatigue: It's about sleep. Sleep Medicine Reviews, 9, 365-380
3. Stewart S and Abboud R. Crew Scheduling, Performance and Fatigue in a UK Airline. Conference Proceedings of Fatigue Management in Transportation Operations, Seattle, USA, 2005.
4. Rosekind MR, Gregory KB, Miller DL, Co EL, Lebacqz JV and Brenner M. (1996). Crew Fatigue Factors in the Guantanamo Bay Aviation Accident. Sleep Research, 25, 571.
5. Folkard S. Fatigue and Accident Risk: What Research Tells Us. Fatigue and Transport Accidents PACTS Conference Proceedings: February 4, 2003.
6. Barger LK, Ayas NT, Cade BE, Cronin JW, Rosner B, Speizer FE and Czeisler, CA. (2006). Impact of Extended Duration Shifts on Medical Errors, Adverse Events and Attentional Failures. Plos Med v.3 (12).
7. Durmer JS, Dinges D (2005). Neurocognitive consequences of sleep deprivation. Semin Neurol. 25(1):117-29, Review.
8. Hawkins, F. H. Human Factors in Flight. Aldershot: Ashgate, 1993.
9. Neri DF, Shappell SA and DeJohn, CA. (1992). Simulated Sustained Flight Operations and Performance, Part 1: Effects of Fatigue. Military Psychology, 4(3).

10. Dinges DF. Performance Effects of Fatigue. Fatigue Symposium proceedings. Washington, DC: National Transportation Safety Board, 1995.

11. Batelle Memorial Institute. An Overview of the Scientific Literature Concerning Fatigue, Sleep and the Circadian Cycle, US Federal Aviation Authority (FAA), 1998.

12. Caldwell JA and Caldwell JL. Fatigue in Aviation: A guide to Staying Awake at the Stick. Aldershot. Ashgate, 2003.

13. Thomas MJW, Petrilli RM, Lamond N, Dawson D and Roach GD. Australian Long Haul Fatigue Study. 59th Annual International Air Safety Seminar (IASS), Paris, France, 2006.

14. Australian Government, Civil Aviation Safety Authority. Fatigue Management: suggested alternatives to prescribed Flight and Duty Times. Discussion Paper, Document DP 04040S, 2004.

15. International Civil Aviation Organisation (ICAO), OPSP Working Group, Draft Document, 2007.

16. Hampton P. Reducing administrative burdens: effective inspection and enforcement. HM Treasury Report, 2005.

17. Strategic Issues: The Underwriters perspective. Journal of Flight Safety Foundation, AeroSafety World. June, (2007)

18. Corporate Manslaughter and Corporate Homicide Act (c19), Ministry of Justice UK, 2007.

19. McCulloch K, Fletcher A and Dawson D. Moving towards a non-prescriptive approach to fatigue management in Australian aviation: A field validation. Paper prepared for the Civil Aviation Safety Authority, Australia, 2003.

20. Stewart S, Holmes A, Jackson P and Abboud R. An integrated system for managing fatigue risk within a low cost carrier, 59th Annual International Air Safety Seminar (IASS), Paris, France, 2006.

21. Ayeko M. Investigation and Reporting of Accidents . Integrated Safety Investigation Methodology (ISIM), GIST Technical Report G2002-2, 2002

22. Koornneef F and Hale, A. Organisational Memory and Learning from operational surprises: requirements & pitfalls. Cited in Andriessen, JH and Fahlbruch B, eds. How to Manage Experience Sharing – from Organisational Surprises to Organisational Knowledge. Elsevier: Amsterdam. ISBN 0 08 0443494, 2004

23. AS/NZS 4360: Australian/New Zealand Risk Management Standard. Standards Australia/Standards New Zealand. Third Edition, 2004.

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