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An integrated system for managing fatigue risk within a low cost carrier

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1. Introduction

This paper reports on the experiences of easyJet, a large European Low Cost Carrier (LCC) in developing a Fatigue Risk Management System (FRMS). The paper begins by presenting the safety case that was developed for progressing beyond the current UK Civil Aviation Authority (CAA) Flight Time Limitations (FTL). The paper then provides examples of operational data that have been used to evidence fatigue risk within the airline. We explain how this evidence has informed decisions about the control of fatigue risk and influenced the design of the airline's FRMS. The paper concludes with an overview of a safety management system (SIRA©) that has been developed to enable fatigue risk to be managed, as one element of overall system risk.

2. Background

In April 2005, easyJet became the first major airline to be granted alleviation from the current FTL. The UK CAA agreed the alleviation based on the results of a safety case report of a 6 month roster trial. The trialed roster was a 5/2/5/4 roster (5 early duties, 2 days off, 5 late duties, 4 days off), which exceeds the FTL (CAP 371) limit of 3 consecutive early duties. easyJet presented a safety case which demonstrated that, compared to the 6/3 roster (3 early duties, 3 late duties, 3 days off) in operation at the time, the 5/2/5/4 roster was associated with a significant reduction in fatigue risk and flight deck error. The 5/2/5/4 roster is now operational network-wide at 14 bases.

A requirement for the CAA alleviation was that easyJet implement an FRMS. An FRMS is an evidence-based system for the measurement, mitigation and management of fatigue risk to as low as reasonably practicable (Australian Safety Transport Bureau, Fatigue Expert Group, 2001). An FRMS is a 'toolset' of processes that are employed within an existing Safety Management System (SMS) framework, thereby enabling fatigue risk to be managed much like any other risk. Fatigue risk management is a recent development and initial reviews of its application in the aviation industry in

Australia and New Zealand have been generally positive (CASA 2003, Australian Safety Transport Bureau 2006).

3. Development of the safety case

3.1 Low cost carriers and fatigue risk

easyJet is a low cost short-haul airline that works European routes. The airline operates in a highly competitive environment against the backdrop of rising fuel costs, skilled labour shortages and reducing year-on-year yields. In order to maintain economic viability, direct costs must be minimised and resource utilisation must be maximized. To make the most of crew resources, low cost carriers adopt scheduling practices that emphasise high productivity measured in hours, multiple sector duty days and minimum crew rest. These scheduling practices, where they are not managed in an informed manner, can have detrimental consequences for crew alertness and performance (e.g. Caldwell, 2004, Bourgeois-Bougrine et al, 2003, Cabon et al, 2003) and potentially lead to an unacceptable level of fatigue risk exposure.

3.2 Criticism of FTL compliance

The most common control for fatigue risk utilized in aviation and other safety-critical industries is compliance with FTL, or other limitations on hours of work (HoW). The effectiveness of HoW limitations as a control for fatigue risk has been criticized on the basis that limitations tend to be used as a rostering target, rather than guidance. In this context, there are a number of reservations regarding HoW limitations. It has been argued that HoW limitations are not scientifically defensible, do not enable actual workforce fatigue to be measured or predicted and can inadvertently encourage rostering practices that increase fatigue (Fatigue Expert Group, 2001). In addition, HoW limitations have been criticized because there is significant variability between prescriptive rule sets offered by different aviation regulation authorities (Cabon et al, 2002).

3.3 5/2/5/4 roster trial

In recognition of the potential fatigue risk associated with LCC operations and the potential weaknesses of controlling fatigue risk via simple adherence to FTL, easyJet developed a Human Factors Monitoring Programme (HFMP©, Stewart and Abboud, 2005). The HFMP© was designed to assess flight crew fatigue, rostering practices and human error, and the interactions between these variables. The HFMP© is a multi-layered programme that mines data from existing Safety Management System (SMS) databases, for example Flight Data Monitoring (FDM), and includes additional measurements, such as predictive modelling of the fatigue associated with work hours and the objective measurement of sleep.

The HFMP© was applied to the 6/3 roster being worked at the time and during the trial of the 5/2/5/4 roster (2 bases). The 5/2/5/4 roster was predicted to reduce fatigue by decreasing the number of days worked consecutively and increasing the amount of time off provided for the changeover from early to late duties.

The weight of evidence collected in the HFMP© indicated that, compared to the 6/3 roster, fatigue risk was reduced during the trial of the 5/2/5/4 roster. Examples of the HFMP© findings, which formed the basis of the safety case that was presented to the CAA, are listed below:

- The two rosters were assessed using predictive fatigue modelling software called FAID®. While 1.8% of duties on the 6/3 roster were categorised as being associated with a high to very high fatigue risk, only 0.7% duties on the 5/2/5/4 roster fell into these categories.

- Line operations safety audit (LOSA™) observers recorded crew threat and error management on both rosters. A mean error rate of 5.2 per sector was recorded on the 6/3 roster and this was reduced significantly to 2.6 on the 5/2/5/4 roster.

- The implementation of the 5/2/5/4 roster, after approval by the CAA, was subject to the vote of crew belonging to the British Airline Pilots Association (BALPA). Of the members that participated in the voting process, 91% agreed that they felt less tired/fatigued on the 5/2/5/4 roster and 93% voted for the new roster.

3.4 Actual sleep duration

Although the majority of evidence collected in the HFMP© showed that fatigue risk was reduced on the 5/2/5/4 roster, data on the actual amount of sleep obtained by crew indicated that fatigue risk required further attention. During the roster trial 22 pilots wore an Actiwatch®, a watch-like device that monitors activity and from which sleep duration can be assessed. The data collected showed evidence of less sleep obtained on early duties than on late duties.

The amount of sleep obtained by crew was comparable to that found in a sleep diary study of short-haul pilots working out of France (Bourgeois-Bougrine et al. 2003). These pilots reported mean sleep durations of 5 hours 41 mins for early flights and 7 hours 26 mins for 'afternoon flights'. For the easyJet crew and the French pilots, a short sleep duration on early duties can be attributed to difficulty in advancing sleep onset, or in other words, failing to sleep sufficiently early.

In addition to highlighting acute sleep loss as an issue, the sleep study results indicated that sleep loss was accumulating across the 5/2/5/4 roster cycle. The amount of sleep obtained on a given duty day also varied widely between crew members. For example, while crew with young children obtained a relatively large of sleep early duties, those with older families obtained relatively more sleep on late duties. As the relationship between acute sleep loss, cumulative sleep loss, recovery and safe crew performance is not yet well understood (Belenky et al, 2003; Van Dongen et al, 2003; Caldwell, 2004; Cabon et al, 2002), this issue will be investigated further within the company FRMS. Within the FRMS, cumulative sleep loss and inter-individual differences (trait and lifestyle) are recognised as important determinants of performance, and ultimately fatigue risk.

4. The 5/2/5/4 in operation

Thus far, an overview of the safety case that supported moving to a 5/2/5/4 roster has been provided and examples of some of the initial information that guided the design of the company FRMS has been introduced. In April 2005 the 5/2/5/4 roster was rolled-out across all 14 bases. In this section we report how the traditional measures of system safety that were collected at the time responded to the new roster. Further examples of evidence-based change are provided, including improvements to the FRMS design.

The introduction of the 5/2/5/4 roster coincided with the annual increase in workload that occurs during the northern hemisphere summer holiday period (May-October). Workload was additionally increased due to the introduction of new routes and crew resource difficulties. The increase in workload meant that crew were scheduled to work longer hours, time off was reduced and roster disruption increased. As shown in Figure 1, annualized block hours (flying hours) increased to around the prescribed limit of 900.

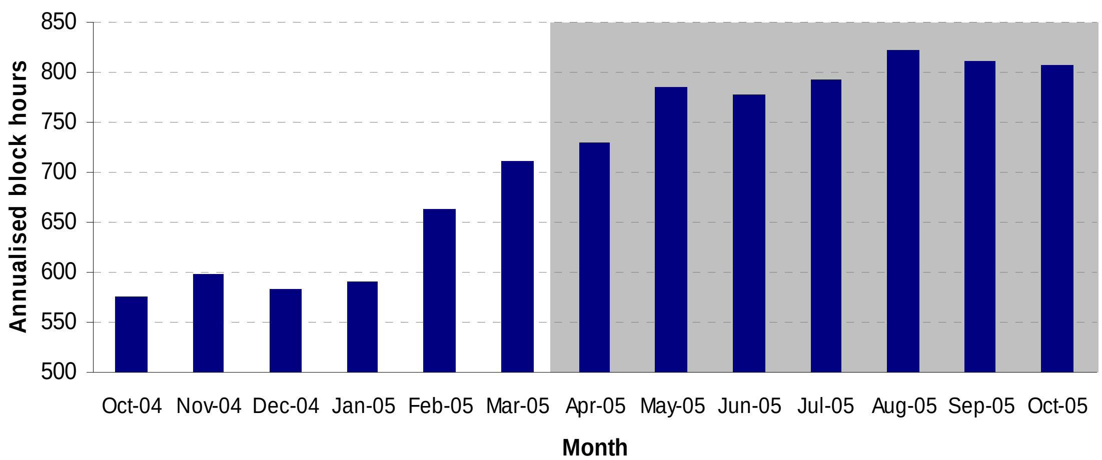

Figure 1. Annualized block hours per month for one large base before and after the 5/2/5/4 roster was implemented at all bases (April 2005).

The SMS tools that were relied upon at the time provided limited information on the impact that the 5/2/5/4 and increase in workload were having on safety. One of the SMS system tools employed was Flight Data Monitoring (FDM) where the incident rate of serious FDM events, for example composite events and 500 foot busts, was analyzed. The FDM event rate was less than one third of that for the same period the previous year (June-Oct 2004 vs 2005), which was assumed to indicate that risk was adequately controlled. However, at the same time, informal crew complaints of fatigue and confidential crew reports of fatigue to the CAA were increasing.

In order to capture a more detailed picture of system risk, the Operations Risk Group (Safety Department) conducted a System Hazard Analysis process that included crew workshops at 5 different bases. The SHA process provides the organizational management with systemic risk elements, Fatigue risk elements, Duty time decrements (re-programmed into FAID®) and a Fatigue Risk grading for validation of the company risk tolerance level.

In addition to crew interviews the process comprises analysis of Air Safety Reports (crew error review), Flight Data Monitoring (fatigue variables: event duty day, duty week, sector, crew base, route, crew age etc..); Quality audit findings review; Roster department metrics (base attrition, sickness, discretion use, roster legality) and Interviews with Aero Medical Examiners overseeing base pilots. Work also commenced on a process for logging and analyzing low risk FDM events and the development of a formal system for crew to report fatigue to the company, both of which were deemed to be essential for the success of the FRMS.

5. Crew workshops

In July and August 2005 crew workshops were conducted at 3 small (A,B and C) and 2 large (E and F) bases. The aim of the workshops was to gain a better understanding of the operational sources of fatigue, such as work hours, and the impact these were having on crew performance.

The workshops highlighted a number of operational elements that were promoting fatigue. The majority of these elements were related to either workload/hassle or scheduling and are listed below.

Workload/hassle
High density airspace, busy airports, engineering faults, insufficient baggage handling staff, delay getting steps to the aircraft, crew room computer usability, slow crew transport to a remote aircraft stand, difficulties getting through security between the crew room and aircraft.

Scheduling
Increase in sectors flown per day, long duty days, multiple roster changes, fatigue accumulates over 5 early duties, 2 days off between early and late duties is insufficient time to both attend to domestic responsibilities and recover from fatigue under current summer schedule workload.

Similar workload/hassle and scheduling elements have previously been reported and found to have a significant effect on subjective ratings of fatigue, particularly in short-haul carriers (Nguyen et al, 2003). For example, a study involving two short haul carriers (KLM-UK and BMI) showed that 'hassle factors' were a significant determinant of fatigue and their effect was compounded on multi-sector days with minimal turn around times between flights (CAA Review of Aircrew Fatigue Research, 2005/04).

6. Operational factors and fatigue risk

To investigate further the impact that workload/hassle factors were having on system safety, the results of the workshops were overlaid against the FDM database. This section describes the results of this investigation and how it has influenced the design of the company FRMS.

6.1 Evidence of fatigue risk

Review of the hassle factors cited by crew indicated that, whilst some factors occurred as isolated events, many could act concurrently and increase operational risk. At base E, which was overrepresented in the FDM database, the influence that operational elements can have on fatigue was particularly apparent. A significant 'hassle factor' experienced by crew was the transport from the car park to the terminal which resulted in a trip of approximately 30 minutes. A simple countermeasure was to consider the increase in time required by crew to compensate for these factors. At base E this was determined to be on average an extra one hour of duty time not accounted for under the roster.

In order to assess how the difficulties with crew transport were impacting on fatigue, a work-related fatigue analysis model called FAID® was utilised. Crew rosters for July and August were analysed using rostered duty start and finish time. Duty start times were then advanced by 60 minutes and reprogrammed for a second FAID® analysis. The extra hour of duty increased the proportion of hours that fell into the high to very high range (FAID® scores>75) from 0.3% to 4.2%, thereby providing objective evidence for increased fatigue risk exposure. It is also likely that the crew transport issue may have influenced performance in ways other than by extending the time spent getting to work, for example by increasing time pressure when crew finally arrived at the terminal.

6.2 FDM events on sector 1

During the workshops crew reported that operational elements were most problematic prior to the first sector of the day. For example, upon arriving at the crew room, crew had difficulty logging on to computers to access the necessary flight information which in turn could delay flight planning and restrict briefing time. Similarly, prior to the first sector, delayed transport to a remote stand, or difficulties getting through terminal security could place added pressure on crew to achieve boarding and an air traffic control slot time.

Subsequent analysis of the FDM event database (events collected over 14 months and corrected for the number of sectors operated for which FDM data was collected) revealed that the vast majority of events occurred on sector one. It seems reasonable to suggest that hassle factors are at least partially responsible for the peak in FDM events on the first sector. It is not known whether fatigue is a mediator between hassle and FDM events, or what other variables might be involved. The important point to recognize is that if fatigue is involved, it is only one of many factors that determine the occurrence of FDM events and safe performance. With this in mind it was decided that the company FRMS should be placed within a broader SMS that considers fatigue risk as one element of overall system risk.

6.3 FDM events across the 5/2/5/4 roster

In the workshops crew reported feeling most fatigued towards the end of the block of early duties. This finding agrees with the FAID® predictions of work-related fatigue and was expected based on the results of the study in which crew sleep was recorded. For example, compared to late duties, sleep duration was significantly lower on early duties and effects of sleep loss have been shown to be cumulative (Belenky et al, 2003; Van Dongen et al, 2003).

In contrast to the fatigue measures, further analysis of the FDM dataset revealed that composite events and 500 foot busts occurred more frequently on days one and two of the late duty sequence. This is in contrast to the trial study of the 5/2/5/4 pattern where crew committed an average of 2.8 errors per sector on early duties compared to 2 errors per sector on late duties. As FDM is by no means a pure measure of fatigue-related performance, the finding that less sleep was obtained on early duties and FDM events were more common on late duties, is not necessarily meaningful. Also, the data set used for analysis was not large enough to establish correlation between FDM events and crew rest and recovery after the days off following early duties. Moreover, it may not be realistic to assume that fatigue and the risk of human error are linearly related (e.g. Folkard and Lombardi, 2004).

The complex nature of the relationship between fatigue and human error was also highlighted in the results of a survey of crew that participated in the 5/2/5/4 roster trial. Crew reported feeling most fatigued and being most reliant on aircraft automatics (automation dependency) on duty days 4 and 5. It is possible that when crew are fatigued they use aircraft automatics as a coping strategy. If this is the case, increased fatigue may at some point be associated with a reduction in captured human error, simply because crew are less actively involved in airmanship i.e. the opportunity for committing errors is reduced.

7. Risk Mitigation - SIRA©

The experience of developing a safety case to work outside FTL and the implementation of the 5/2/5/4 roster has enabled the company to develop a sophisticated FRMS. The company acknowledges that even a well-designed roster does not *ipso-facto* provide adequate protection from fatigue risk. The easyJet FRMS has been designed to incorporate the collection of multiple measures of fatigue (predicted, actual, acute and cumulative), fatigue surrogate variables (e.g. workload, roster variables) and improved metrics for assessing human performance, for example low-risk FDM events. This information will assist in the evidencing of a fatigue risk boundary for the operation and form the basis of a continual monitoring program to support risk detection and evidence-based change.

The significant impact that workload/hassle has been found to have on performance highlighted the fact that fatigue is only one of many elements that contribute to overall system risk. Weight of evidence (not all presented here) including sleep analysis, subjective crew reports (fatigue report forms), FDM fatigue surrogate variable analysis, crew work rate metrics (duty hours, sickness, discretion analysis, attrition) and liaison with Aero Medical Examiners has lead to the implementation of a 5/3/5/4 pattern. Essentially, an extra full day of rest has been programmed into the pattern as a risk mitigation step between early and late sequence duties. This is a proactive measure to mitigate operational risk through more efficient rostering practice without attendant loss of crew productivity. This action represents co-operation between the company, Regulatory Authority and the pilot union (BALPA) until the relationship between flightcrew fatigue, workload, scheduling practices, and crew recovery to safe performance could be defined and understood within the framework of the FRMS.

To facilitate further investigation into this area the company FRMS has been designed to be contained within a broader risk management system called Systems Integrated Risk Assessment (SIRA©, see Figure 2) which considers overall system risk. SIRA© involves the detection of sources of system risk within the operation, analysis and encoding of risk knowledge, review of system defences and the implementation of measures, as necessary, to mitigate operational risk.

SIRA© is an extension of the holistic approach to integrated performance assessment applied to Fatigue risk assessment adopted by Stewart and Abboud (2005). SIRA is based on the ‘defence in depth’ approach to incident/accident investigation proposed by the Integrated Safety Investigation Methodology (ISIM) of Transport Safety Board Canada (Ayeko, 2002) and the steps to active foresight as a goal of organisational learning within the Active Learning Model of Toft and Reynolds (1994). The Active Learning Model (ALM) links organisational learning with action steps to mitigate or control risk to an operational system. The SIRA approach also considers the DSME process (Define, Select and Implement, Monitor and Evaluate) (Cacciabue, 2004) and six-sigma approach (define, measure, analyze, design, verify) (Brue & Launsby, 2003).

8. Conclusion

By integrating and extending these approaches SIRA encompasses a strategic organizational learning and reporting stage based on a risk modelling platform and a system risk tolerance boundary. The System Risk Database allows for data mining of free text and numerical analysis of contextual fields for fatigue risk surrogate variables. The tactical and strategic cycles of the model work in sync, but out of phase, as the strategic process encodes system risk knowledge post tactical response and monitoring.

In short, SIRA© enables the company to measure, mitigate and manage fatigue risk as well as providing the Regulatory Authority with dynamic information on the company risk state.

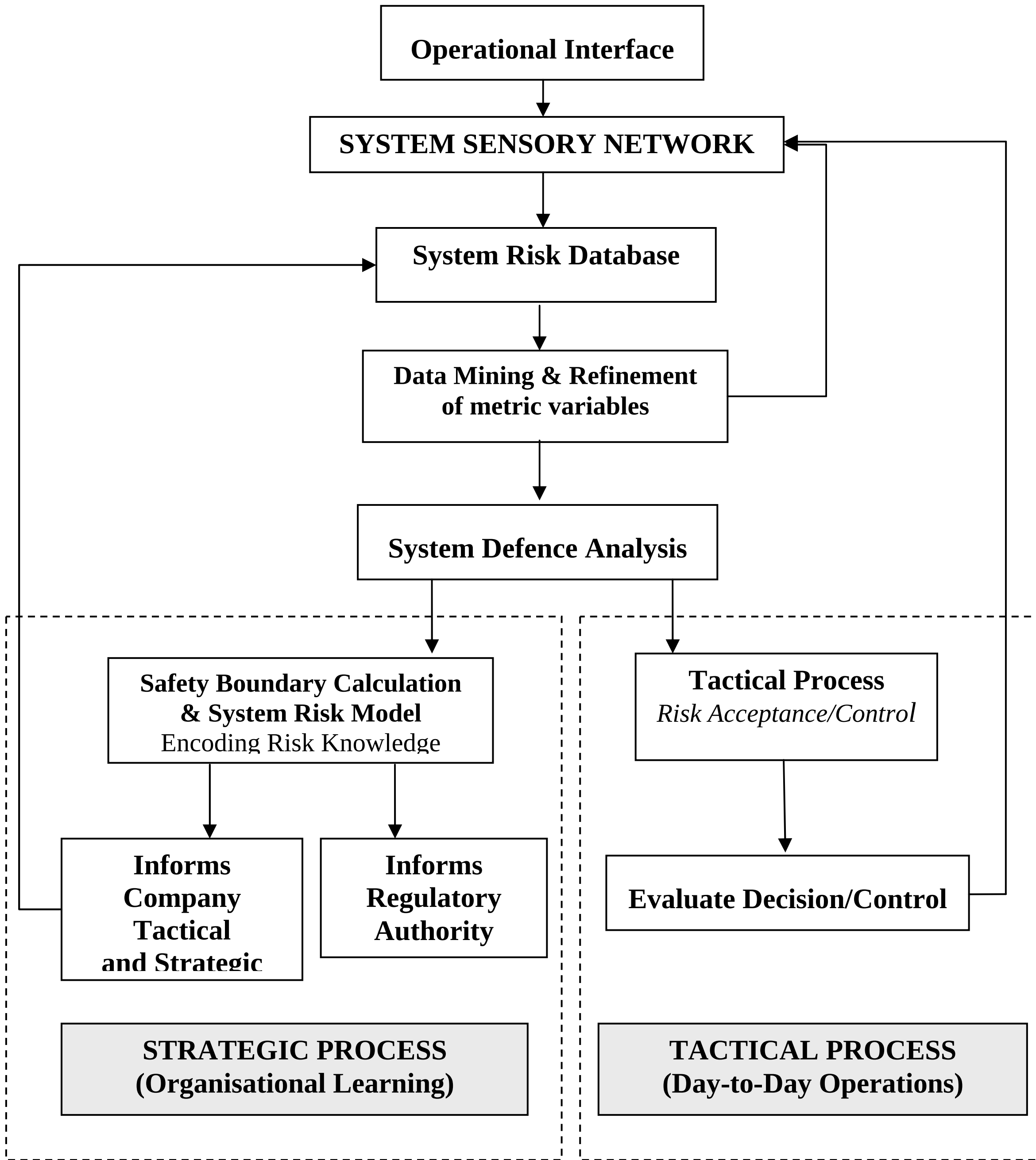

Figure 2. Overview of SIRA© (System Integrated Risk Assessment)

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