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Flight crew evaluation of the flight time limitations regulation

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A R T I C L E I N F O

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A B S T R A C T

Fatigue has been a long-standing concern in modern aviation. The duty hours of those who operate (cabin crew and pilots) have increased significantly. In order to combat the effects of fatigue, operators must adhere to Flight Time Limitations (FTLs) strictly set by regulatory bodies. With advances in the science of fatigue, the European Aviation Safety Agency (EASA) in February 2016 altered the duty limits and rest periods. A quantitative self-report survey design using descriptive statistics, chi-square tests of association and probit regressions with marginal effect calculations gathered the crew perceptions about the impact of the FTL regulation change to fatigue levels, reporting and safety/just culture. Participants (n = 794) were commercial cabin crew and pilots operating under European Aviation Safety Agency (EASA) regulations. 73.2% said they have not reported fatigue to their airline and 81.7% having operated fatigued. Scales on Fatigue Knowledge and Just/Safety Culture were constructed. Each point increase on the 6-item Just/Safety Culture scale shows that respondents are 8.6 percentage points less likely to operate fatigued. This study signifies that fatigue is under-reported and is a real risk to safety in the aviation industry. A substantial change to the existing safety culture should be encouraged and the fatigue's safety implications should not be underestimated and safety be compromised for maximum aircraft and labour utilisation.

1. Introduction

Air travel has increased and airlines try to achieve unit cost savings by increasing the aircraft and labour utilisation (Efthymiou and Papatheodorou, 2018; O'Connell, 2011). This has resulted in heavier workloads and increased hours of duties for pilots and crew (Harris, 2011). Therefore, there is a discernible pattern of higher probability of an accident (Goode, 2003). Papatheodorou and Platis (2007) discussed the tort liability in the context of safety standards in the deregulated airline environment. They argued that the absence of tight safety regulation could lead to a compromise of safety standards. Despite regulators and industry efforts and with air traffic steadily growing, accidents do happen (Arnaldo Valder and Gomez Comendador, 2011). Many of the aviation disaster lead to high mortality (Corbet et al., 2021) and substantially elevated levels of airline share price volatility (Akyildirim et al., 2020). The number of fatigue related safety incidents has grown, with crew sighting fatigue and sleep loss as the causation of operational errors such as landing on incorrect runways or fuel miscalculations (Rosekind et al., 1994a; 1994b).

In 2012, Member Associations of the European Cockpit Association (ECA) carried out a 'Barometer on Pilot Fatigue' study bringing together several surveys on pilot fatigue. Between 2010 and 2012, more than 6000 European pilots self-assessed the level of fatigue they were experiencing. The surveys confirm that pilot fatigue is common, dangerous and an under-reported phenomenon in Europe (ECA, 2012). According to Roach et al. (2012), the duration of duty time has a significant effect on fatigue levels of crew. Although extensive research has been conducted on the effect of fatigue in aviation, research exploring the impact of a regulation or policy related to the hours of service to safety levels is very limited.

The literature applied to fatigue in aviation is scare compared to other industries. There are papers published on driver's fatigue (e.g. Bowden and Ragsdale, 2018) or the factors contributing to airline pilot fatigue (e.g. Lee and Kim, 2018), but to the best of our knowledge there are no papers published about the use of regulation as a method of fatigue control in aviation. Airline managers like Michael O'Leary (in 2017) become more and more vocal about the pilots' salaries and their working hours (Efthymiou et al., 2021) ignoring the implications this might have on safety standards and practices. Given the recent strikes of Ryanair pilots (one of the reasons are the roasters) and pilot shortage,

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flight crew fatigue is deemed very important for the overall safety of air transportation.

Due to growing research in fatigue in aviation and significant advancements of sleep studies, the aviation industry reviewed and adapted the flight limitations. In February 2016, the European Aviation Safety Agency (EASA) implemented new rules known as Flight Time Limitations (FTLs). Regulation' changes related to FDPs, rest times, and a redefinition of terminology to create clarity and avoid misinterpretation, were implemented. All aircraft operators must implement Fatigue Risk Management (FRM) practices and fatigue training for all staff directly involved in the flight operations. Moreover, operators must provide evidence to the authorities that these measures have been taken.

The main purpose behind changes to the regulation is a shift to a risk based approach for managing fatigue (Dawson et al., 2012). The regulation proved controversial, since some welcomed the changes and others criticized the approach citing lack of clarity and argue the focus is still upon regulating hours of work which only addresses one part of the problem i.e. fatigue related to work duration (Signal et al., 2006).

This paper aims to explore the perceived impact of the changes made to FTLs on respondents reporting of fatigue, and operating fatigued. One major premise behind this risk management approach of fatigue is having a 'just reporting culture', were crew members are encouraged to report any safety related issue which is or could be related to fatigue (Dekker, 2012). For this reason, this research also explored the respondents' perceptions about their airlines' safety culture and examined the relationship between Just Culture and willingness to report, if they operate fatigued as well as the relationship to fatigue training.

2. Fatigue

The International Civil Aviation Organisation (ICAO, 2011a; 2011b; 2011c), defines fatigue as: "*a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety-related duties*".

Fatigue can be categorized into either acute fatigue which is said to be short-lived often caused by insufficient sleep or chronic fatigue developed at a slower pace after long exposure to fatigue (Craig and Cooper, 1992). Caldwell and Caldwell (2016) highlights the need to move away from the misconceptions that fatigue is merely a state of mind rather than something real and tangible.

Workplace fatigue has been well-researched (Bowden and Ragsdale, 2018). Nevertheless, aviation fatigues still remain under-researched and scholars have not reached an agreement on how to operationalize fatigue when studying exertion in human transport operators (Phillips, 2015). A number of models systems about the risks that fatigue introduces, have been developed (e.g. Fatigue Risk Management Systems (FRMS), Fatigue Avoidance Scheduling Tool (FAST), Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE)).

Davidović et al. (2018) studied the bus and truck drivers' fatigue. They found out that circadian rhythm, sleep and work factors have an impact on drivers' fatigue. They concluded that drivers working over the legal limit, have more reduced driving performance and increased chance of being involved in an accident. Anderson et al (2017) researched the changes in the hours of service regulation policy that restricts the number of duty and driving hours a truck driver can operate in order to reduce the fatigue related accidents involving trucks and concluded that they have not led to a significant change in accidents.

Fatigue in aviation has been at the top ten safety concerns for the National Transportation Safety Board (NTSB, 2016) for many years. Although percentages vary, it has been estimated that between 60 and 80% of aviation accidents are due to human error (Shappell & Wiegmann, 1996). Human error is defined as "the failure of planned actions to achieve their desired ends—without the intervention of some unforeseeable event'' (Reason 1997). It can thus be understood that human errors are typically associated with pre-planned actions, especially within systems of higher complexity, where the human element malfunctioned at some stages of the process. Nowadays, the contribution of human error in aviation accidents has been a major factor as 66% of hull-loss accidents were associated with flight crew in the period between 1992 and 2001 (Boeing, 2006). The impact of human error in general aviation is even more significant. For example, 79% of the fatal accidents that occurred in the United States in 2006 were attributed to pilot error (Krey, 2007).

Human error is responsible for 92% of the collisions between aircraft and ground vehicles or structures at airports and costs, not including taxiway operations, the airline industry globally about US$10 billion annually (Lacagnina, 2007). Fatigue is considered one of the most critical factors that has an impact on the decision making of flight crew members. Caldwell (2005) presented a study of major accidents on US domestic airlines from 1978 to 1990 produced by the National Transportation Safety Board (NTSB), the study estimated that fatigue contributed to between 4 and 7% of civil aviation mishaps (Kharoufah et al., 2018).

Furthermore, Caldwell (2005) presented a survey of flight crew members where the international crew surveyed indicated that sleepiness and lethargy, cognitive slowness, and concentration difficulties were common causes of flight crew fatigue. International pilots regularly attribute fatigue to sleep deprivation and circadian disturbances related with time-zone transitions. In addition, the survey found that around 70% of the corporate jet pilots reported that they had fallen asleep during a flight. Meanwhile, 90% of the flight crews surveyed recommended flight scheduling as a major factor on diminishing fatigue within their operational circumstances (Caldwell, 2005; Kharoufah et al., 2018). Research conducted in Europe indicated that 50–54% of pilots admitted to falling asleep in the cockpit (BALPA 2015). Fatigue impairs alertness and overall performance and can be a huge threat to aviation safety (Wise, 2010; Federal Aviation Administration, 2018).

The Federal Aviation Administration (2011) reported that human error has not decreased over the past few decades and remains a major cause of aviation mishaps. Shappell et al. (2007) found that nearly 60% of commercial aviation accidents can be directly attributed to unsafe acts, which can be classified into unintentional errors or willful violations (Scarborough et al., 2005). The errors are further categorized into decision error, skill-based errors, and perceptual errors (Shappell and Wiegmann, 2003).

There are a number of factors, which contribute to fatigue and some are unique to the aviation operation. Lee and Kim (2018) have listed all the pilot factors putting then to 8 categories (Flight direction, Crew scheduling, Partnership, Aircraft environment, Job assignment, Ethnic differences, Hotel environment and others). In aviation, crew are required to work irregular hours and long shifts adding to the crossing of time zones (Caldwell, 2005). Research has demonstrated that insufficient duration of sleep prior to a Flight Duty Period (FDP) is a predictor of delayed response times and/or errors (Cabon et al., 2008).

Scientific evidence suggest that humans need on average 8 h of good quality and continuous sleep in every 24-hour period to avoid the onset of fatigue (Campbell and Bagshaw, 2008; Ewing, 2008). Crew operating long shift patterns, altering days and nights are at risk of cumulative sleep debt (Caldwell, 2005). This phenomenon suggests that a reduction in sleep by as little as one hour per sleep period can cause fatigue, which can become progressively more pronounced with reduced sleep in subsequent periods (Darby and Walls, 1998).

Disruptions to sleep cycles, sleep loss and deprivation can cause fatigue (Caldwell et al., 2012; Samel et al., 1997). Moreover, sleep obtained during the day is not as effective as night sleep (Harrison and Horne, 1999). The crew shift patterns add disruption to sleep cycles and pose challenges to vigilance and alertness during duties (Previc et al., 2009). Gander et al. (2015) found that the average duty period for pilots on short haul operations was 10.6 h. Further research also showed pilots have increased performance lapses in the latter part of duty periods (Gander et al., 2014). Duty periods, which extend into night time hours, cause disruption to circadian rhythms and research demonstrates that working during these hours result in reduced performance and increased mistakes (Akerstedt, 1995). Moreover, the combination of non-traditional work hours, technological advances and increased automation has a direct impact on crews' fatigue levels (Dinges, 1995). Finally, the European Cockpit Association (ECA, 2012), surveyed pilots and found that night flights were a major factor for fatigue.

More than 70% of aviation accidents can be attributed to human factors, now recognized as one of the key determinants for managing and improving flight safety (Kelly and Efthymiou, 2019; Gander, 2001; Jin-Ru et al., 2009; Jeng-Chung and Yu, 2018). Jin-Ru et al. (2009) surveyed 1891 pilots (1062 captains and 831 first officers) working for Taiwanese carriers and found that the majority of the pilots reported feeling fatigued or even nodding-off during long-distance flights. It has been demonstrated in a number of studies that fatigue, sleep-loss, and circadian disruption due to flight operations can affect both crew performance and flight safety (Rosekind et al., 1997; Spencer, 2001).

According to the US National Transportation Safety Board, more than 300 fatalities are attributed to fatigue, some of which are direct causes of long duty periods, circadian disruptions, and sleep loss (Avers and Johnson, 2011). According to Goode (2003), the number of accidents per pilot is proportional to the length of his/her duty periods and directly correlates with his/her fatigue level. Folkard and Lombardi (2006) concluded that the risk of errors and incidents increased 13% for 10 h shifts and 28% for 12 h shifts in comparison to 8 h shifts.

Workload and other factors, such as fatigue, influence flight crew's performance and should be have kept at suitable levels to ensure safe operations (Efthymiou et al, 2019). The US FAA mandated a 9-hour rest period for many decades, however, a new rule requires 10-hour rest periods with the opportunity for at least 8 h of uninterrupted sleep. Maximum flight times have also been updated: maximum daytime flight time is 9 h and maximum night time flight time is 8 h. The new rule also limits a pilot's flight duty period to 9–14 h, depending on the start time and number of flight segments. Risk Management System to assist pilots with meeting the new requirements. Finally, the FAA proposed that airlines implement a Fatigue Risk Management System to assist pilots with meeting the new requirements (Department of Transportation. Federal Aviation Administration, 2012). In a report by Jeppesen, it was shown that current aviation rules by themselves are ineffective to account for fatigue (Olbert and Klemets, 2011).

2.1. Flight time limitations

Driver fatigue is a significant factor in approximately 20% of heavy commercial vehicle crashes according to European Transport Safety Council (2001). Over 50% of long-haul drivers have at some time fallen asleep while driving (Hamelin, 2000). Collisions due to fatigue are 3 times more likely to result in death or serious injuries because of the high impact speed and the lack of avoiding action (Road Safety Authority, 2008). Truck drivers are more vulnerable because they work in shifts, spend long hours behind the wheel and drive regularly during peak times for sleep-related collisions. Therefore, limitation in the working hours of drivers, also known as hours of service regulations, were implemented to eliminate the type of drowsiness that can lead to crashes (Federal Motor Carrier Safety Administration's, 2017).

Flight Time Limitations (FTL) regulate the working hours of those who operate in aviation. The main aim of FTLs is to ensure control of fatigue and standardisation in the regulations (Steiner et al., 2012). These limitations outline in detail the maximum time on duty a person can work, the cumulative time of duty, maximum flight times and the minimum rest period required for a crewmember. Table 1 summarises the changes in the regulations and the rationale of the changes.

The prevention of fatigue through a rostering system is one of the essential requirements for air operations. Yet, some have questioned the regulation as it does not take into consideration other variables such as variations of work load severity, work/life factors and the levels of alertness which are susceptible to individual differences, as well as recovery times (Fletcher et al, 2015). A number of studies concluded that fatigue management in aviation needed to consider several causes for fatigue. Some of them are the lack of adequate sleep (Dawson and McCulloch, 2005), workload (Bennett, 2016), time zones crossed (Gander et al., 2014), Daily body rhythms, known as circadian rhythms (Gander et al., 2015), time on task (Gunzelmann et al., 2010), quality of sleep (Sieberichs and Kluge, 2016) and benefits of napping (Hartzler, 2014).

Rest periods, commanders' discretion and joint responsibility are areas highlighted by the new regulation. Fatigue training is a mandatory requirement and should cover the possible causes and effects of fatigue and methods to counteract fatigue. The differences between operations (e.g. long haul vs short haul) are ignored by FTL regulation (Steiner et al., 2012). Stewart (2009) identified a number of variables relating to fatigue which FTLs do not consider:

- crew sleep opportunity in reflection of lifestyle and social needs.
- difficulty of sleep obtained while balancing flexible shift patterns.
- altering sleep during day and night.
- individual differences in the ability to perform safety related tasks in a sleep deprived state.
- changes to rosters due to adverse operational changes such as weather and the effect these changes may have on sleep opportunity.
- the complexity and variation of workload.

Maximum daily Flight Duty Period (FDP) remains at thirteen hours. A maximum of four sectors per night duty can be operated in the case of consecutive night duties. An appropriate FRMS approved by the authority must be applied in the case of night duties of ten hours of more (EFT, 2014).

Another new element related to fatigue and FTL is the Fatigue Risk Management System (FRMS) that became a mandatory requirement for airlines. The aim of FRMS is to ensure that crew operate on a satisfactory level of performance (ICAO, 2012). The system takes into consideration the variability of capacity of individuals as well as the predictions of sleep and circadian levels relative to performance.

In 1995, the New Zealand Civil Aviation Authority changed their regulations in order to allow operators to use FRMS (Civil Aviation Authority of New Zealand, 2007). The FRMS in New Zealand aviation showed the percentage of pilots self-reporting fatigue at least once a week falling from nearly 70% in 1993 to below 40% in 2010. FRMS takes into account additional factors that may result in fatigue such as rest prior to duty and effects or time zones (Signal et al., 2008).

Singapore Airlines utilized FRMS in order to mitigate against fatigue related to the introduction of ultra-long-haul flights in 2003 (Spencer and Robertson, 2004). The Civil Aviation Authority (CAA) reviewed EasyJet's rosters over a period of 6 months and after a safety review, EasyJet was granted permission to deviate from FTL as there was a significant reduction in fatigue risk and flight deck error due to the new roster system (Stewart, 2009).

FRMS takes a more scientific approach to regulating crew rest, recognizing the requirement that crew should be well rested before work and that adequate periods of rest are provided in flight and following duties (ALPA, 2008). Under the new EU occurrence reporting regulation (Reg. 376/2014), fatigue reporting was no longer a choice, but an obligation (ECA, 2016).

More and more employees are facing the dilemma to report fatigue or colleagues who work while fatigued. Research has indicated that individuals will lie when it is beneficial to them (Ellingsen and Johannesson, 2004; Gneezy, 2005; Gibson et al., 2013; Gneezy et al., 2013). Moreover, reporting a colleague is many times avoided due to fears of ostracism and punishment by their peers since 'whistle-blowers' are not even welcome by individuals who act honestly (Reuben and Stephenson, 2013). Reporting fatigue might have social, financial and legal consequences. The willingness of crew to report fatigue relies heavily upon the type of reporting culture they are encompassed in (CAA, 2015). Therefore, Just Culture (i.e. crew members encouraged to report any

Table 1
Changes in the regulation related to crew fatigue (Source: Based on ETF, 2014).

Regulation Title	Subpart Q (Old Regulation)	ORO.FTL. (New Regulation)	Reason for change
Fatigue Risk Management (FRM)	Was not included in old regulation	Operator shall establish, implement and maintain a FRM as an integral part of its safety management system. (ORO. FTL.120)	FRM supports the application of FTL schemes recognizing through scientific research on sleep loss and performance, the need for aircrew to be adequately rested before flight duties. This is achieved by airlines continuously monitoring the safety of their operation relating to potential fatiguing duties and acting accordingly. This process is monitored through the airline safety management system and reviewed periodically by the national authority (ICAO, 2011a; 2011b; 2011c).
Flight time specification schemes	Was not included in old regulation	Must comply with regulation (EC) No 216/2008. (ORO.FTL.125)	Understanding the complexity of airlines operations, and how they vary significantly as per operational demand. Flight time specifications schemes gave opportunity to airlines who can demonstrate they are mitigating fatigue to the national authority with more flexibility surrounding flight time limitations. If deviation is requested airlines must submit periodical reports using scientific principles outlining the effects on aircrew fatigue. (ORO.FTL.125)
Maximum daily FDP	13 h (OPS 1.1105 1.3) 22:00 – 04.59 = max FDP 11:45	Remains unchanged at 13 h but there is a detailed table. Maximum of 4 sectors per duty in the case of consecutive night duties (FTL.1205 (a)) Time period changed to 17:00 – 04.59 max FDP reduced to 11 h Detailed rules around crew members in an unknown state of acclimation. FRMS must be applied in the case of night duties of more than 10 h.	Detailed table in order to avoid misinterpretation. Scientific research on chronic sleep loss of consecutive duties during the Window Of Circadian Low (WOCL) period which has been shown to hinder alertness levels and performance of duties, taking key research from the research on sleep and performance strict limits have been set. (Rosekind et al, 2006).
Extension to FDP due to in-flight rest	Left to the national aviation authorizes, not harmonized European standards set. (OPS 1.1115)	Different classes of crew rest defined. Different duty times set pending the type of crew rest provided. Class 1 = Bunk = 80 degree recline located separately from flight crew compartment and passenger cabin. Class 2 = seat = 45 degree recline with leg and foot support separated from PAX by curtain. Class 3 = seat = 40 degrees recline leg and foot support separate from PAX by curtain. (FTL 1.204) FDP extended with the addition of a flight crew member by= 14 hrs with class 3 15 h with class 2 16 h with class 1 Detailed table of minimum rest on board for flight crew with extension, all counted as FDP.	Advances in aviation technology now allow aircraft to travel for 16 h or more. This leads to crew performing safety related duties for extended periods of wakefulness and a greater accumulation of time on task fatigue. One measure to mitigate against this type of fatigue in long haul duties is the introduction of inflight rest. This has been studied scientifically and medically by a number of researchers in the field as an aid to help combat fatigue in long haul operations (Roach et al., 2011).
Extension without in-flight rest	Extension of 1 h. Not allowed for 6 sectors or more or 4 sectors when WOCL encroached by 2 h. Only twice in 7 consecutive days Pre and post rest increased.	Not to be combined with extension due to in flight rest or split duties. Detail table included for clarity (ORO.FTL.205 (D), with following amendments = Not allowed for flights between: 19:00–06:14 (1 – 2 sectors) 15:30 – 06:14 (3–4 sectors) 13:30 – 06:15 (5 sectors) (FTL 1.205 (b))	The new restriction limits take into consideration varying WOCL times taking into consideration this been the time when the body is programmed to sleep, where performance and alertness are degraded. (Flight Safety Foundation, 2014).
Commanders discretion	2 h for flight crew not augmented 3 h for augmented crew. (OPS 1.1120)	Limits remain the same. A non-punitive process must be used for the use of discursion. All crew members must be consulted on the alertness levels before agreeing to discretion. ORO.FTL.205 (f)	The introduction of a non-punitive process for the use of commander's discretion was introduced. This is due to the advances in scientific evidence which suggest that crew members may conform to discretion when levels of alertness are not adequate for safety due to pressure or groupthink occurring (Moorehead et al., 1991). All crew members must be individually consulted when discretion may be used to individually access their own alertness levels to continue with the duty. The non-punitive process is in keeping with the introduction of the just culture regulation introduction in 2014 (EU 376/2014).
Flight Time and Duty Periods	Cumulative hours = 60 duty hours in 7 days 190 duty hours in 28 days 900 duty hours in 12 months	Cumulative hours remain the same with the exception of new limits added = 110 duty hours in 14 consecutive days 1000 flight hours in 12 consecutive months. This is a rolling limit.	Rolling limits were introduced to combated airlines maximizing duty hours in short periods of time. This ties in with industry new norms which see airline staff been contracted in for the busy periods of the year, there hours been maximized and then let go or on zero contract hours for the remainder of the year (European Parliament, 2016).
Reserve	Not mentioned in old regulation	New concept introduced. Must be notified of reserve 10 h in advance. (ORO. FTL.230) Operator defines maximum number of consecutive reserve days. Must have 8-hour sleep opportunity. Reserve times	Unknown reason

(continued on next page)

Table 1 (*continued*)

Regulation Title	Subpart Q (Old Regulation)	ORO.FTL. (New Regulation)	Reason for change
		do not count as FDP, only begins when assigned a duty. FDP starts at duty report time. (FTL.1.230)	
Rest Periods	Minimum rest of 12 h at home base of the length of the proceeding duty. 10 h away from home base or length of proceeding duty. Time zone differences to be compensated for by the authority. Reduced rest defined by the authority Rest periods = 36 h including 2 local nights after maximum of 168 h.	Improvements made to recurrent extended rest periods increased to 2 local days twice every month. Additional rest must compensate for time zone differences, extensions to FDP, disruptive schedule and change of home base. (ORO.FTL.235) Stricter guidelines (FTL 1.235), Transition from a late finish/night to an early start must have a rest period of 1 local night. 4-hour time difference = minimum rest at home base extended to 2–5 local nights. East to west coast = at least three local nights' rest. Reductions can be made to rest but only under consultation under fatigue risk management and limited to 10 h out of base, and 12 h at home base.	New regulations take into consideration the changing nature of the industry, compensation to rest periods are made in relation to disruptive to the schedule. Rest periods must take into consideration the effects on the body from crossing time zones. Rest periods must be extended for longer time zones crossed. (Caldwell et al 2009).
Fatigue Management training	Never instructed before.	Must be included in the initial and recurrent training of all flight crew. (ORO.FTL.250)	Educating crew around the body clock and sleep patterns, effects of slept debt and introduction of a reporting process to report fatigue in a non-punitive method to combat the effects of fatigue on safety (Werfelman, 2012).

safety concerns they may have in a confidential manner without fear of reprisal) is essential in high reliability organisations, like airlines and airports. Finally, according to European Cockpit Association (2017) 'the complexity of the FTL rules, combined with a sometimes rather rudimentary FTL expertise at national authority level, means that their harmonised interpretation and implementation remains a challenge'.

3. Methodology

A self-reported, anonymous, online questionnaire was administered in 2017 via online networking communities (e.g. Flying in Ireland, groups in LinkedIn), to commercial cabin crew, pilots and line trainers operating under EASA regulations. The online communities of flight crew allowed us to circulate the questionnaire to a geographically wide population, but makes the participation rate unknown. We gathered 922 responses, but after data cleaning a total of 794 complete questionnaire responses were included within our analysis.

Drawing from the literature, several relevant factors were identified including measures for operators' safety culture, operators' fatigue reporting and training, participants' knowledge of FTLs, knowledge of regulatory changes and relevant socio-demographic factors. These measures are reported in Table 2. Although the majority of these factors are treated as dichotomous, two measures are based on a set of Likert scales.

The first construct, (Knowledge of FTL) is a scale inspired by Rudari et al. (2016) for exploring the perceived impact of pilots on changes made to crew rest, was used in this study to measure crew perceptions on FTL regulation changes. Adapting scales and questionnaires designed by other researchers is a common practice for informing the design of a new questionnaire that has been used by various researchers (e.g. McMullan et al., 2016; Efthymiou and Papatheodorou, 2015). The questions related to the perceptions of the regulations' impact on a personal level, adopted the same parameters as in Rudari et al. (2016): overall safety, ability to operate the aircraft safely, overall pilot alertness, ability to adapt to an adequate sleep cycle and overall pilot fatigue level. But, the wording of the questions required alterations to reflect the experiences of both pilots and cabin crew. Respondents indicated on a five-point Likert scale (1 = Strongly Negative, 2 = Negative, 3 = Neutral, neither positive nor negative, 4 = Positive, 5 = Strongly Positive) how negative or positive they perceived each of the five statements to be impacted by FTL regulation changes. The items were summed and averaged to create the 5-item scale (Knowledge of FTL). This 5-item scale (Knowledge of FTL) had a high internal consistency with a Cronbach's alpha of $\alpha = 0.92$.

The second construct, (Safety/Just Culture scale) measured respondents' agreement with six items:

- The crew who report safety-related occurrences are treated in a just and fair manner;
- Voicing concerns about safety are encouraged;
- We get timely feedback on the safety issues we raise;
- I am satisfied with the level of confidentiality of the reporting and investigation process;
- I am prepared to speak to my direct manager when unsafe situations are developing;
- A staff member who regularly takes unacceptable risks would be disciplined or corrected in this company.

Respondents indicated on a five-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, neither agree nor disagree, 4 = Agree, 5 = Strongly Agree) how much they agreed or disagreed with each of the six statements. Again, the six items were summed and averaged to create the 6-item scale. This 6-item scale (Safety/Just Culture), also had a high internal consistency with a Cronbach's alpha of $\alpha = 0.84$.

The questionnaire was pilot tested to ensure instrument validity and reliability, using aviation professionals, academic professionals, regulatory representatives from both the pilot and cabin crew departments, as well as a few front-line professionals including cabin crew, pilots, line trainers and safety consultants.

The analysis was conducted using STATA (StataCorp: Release 14.2/SE) and involves the use of descriptive statistics, chi-square tests of association, and probit regressions with marginal effect calculations. In total, two probit regression models were used to estimate the relationship between two binary (0–1) dependent variables (reporting fatigue and operating fatigued) and a set of explanatory variables using the following function (see Table 2 for the entire list of explanatory and dependent variables):

$$Dependent\ variable = f[socio-demographics,\ position,\ fleet,\ FTL\ knowledge\ and\ perceptions,\ airline\ safety\ culture]$$

Table 2
Explanatory and dependent variables.

Variables		Description
Explanatory		
Gender		
Female	31% (246n)	1 if female, 0 otherwise
Age		
34 or under	45.2% (259n)	1 if aged 34 or under, 0 otherwise
35–44	29% (230n)	1 if aged 35–44, 0 otherwise
45 or older	25.8% (205n)	1 if aged 45 or older, 0 otherwise
Experience		
Less than 5 years' service	38% (302)	1 if yes, 0 otherwise
Job type		
Pilot	47% (373n)	1 for Pilot, 0 otherwise
Cabin Crew	42.7% (339n)	1 for Cabin Crew, 0 otherwise
Airline Trainer	10.3% (82n)	1 for Airline Trainer, 0 otherwise
Flight routes		
Short Haul	51.2% (407n)	1 for Short Haul only, 0 otherwise
Mixed Haul	26.1% (207n)	1 for Mixed Haul only, 0 otherwise
Long Haul	22.7% (180n)	1 for Long Haul only, 0 otherwise
FTL Knowledge		
Poor FTL Knowledge	16.5% (131n)	1 for Poor FTL knowledge, 0 otherwise
Average FTL Knowledge	56.2% (446n)	1 for Average FTL Knowledge, 0 otherwise
Above Average FTL Knowledge	27.3% (217n)	1 for Above Average FTL Knowledge, 0 otherwise
FTL Crew Responsibly		
Poor	11.1% (88n)	1 for Poor FTL Crew Responsibly, 0 otherwise
Average	56.5% (449n)	1 for Average FTL Crew Responsibly, 0 otherwise
Above Average	32.4% (257n)	1 for Above Average FTL Crew Responsibly, 0 otherwise
Flight Risk Management Familiarity		
Familiar with FRM	63.1% (501n)	1 for Familiar with FRM, 0 otherwise
Awareness		
Aware of Flight Duty	63.4% (503n)	1 for Aware of Flight Duty, 0 otherwise
Aware of Rest Period	60.6% (481n)	1 for Aware of the Rest Period, 0 otherwise
5-item (Fatigue Knowledge)		
Mean (SD)	3.33 (0.77)	Average score over five items
6-item Just/Safety Culture Scale		
Mean (SD)	3.46 (0.82)	Average score over six items
Fatigue		
Comfortable reporting fatigue	53.5% (425n)	1 for Agreement, 0 otherwise
Fatigue Support Available	33.2% (264n)	1 for Agreement, 0 otherwise
Received Fatigue management training	31.9% (253n)	1 for Agreement, 0 otherwise
Dependent Variables		
Reported fatigue	26.8% (213n)	1 for Agreement, 0 otherwise
Operated fatigued	81.7% (649n)	1 for Agreement, 0 otherwise

N = 749.

Multicollinearity checks were undertaken with no issues found, as evident by a maximum variance inflation factor (VIF) value of 2.79 and a mean VIF of 1.66. Additionally, to correct for any concerns regarding heteroskedasticity the three probit regressions use robust standard errors.

4. Findings and discussion

4.1. Flight time limitations

The results from Table 2 highlight that 16.5% of the sample self-reported (i.e. perceived) their knowledge of the FTL scheme as poor. However, a relatively large portion of the sample were aware of changes made to FDP (63.4%), as well as being aware of the rest period (60.6%). As is also highlighted in Table 2, 36.9% of the sample indicated they had limited familiarity with Flight Risk Management.

This 5-item scale (Knowledge of FTL – see Table 3) was used to measure perception of crew members of the impact of changes made to FTLs Subpart, which came into effect in February 2016, on safety, duties, alertness, sleep cycle and fatigue levels. Overall, the perceptions of the respondents to these five questions were clustered towards the neutral and positive points on the Likert scales (see Table 3). These results suggest that depending on the item positive perceptions of these regulation changes ranged between 35.7% and 51.7%. Where negative perceptions ranged from 14% to 20.2% depending on the question.

Where dissatisfaction with the changes made to FTLs was found, an open-ended question indicted this was due to respondents perceiving that they had received no notification of changes to FTLs from their operators. A number of comments also mentioned how entangled airline culture was with fatigue risk management and the implementation of the new changes made to FTLs. They mentioned FTLs were used as crewing targets rather than procedures to combat fatigue.

4.2. Safety culture

Safety culture refers to the safety-related norms, values, and practices shared by groups managing risk in an organization (Guldenmund, 2000).

Research has demonstrated that in order for an airline to have an effective safety management system, it should have a strong positive safety culture (CAA, 2015). Overall, perceptions of safety culture amongst cabin crew and pilots operating in Europe were favourable (Table 4). Majority of crew (58.8%) agreed that reports were treated in a just and fair manner, 64.9% agreed that voicing concerns were encouraged, 67.2% agreed they could speak directly to a manger, and 58.7% agreed that those who take risks would be disciplined or corrected. Overall, this indicates that participants perceive their airlines safety system to be positive and carry "Just Culture" principles. However, on two of the statements, there was a dissatisfaction of higher then 20%. 34% did not feel feedback on safety issues was given within a

Table 3
Perception of changes to the regulation (new FTLs).

	Strongly Negative	Negative	Neutral	Positive	Strongly Positive
Overall Safety	2.1%	14.2%	44.8%	33.1%	5.7%
Ability to operate duties	2.6%	17.6%	44%	32.6%	3.1%
Overall alertness	2.5%	15.7%	39.8%	36.5%	5.4%
Adaption to sleep cycle	2.3%	11.7%	36.5%	36.5%	13%
Overall fatigue	0.9%	13.2%	34.3%	38.3%	13.4%

N = 794.

Table 4
Safety/just culture scale.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Crew who report safety related occurrences are treated in a just and fair manner	3.7%	16%	21.5%	42.8%	16%
Voicing concerns about safety is encouraged	2.9%	13.7%	18.4%	42.4%	22.5%
Timely feedback on the safety issues raised	9.3%	24.7%	25.1%	31.7%	9.2%
Satisfied with the level of confidentiality related to reporting and subsequent investigation.	6.3%	20.9%	25.4%	32.4%	15%
Prepared to speak with direct manager regarding unsafe situations.	4.4%	14.1%	14.4%	43.6%	23.6%
Staff members who regularly take unacceptable risks are disciplined or corrected.	3.4%	16.5%	21.4%	40.1%	18.6%

N = 794.

reasonable timeframe, and 27.2% were not satisfied with the levels of confidentiality of reporting. These results are in line with previous research exploring the perceptions of 7,239 pilots in Europe surrounding safety culture (Reader et al., 2016). Previous research has also highlighted the correlation between an airline safety culture and willingness of those who operate in the organization to openly report any safety concerns to their airline (Reason, 1998). Therefore, the majority of participants rating their safety culture as positive should therefore relate with willingness to report.

4.3. Fatigue scale

Fatigue study results indicated that overall there was a negative perception toward fatigue. A total of 81.7% of the sample has operated while feeling fatigued, and only 26.8% of the participants felt comfortable with reporting fatigue to their airline. The most common reason reported was fear of suspension and the lack of understanding about how to report fatigue. Moreover 66.8% of respondents suggested that no fatigue support was in place.

The research results also back previous research by the London School of Economics (LSE), which carried out research on safety culture of airlines and results indicated that 51% of pilots surveyed reported that fatigue was not taken seriously by their airlines (Reader et al., 2016). Therefore, the perception surrounding reporting fatigue in European crewmembers needs to be addressed and further research would benefit from exploring the causes of this lack of willingness to report. As previously stated some have displayed their levels of dissatisfaction with the confidently of the reporting system and this may need to be carefully examined. Further research would also benefit from exploring and comparing other safety critical occupations, which have similar fatigue reporting systems such as the healthcare profession to see if similar trends emerge (Helmreich, 2000).

To date there is very little empirical research on the rate of fatigue reporting in the industry of aviation (Houston et al., 2012). ICAO have issued guidelines for regulators and commercial operators on the implementation of FRMS which highlights the importance of a reporting system, which is, embedded in the airlines Safety Management System (SMS).

Table 5
Participants' comments related to fatigue reporting.

Role	Responses
Cabin Crew	Ringing in sick is nearly forbidden, it's like committing a deadly sin so ringing in fatigued would not be taken very well.
Cabin Crew	When reporting fatigue there is an immediate suspension followed by an investigation. Colleagues have refused to operate due to fatigue in past and were disciplined severely.
Cabin Crew	I wouldn't know how to even report fatigue; There is no reporting system.
Cabin Crew	Operator tried to put my fatigue down to social effects not operational and put it on my record as sick leave.
Cabin Crew	When fatigued, I was given an off day, with no questions asked.
First Officer	There is no fatigue reporting facility, if you speak to management they are reluctant to accept what you are saying and push back the solution to the individual.
Frist Officer	My operator is currently changing rosters due to fatigue reports, so I do feel they are taking fatigue reports seriously and quickly.
Captain	Colleagues whom I have known have reported feeling fatigued have become completely victimized. It becomes more about challenging the colleagues rather than supporting them. There entire life is pulled apart and every single aspect of what they do in their personal time and when away from work is scrutinized. It's very much guilty until proven innocent.
Captain	I was told by the company doctor that according to EASA, fatigue can only exist for 48 h, after 48 h (or two nights sleep at home), so I should not feel fatigued.

Results from this study indicate that 26.8% of participants felt they could not report fatigue. Participants were given an opportunity to explain the reasons behind their answers, and the main themes, which emerged, were fear, uncertainty and an invasive reporting process (Table 5). This figure is in keeping with previous fatigue research by the Ghent University, which found from a total of 7000 pilots, 48% felt they could not fill a fatigue report.

The overall majority of 73.2% said they have not reported fatigue to their airline. This may have been for a variety of reasons including fatigue not been an issue in some operations. Of those participants who had reported fatigue (i.e. 26.8%), the opportunity was given to give feedback on the process. Most of those who reported fatigue said that they faced an unfriendly invasive investigation process, or a reluctance of management to acknowledge the fatigue report. We partly believe that those who took the time to explain their negative perception may have needed to vent frustrations, and therefore may not represent the entire populations' perceptions. The company culture was noted in a number of responses and this is in keeping with previous research which demonstrates how entangled an organizational and safety culture is with the wiliness of crew to report (Cooke et al., 2007).

This research demonstrated that 81.7% admitted operating while fatigued – which is an extremely high rate. Crew perceived the changes made to FTLs to act negatively towards safety, alertness and overall fatigue. The main aim of the change made to FTL regulation was to combat fatigue risk in the operation of aviation by advances to the limitations in which crew operate to reflect the advances in sciences surrounding sleep, rest, workload and advancement in the understanding of the detrimental effects fatigue can have on performance and cognitive ability. Overall, this sample of crew operating in Europe do not feel this has been achieved.

This research found that 68.1% of the sample, had either not completed fatigue training or do not remember if they did. The regulation mentions that fatigue training is now a mandatory obligation for operators who need to train all crew on causes of fatigue, countermeasures and how to report fatigue as a safety issue. On the one hand, the regulation stipulates what needs to be covered in the fatigue training, but on the other hand it does not highlight the retention rate of the training. This response rate may also reflect the lack of interest some crew may have for the topic of fatigue, therefore, may not represent the overall population. Open-ended comment on feedback of training received did highlight on several occasions fatigue training been carried out through eLearning, and been a tick box exercise, this may have been caused by participants who do not remember completing the training.

In order to explore the extent to which has operated fatigued or have reported feeling fatigued were interconnected with fatigue_support, and fatigue training four chi-squared ($\chi 2$) tests of association were performed. The tests suggested no significant association between reporting fatigued and fatigue_support or fatigue training. But the tests indicated a significant association between having operated fatigued and indicating that fatigue_support was available ($\chi^2 = 72.893$, df = 1, $p < 0.001$) with 63.4% (n = 92) of respondents who had operated fatigued also indicating they had fatigue_support. Having operated fatigued was also significantly associated with having not received fatigue training ($\chi 2 = 6.774$, df = 1, $p = 0.009$) – i.e. of the 145 who operated fatigued 77.2% (n = 112) suggested they had no fatigue training.

4.4. Regression analyses

The results in Tables 6 and 7 explore the relationship between socio-demographics, position, flight type, FTL knowledge and perceptions, and airline safety culture, and the two dependent variables: reporting fatigued, and having operated fatigued. Note, that the marginal effect values reported from the two probit regression models are calculated having controlled for all other explanatory variables assessed at their mean values. Table 6 reports the probit model with marginal effects for reporting fatigued. Two factors were found to be significant and negative: having less than 5 years' experience in the industry and positive perception of FTL 5 item (Fatigue Knowledge).

The significant marginal effect values revealed that the probability a respondent has reported feeling fatigued at work decreases by 10.1 percentage points (pp) for each point increased on "FTL 5 item (Fatigue Knowledge)", with all other explanatory variables equal to their means, as stated above. Reporting fatigue also decreased by 9.5 pp if the respondents had less than 5 years' experience. Of note, being an airline trainer also had a significant negative relationship with reporting fatigue (−9.1 pp), but this was only significant at $p = 0.089$.

Table 6 also shows that additional three factors had a significant but positive relationship with the dependent (reporting fatigue): being 45 or over, having poor knowledge of the FTL Scheme, and being comfortable with reporting fatigue. These marginal effect values revealed that the probability a respondent reports fatigue is increased by 12.1 pp if they are 45 or over, by 11.7 pp with poor knowledge of FTL Scheme, and by 31.8 pp if they stated they were comfortable with reporting fatigue.

Similarly to Table 6, Table 7 reports the probit model with marginal effects for a respondent having operated fatigued. Our results identify four significant factors: the airline Just/Safety Culture (6-item), issues surrounding fatigue being taken seriously, and positive perception of FTL 5 item (Fatigue Knowledge), and being familiar with airlines fatigue risk management –all found to have a significant negative relationship with having operated fatigued.

The marginal effect estimations showed the probability a respondent declared they had operated fatigued fell by 9.3 pp if issues surrounding fatigue were taken seriously in their airline, by 8.6 pp for each point increased on the 6-item Just/Safety Culture, by 7.3 pp if the respondent was familiar with Airlines Fatigue Risk Management, and by 4.7 pp for each point increased on "FTL 5 item (Fatigue Knowledge)". Reminder, all other explanatory variables are equal to their means, as stated above.

Also, being an airline trainer had a slightly significant and negative relationship a respondent having declared that they had operated fatigued (−7.6 pp), but this was only significant at $p = 0.069$.

5. Conclusion and policy recommendations

Fatigue is a clear and present concern for European crew. As a means to combat fatigue in the industry, a number of preventative strategies have been put forward, one of which is the prescribed approach by limiting the hours and rest periods in which crew can operate. There have been a number of criticisms, citing differing interpretations and lack of guidance on correct implementation (ECA, 2017). This has also been confirmed by the study results.

This paper aimed to explore the perceived impact of the changes made to FTLs on overall safety, alertness and fatigue by exploring the perceptions of cabin crew and pilots. The results indicated a neutral/none and negative perception for all three variables. This highlights the concerns that those who operate under the regulation have, towards their effectiveness. These negative perceptions may be indicative of the mixed interpretation, which airlines have towards using FTLs, and may not be reflective of the overall regulation. However, some could conclude that these results may display overall levels of dissatisfaction with the regulatory changes surrounding FTLs. As previously stated

Table 6
Report fatigue – probit regression.

	Probit regression			Marginal effects		
	Coef.	Robust Std. Err.	P	dy/dx	dy/dx 95% Conf. Interval	
Female	−0.005	0.150	0.973	−0.002	−0.088	0.085
Age 35–44	0.096	0.138	0.485	0.028	−0.052	0.108
Age 45 or over	0.409**	0.151	0.007	0.121**	0.032	0.210
Less than 5 years' experience in industry	−0.323*	0.131	0.014	−0.095*	−0.171	−0.020
Cabin Crew	−0.165	0.149	0.269	−0.049	−0.135	0.038
Trainer	−0.309	0.181	0.089	−0.091	−0.197	0.014
Short Haul	−0.047	0.137	0.730	−0.014	−0.093	0.065
Mixed Haul	−0.249	0.158	0.116	−0.074	−0.165	0.018
FTL Scheme (Own Knowledge – Poor)	0.397*	0.159	0.013	0.117*	0.026	0.209
FTL Crew Responsibilities (Own Knowledge – Poor)	−0.042	0.209	0.840	−0.013	−0.134	0.109
Familiar with Airlines Fatigue Risk Management	0.205	0.129	0.112	0.061	−0.014	0.135
Aware of changes to Flight Duty Period (FTL)	0.231	0.183	0.206	0.068	−0.038	0.174
Aware of changes to rest periods (FTL)	−0.164	0.183	0.369	−0.048	−0.154	0.057
FTL 5 item (Fatigue Knowledge)	−0.342***	0.080	0.001	−0.101***	−0.147	−0.055
Just/Safety Culture (6-item)	−0.017	0.084	0.840	−0.005	−0.054	0.043
Comfortable with reporting fatigue	1.075***	0.128	0.001	0.318***	0.245	0.391
Agrees issues of fatigue are taken seriously	−0.113	0.136	0.404	−0.033	−0.112	0.045
Constant	−0.395	0.348	0.255			
Chi-squared (df = 18)	$\chi^2 = 157.33$***					
Log Likelihood	−375.15693					
Correctly classified	77.2%					
N	794					

Note: *$p \le 0.05$, **$p \le 0.01$, ***$p \le 0.001$.

Table 7
Operated fatigued – probit regression.

	Probit regression			Marginal effects		
	Coef.	Robust Std. Err.	P	dy/dx	dy/dx 95% Conf. Interval	
Female	0.180	0.157	0.251	0.039	−0.028	0.106
Age 35–44	0.189	0.159	0.235	0.041	−0.026	0.109
Age 45 or over	0.198	0.167	0.236	0.043	−0.028	0.114
Less than 5 years' experience in industry	−0.191	0.141	0.174	−0.042	−0.102	0.019
Cabin Crew	−0.107	0.149	0.471	−0.023	−0.087	0.040
Trainer	−0.349	0.192	0.069	−0.076	−0.158	0.006
Short Haul	0.203	0.151	0.177	0.044	−0.020	0.109
Mixed Haul	−0.063	0.164	0.702	−0.014	−0.084	0.056
FTL Scheme (Own Knowledge – Poor)	−0.098	0.180	0.585	−0.021	−0.098	0.055
FTL Crew Responsibilities (Own Knowledge – Poor)	0.254	0.231	0.272	0.055	−0.043	0.154
Familiar with Airlines Fatigue Risk Management	−0.337*	0.137	0.014	−0.073*	−0.132	−0.015
Aware of changes to Flight Duty Period (FTL)	0.024	0.199	0.904	0.005	−0.080	0.090
Aware of changes to rest periods (FTL)	0.320	0.197	0.104	0.070	−0.014	0.154
FTL 5 item (Fatigue Knowledge)	−0.216*	0.087	0.014	−0.047*	−0.084	−0.010
Just/Safety Culture (6-item)	−0.396***	0.095	0.001	−0.086***	−0.126	−0.046
Comfortable with reporting fatigue	−0.177	0.136	0.194	−0.038	−0.096	0.019
Agrees issues of fatigue are taken seriously	−0.429***	0.133	0.001	−0.093***	−0.150	−0.037
Constant	3.180	0.392	0.001			
Chi-squared (df = 18)	$\chi^2 = 116.67$***					
Log Likelihood	−309.37893					
Correctly classified	82.49%					
N	794					

Note: *p ≤ 0.05, **p ≤ 0.01, ***p ≤ 0.001.

regulatory changes aimed to embrace scientific literature surrounding the physiological and psychological effects fatigue has on performance and therefore safety.

As part of changes made to FTL regulations, an emphasis was put upon managing fatigue as a safety risk. The regulations stipulate that fatigue risk must be proactively managed and monitored through an airline's SMS. The effectiveness of an SMS is based upon two key principles – just culture and a positive safety culture. Crew must operate in an atmosphere were safety related reporting is welcomed and not treated in a punitive way. This is achieved through a culture, which is open and welcoming.

Although the majority had average knowledge of their responsibilities, a significant proportion showed unawareness around their personal obligation towards the regulation. This may need more exploration and a possible solution may be focusing attention of joint responsibilities of both employer and employee in the mitigation of fatigue through initial and recurrent training. The majority of airlines have safety intranet pages, and this could be a potential safety topic of the month for airlines to ensure understanding.

Our probit regressions suggested a positive perception of FTLs changes (5-item) has a significant and positive effect in reducing the number of respondents who reported feeling fatigued at work, as well as the number who operated fatigued. However, Table 3 showed that while many respondents were not negative about the FTL changes a sizable percentage were neutral. In order to maximise the effectives of these FTL changes, there is a need to further improve perceptions. For example, only 38.8% of the participants deemed that the FTLs changes had a positive effect on overall safety. Moreover, only 51.7% suggested it was effect in combating fatigue, and 49.5% believed the changes to the regulations had a positive effect on the adaption to sleep cycles. As previously stated, advances in sciences show the negative effects of sleep disruption and the importance of regulating sleep patterns in order to have full cognitive ability, which for the occupation of aviation as a safety critical business is a necessity. Future research would benefit from exploring the sleep patterns of crew who work in aviation and observe any possible effects this may have on individuals and possible effects to safety.

This study indicated that crew had an overall positive perception of their safety culture, indicating the majority felt reports were dealt with fairly, voicing concerns were welcomed and the feeling of comfort to speak directly to a manager relating to safety concerns. This study also found that a Just/Safety Culture (6-item) has a highly significant and negative effect on operating fatigued. Suggesting, for each point increased on the 6-item Just/Safety Culture respondents are 8.6 percentage points less likely to operate fatigued (calculated with all other variables set to their means). Future research would benefit from exploring individual airline practices in order to observe differing interpretations and their effect on safety e.g., one airline may use the FTLs as targets, whereas another airline may use FTL maximums as danger points.

The investigation process relating to safety reports is a lengthy process. In order to encourage crew to submit safety reports either voluntary or mandatory, timely feedback is of high importance in order to create levels of trust in the system, which in turn encourages crew to submit reports relating to safety concerns. A sound safety system relies heavily on volumes of reports in order to trend data, which may highlight safety practices, which may need to be altered.

If an airlines organisational culture is perceived as threatening or unwelcoming, the possibility of crew reporting fatigue is significantly limited. Probit analysis suggested that the reporting of fatigue could be raised by 31.8 percentage points where crew are comfortable with the reporting culture associated with fatigue for their airline. However, many participants in this study noted they had not reported fatigue to their airline (73.2%). Regulatory boards through auditing of airline practices may need to focus their attention not only on paper trails to demonstrate a safe operation, but also to look to the culture and perception of those who work for these airlines. A positive reporting system needs a steady flow of reports in order to trend data, therefore a clear indictor of a fatigue management reporting system not operating effectively would be the lack of reports. Further research needs to explore the reasons for the lack of reporting, and the overall understanding of crew surrounding fatigue and its effects.

Research has indicated that teaching awareness of fatigue, its symptoms, effects and countermeasure; helps combat its long-term effects on an operation. Fatigue training is now a mandatory requirement for all personnel who encounter an airline's operation. However, the regulation does not stipulate the areas, which need to be covered in the training, they do not ask for a retention rate to be acknowledged. Regulators should provide guidelines about the coverage of material and the monitoring of the training. A data driven approach to managing fatigue is a necessity for the industry, were everyone is educated about sleep, fatigue and its effects.

In a nutshell, the changes in the regulation failed to reach their aim, which was to improve safety levels in flight operations. Pilots and cabin crew are the only ones that can evaluate their levels of fatigue and the results of this survey proved that the policy reform was not effective. Moreover, the findings of the study, are in line with the theoretical framework arguing that fatigue has negative safety implications. The theoretical framework of this paper elaborated in section 2.1, brought forward the specific parameters that impact flight crew's fatigue levels and how a regulatory framework is designed comparing its parameters with the literature review. This study is relevant in the post-COVID 19 aviation environment where the traffic volume is expected to recover, whereas fatigue reporting and safety culture remain important issues and are not linked to traffic volume. Finally, this study expanded the theoretical framework by highlighting the importance of just culture and fatigue training for safety.

CRediT authorship contribution statement

Marina Efthymiou: Supervision, Conceptualization, Writing - original draft, Writing - review & editing, Validation. **Sinead Whiston:** Conceptualization, Writing - original draft, Investigation. **John F. O'Connell:** Writing - review & editing, Validation. **Gavin D. Brown:** Formal analysis, Methodology.

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