https://doi.org/10.26552/ pas.Z.2021.2.22

ASPECTS OF AIRLINE CREW ROSTERING

PREVÁDZKOVÉ ASPEKTY PLÁNOVANIA POSÁDOK

Manh Le Duc
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina
Le_duc@stud.uniza.sk

Benedikt Badánik
Air Transport Department
University of Žilina
Univerzitná 8215/1
010 26 Žilina
Benedikt.badanik@fpedas.uniza.sk

Abstract

Airline crew rostering is a complicated planning-type problem, and its objective is to assemble pairings into schedules that maximise the satisfaction levels of crews. The rostering process focuses on achieving a more balanced workload distribution among the crewmembers that allows designing rosters in the interest of the crew. The main purpose of the paper was to explain the fundamental aspects of airline crew rostering and its impact on crewmembers' fatigue. Additionally, the research identified mitigation measures that airlines should make to combat or mitigate crewmembers' fatigue when designing their rosters. The paper also allowed readers to understand the effects of fatigue on crew's alertness and performance. The qualitative research methods (such as literature review) was used to understand the complexity of the airline crew rostering, the flight and duty time limitations, crew's rest requirement and crewmembers' fatigue. The survey was used as the quantitative research method to identify crewmembers' satisfaction with their rosters that would help to optimise the rostering process. An online survey (using Google Forms) was distributed to potential respondents (experienced crewmembers) via email addresses and online platforms. Respondents were asked 18 close-ended questions divided into two parts (demographic and operational experience). One hundred eleven responses were gathered, which showed that age plays a crucial role in crewmembers' fatigue. In addition, cargo pilots are usually more dissatisfied with their rosters due to exhausting flight duty periods at nights.

Keywords

Airline crew rostering. Flight time and duty time limitations. Rest requirements. Crew's fatigue.

1. Introduction

One of the most crucial and challenging operational processes in the airlines' industry is scheduling process. An airline's schedule is considered an essential indicator of its business strategy. Crew related costs represent a major operating airline's expense. Therefore, the effective utilisation of crews is substantial. The importance of understanding airlines crew scheduling and creating effective and optimised rosters for crewmembers is essential, due to its impact on airlines' financial performance. Even a little improvement of crew scheduling can save a lot of money for airline. Poor quality of crew planning (e.g. lack of crewmembers) can lead to a downfall. For example, scheduled flights might get cancelled/delayed or crewmembers may report sick. Generally, airlines use standby crews to solve these disruptions.

Crew scheduling is a complicated and challenging task, which is constantly influenced by predictable and unpredictable occurrences, such as staffing shortage or weather conditions. I have decided to address this topic because it has major influence on airline safety. In addition, addressing this topic helps to better understand flight time limitations and aspects that must be considered when designing rosters for crewmembers, particularly awareness of fatigue. Good crew planning and scheduling are considered the main aspects that make an airline's operations successful. However, crew planning and scheduling must follow many rules and regulations laid down by aviation legislation. Limitations are defined by rules and regulations that airlines must not violate to provide safe operations. Crew fatigue is a hazard that should be avoided as much as possible because it might cause potentially dangerous situations during operations. Fatigue affects all aspects of human functioning. Sleep loss and circadian body clock disruptions lead to degraded alertness and performance of crewmember.

Typically, airlines scheduling is divided into two stages: crew pairing and crew rostering. The objective of the first stage – crew pairing is supposed to cover the monthly plan with the smallest crew resources possible. Crew rostering is the next stage of the scheduling that aims to assign pairing and required training to actual crewmember considering their qualifications, personal requests, holidays, and others (as discussed in chapter Chyba! N enašiel sa žiaden zdroj odkazov.).

The main objective of this paper is to analyse major aspects of the airline's crew rostering process that ensure the airline's safe operations and suggest new approach to crew rostering that could help avoid any rostering complications. In addition, the paper defines the regulator's rules and restrictions that define flight time limitations of crewmembers (chapter Chyba! N enašiel sa žiaden zdroj odkazov.). An important part of the paper is survey research (chapter Chyba! Nenašiel sa žiaden zdroj odkazov.) that helps to understand the importance of crew's satisfaction in terms of roster. Key findings are summarised, and a new approach is suggested.

2. The Crew Scheduling Problem

According to Devici and Demirel an airline crew scheduling can be defined as "the assignment of flight and cabin crews to scheduled flights, so as to ensure that the crew needed for all flights are covered" [1]. In other words, it can be understood as the problem of determining cost-minimizing assignments for both flight and cabin crew to a set of tasks and to each flight leg in the airline's schedule. A crew schedule is specified by the sequence of flight legs and other activities (e.g. vacation leave, training, and others) to be accomplished by a crewmember over a period of time. All regulations and rules must be applied in order to construct crew schedules. [2] [1]

Airline crew scheduling problem is very complex and difficult problem. Therefore, it is generally divided into two subproblems: crew pairing problem and crew rostering (assignment) problem. For a large airline, the integrated problem is too large to be solved simultaneously. These two subproblems are planning-type problems. Authors Deveci and Demirel are explaining that crew scheduling problem is broken down into these subproblems, due to their different objectives and difficulty to calculate crew rostering prior to generating crew pairings. Finally, the rules that cockpit and cabin crews are obligated to follow, are specified under two different headings: pairing and rostering. [3]

Firstly, the crew pairing problem must be solved, which results in generating mini schedules, called pairings, typically spanning 1-5 days. The objective of the crew pairing problem is to minimize the crew costs associated with covering all flight legs in the flight schedule [2]. After the crew pairing problem, the crew rostering problem is solved in which pairings are assembled into longer crew schedules in the form of either rosters or bidlines, typically spanning approximately 30 days [1]. In the other words, the objective of crew rostering problem is typically to assemble pairing into schedules that maximize the satisfaction levels of crews. Each subproblem will be furthermore described in the following subchapters. This paper is mainly focused on the airline crew rostering problem.

2.1. Crew Pairing Problem

According to author Barnhart "the crew pairing is composed of a sequence of flight legs, with the flight legs comprising a set of daily work activities, called duty periods or duties, separated by overnight rest periods" [2]. Besides that, the first and last legs of the pairing must begin and end at the same crew base. Crew paring is the vital phase of the crew scheduling, because during this process airline is minimizing the operational crew costs while maximizing the efficient use of the crew. The crew costs represent is the second largest operating costs that airlines must cover. Moreover, airline must consider rules and meet restrictions set by regulatory agencies, e.g. Federal Aviation Administration (FAA) in U.S. or European Union Aviation Safety Agency (EASA) in Europe. The main purpose of crew pairing optimization is to determine the most cost-effective crew pairing consisting of all the flights in the flight schedule.

Crew Rostering (Assignment) Problem

The second subproblem an airline must solve is the crew rostering problem, also called crew assignment problem. This phase is important as much as the crew pairing process and it is solved after the crew pairing problem. Authors Kohl and Karish state that the main objective is "to assign anonymous crew pairing either to personalized rosters or to anonymous bidlines which subsequently will be assigned to individual crewmembers" [4]. Authors Kohl and Karish provided a detailed description of the essential aspect of the airline crew rostering problem and elaborate on the main elements. A graphical representation of the crew rostering problem is shown in Figure. When solving crew rostering problem, the input generally consists of crew information, activities to be rostered, rules and regulations, and the objectives for creating the rosters. When designing personalized rosters, crewmember's information about his/her personal records, qualifications, pre-assigned activities, and vacation days are provided. Crewmember's qualifications are understood as information about the crewmember's allowed equipment that he/she can operate or list of destinations he/she cannot fly to. When flying internationally, language proficiency can be a factor that decides the cabin crews' destination. Inputs of pre-assigned activities are ground duties (e.g. medical checks), pairings, reserves (e.g. standby duties), and training activities [4]. The rules and regulations are described in detail in the chapter **Chyba! Nenašiel sa žiaden zdroj odkazov.**.

An airline's planning/scheduling department should design rosters to meet a fair balance between an effective usage of crewmembers' capacities and the airline's operational needs [5]. In a real-life operation, the poor quality of roster planning (including unforeseen circumstances or operational delays) can lead to sleep and health disorders caused by crew's fatigue.

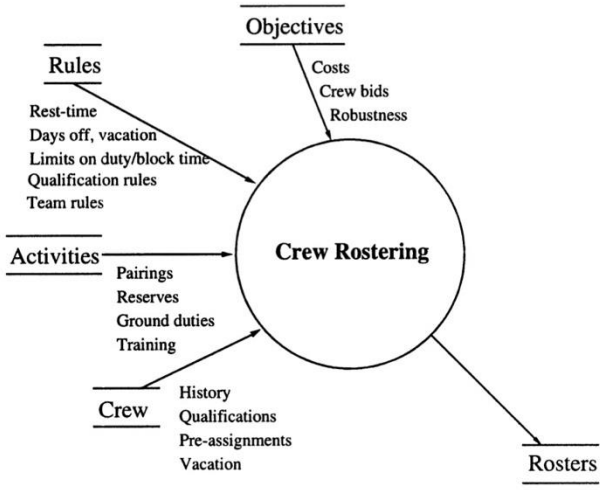

Figure 1: Graphical representation of the airline crew rostering problem Source: N. Kohl and S. E. Karisch, "Airline Crew Rostering: Problem Types, Modelling, and Optimization", 2004.

The crew rostering problem can be solved in different ways and usually one of the following approaches is used:

A) Bidlines approach are typically used in North America (especially in the U.S.), where the rostering problem is solved in two steps. During the first step, the anonymous set of schedules are created such that each pairing is included in exactly as many schedules as are needed to fully staff the flight. In the second step, these created schedules are assigned to individual crewmembers based on the bidlines approach. This approach allows crewmembers to bid on their preferred work schedules and based on their

seniority the schedules are then allocated. In other words, bidlines schedules are assigned to a crewmember through a bidding and allocation process based on seniority.

B) Personalized rostering (i.e. preferential bidding) is an approach, where individual rosters are created directly for each crewmember. The outcome are individualized schedules, called rosters. This approach takes into consideration the needs (e.g. trainings), requests and preferences (such as holidays or day off, or even desired destinations of assigned flight legs) of each crewmember, in order to satisfy certain quality criteria. Then they are directly assigned to the pairings equally between all flights. This approach is used by many European airlines with small differences. Crewmembers' preferences are considered during the creation of the individual roster. Their preferences can be awarded according to crew seniority (e.g. a crewmember who has worked the longest for the airline is the most senior crewmember and therefore a maximum of his/her preferences get granted compared to less senior crewmembers) or based on fair share basis. [6] [4] [3] [2]

From the crews' point of view, the most beneficial approach for them is the bidlines approach. This process allows a crewmember to bid for a specific line, therefore he/she can expect what the schedule will look like if the bit is granted. Within the personalized rostering a crew can only express preferences for specific attributes of their rosters, but not knowing how exactly the roster will look like. The M2P Crew Study 2018 has proven that bidding and duty plan stability are most important for airline crewmembers [7]. Nowadays preferential bidding systems give an immediate feedback for a crewmember during a bidding phase and characterize important aspects of the expected rosters. According to authors Kohl and Karisch "drawbacks of bidlines are greater costs that occur when the bidlines cannot be assigned entirely to individuals due to conflicts with pre-assignments and vacations days, and some pairings of the bidline can hence not be assigned" [4].

All mentioned rostering approaches are very similar, if they are considered from a solution point of view. However, from a modelling point of view, the approaches differ mainly in the formulation of the objective function. The main objective is to minimize crew costs, but also taking into consideration quality of life criteria for the crew. Airlines usually apply various rostering principles differently, which are also combined and extended. Rostering systems that support modelling of the different rostering environments and bring proper optimization to solve the resulting problems must be universal and flexible. [4]

3. Flight and Duty Time Limitations and Rest Requirements

Flight and duty time limitations (FTL) are rules and restrictions necessary to ensure that crewmembers do not endanger the safety of the flights. FTL aims to ensure control of fatigue and standardisation in the regulations. An airline is prohibited from scheduling a crewmember to work over these limits. In addition, the objectives of FTL are to ensure adequate rest periods for crewmembers but also to roster the duration and timing of individual duty periods that will enable them to operate to a satisfactory level of efficiency and safety in all situations. Limitations included in this chapter are concerned with the prevention of fatigue and the maintenance of alertness of crewmembers during flight time and duty period. Flight and duty time limitations and rest requirements must be adhered to, but operators generally consider them by as a target to maximise duty times and minimise rest times [5]. The FTL should be considered as a recommendation for guiding air carriers on the utilisation of their personnel.

4. Crew Fatigue

Crew fatigue is acknowledged as a hazard that predictably degrades various types of human performance and cause accidents and incidents in the aviation industry [8]. Even a light fatigue might be an important contributor to a large number of aviation accidents, however it is difficult to identify whether or not fatigue is the cause of the associated accident [9]. The 24/7 nature of aviation business requires high level of alertness from its operatives. Furthermore, the fatigue will always be inevitable part of high-risk industries because the human brain and body function optimally with unrestricted sleep at night. Even though the crew fatigue cannot be eliminated, it must be managed. In order to manage the risk, the ICAO has set an international standard for FRM that requires the National regulator (Aviation Authority) to set in place either an FRM System (FRMS) or develop prescriptive measures for allowed duty periods for crewmembers based on sound scientific principles [10].

Caldwell states that more than 70% of aviation accidents are caused by human factors, in addition the crew fatigue is recognized as one of the key determinants for managing and improving flight safety [11]. Scheduling factors, sleep deprivation, circadian disruptions, and extended duty periods continue to affect flight safety, crew's alertness and performance levels on both short-haul and long-haul flights. Therefore, the solutions for these problems are not straightforward, but they can be developed through the cooperative efforts of scientists, regulators, managers, and the pilots themselves. Although there have been regulatory efforts for imitating max. flight hours and the min. crew rest periods from regulatory institutions and organisations (such as ICAO or EASA), there has remained much to be done about this insidious threat to air safety. Due to long duty periods, unpredictable work hours, circadian disruptions, and insufficient sleep; the pilot fatigue is a significant problem in both civilian and military flight operations [11]. This chapter is focused on understanding the general knowledge about fatigue, what makes crewmembers fatigue, factors affecting crew's fatigue, and

explaining the fatigue management approaches in aviation.

5. Methodology

This paper explains the main aspects of airline crew rostering and their impact on everyday business of airlines. The main research question is: What is the impact of airline crew rostering on crewmembers' fatigue? In addition, the paper answers secondary research question: What mitigation actions should airlines make to combat or mitigate crew's fatigue but still follow regulations, when they design crew rosters? This paper allows readers to understand the effects of fatigue on crew's alertness and performance.

We have conducted an online survey with a view to find answers to both our research questions (indicated earlier in this section).

The survey uses both types of methods (qualitative and quantitative) that help to describe compare, evaluate and understand different aspects of the research problem. Comprehensive information about airline crew rostering problem was obtained from authors, such as Barnahrt et al.; Brezoňaková; Novák et al.; or Kohl and Karisch. For summarizing and explaining crewmembers' flight and duty time limitations and rest requirements (Chapter Chyba! Nenašiel sa žiaden zdroj o dkazov.), the EASA FTL 2016 was used as the primary source. The regulation can be found on the official website of the EASA. In addition, extensive source of information about fatigue in aviation was provided in articles from authors: Caldwell; or Bendak and Rashid. These articles were published on websites containing an extensive database of scientific research, such as ScienceDirect or ResearchGate. Moreover, to define measures for combating or mitigating the crewmembers' fatigue, the Fatigue Management Guide for Airline Operators was applied. ICAO, IATA and IFALPA provided the guide on the ICAO's official website.

With the quantitative research method, a survey (Chyba! N enašiel sa žiaden zdroj odkazov.) was used to collect data from crewmembers by asking them specific questions about their past/present experiences of sleep, fatigue, factors causing fatigue and their satisfaction with their rosters. Google Forms was chosen as an online tool for constructing the questionnaire. The survey contains closed-ended questions with binary answers, scales, and lists of options with single/multiple possible answers. Due to the COVID-19 pandemic, interviews (face to face) could not be realized. Therefore, the questionnaire was distributed to experienced crewmembers only by mail and online platforms, such as social media. An analysis of the survey results is presented in chapter Chyba! Nenašiel sa žiaden zdroj o dkazov..

6. Summary of Key Findings

Based on the conducted data of survey from 111 respondents, the demographic characteristics of respondents is summarised in **Chyba! Nenašiel sa žiaden zdroj odkazov.** that shows the d ominating category in each question. The analysis has shown that younger (18 – 39 years) and less experienced (commercially flying 1 – 5 years) crewmembers are able to combat and mitigate fatigue better than older (40+ years) and more experienced colleagues. Tiredness was chosen by 82% of respondents as the most common symptom of fatigue. It has been proved that age plays a crucial role in crew's fatigue because older respondents (50 – 59 years) suffer from more frequent signs/symptoms (sleep disorders, erratic behaviour, somnolence, difficulties concentrating and difficulties with memory) when feeling fatigued. According to respondents' self-ratings, night shifts are the most common cause of their fatigue. Responses received from older crewmembers (40+ years) have indicated that they are more susceptible to rostering causes of fatigue, such as working consecutive late finishes, number of flown segments, extended duration of duty period, excessively exhausting roster, or insufficient rest period. It has been discovered that pilots notice (frequently, often, or always) their colleagues being fatigued (especially cargo pilots) compared to flight attendants' responses. Cargo pilots have available rosters more than 14 days before operating the first flight. Providing rosters less than 14 days in advance is typical for business/private companies. Additionally, passenger airlines dominate in providing rosters precisely 14 days before the first operated flight. The majority of cargo pilots believe that the companies they work for provide sufficient rest period during a layover. On the other hand, crewmembers of passenger airlines feel that their rest periods are inadequate, and companies should evaluate external factors.

Generally, crewmembers' roster requests are categorised based on their seniority. However, the analysis of collected data has discovered that younger and less experienced crewmembers do not feel discriminated against in terms of their roster requests. Roughly 56% of all respondents are generally satisfied with their rosters. A significant difference was discovered between cargo pilots and pilots working for passenger airlines. Cargo pilots are generally more dissatisfied with their rosters than passenger pilots. In addition, there is no significant difference when comparing job positions. More than half of the respondents (53%) do not feel discriminated against or disadvantaged in roster requests compared to their colleagues. Respondents who feel disadvantaged are mainly male crewmembers older than 30 years with more experience (5 000 – 10 000 light hours), and they work for passenger airlines.

Almost 55% of all respondents are willing to work shorter duty hours, including pay reduction. Responses of cargo pilots (30+ years old) with more experience who would agree to work shorter hours were expected because they usually must work exhausting night shifts. Respondents who do not agree to work shorter duty hours are characterised as young flight attendants (18 – 19 years old) with 1 – 5 years of work experience. The most common reason to accept shorter working hours would be spending more time with family and friends. Inappropriate airlines crew rostering is a significant factor affecting crewmembers' loyalty toward companies.

7. Recommendations

The following recommendations have been made for the mitigation actions that airlines should take to combat the fatigue of crewmembers. Based on the research, airlines' scheduling departments play an essential role in airline crew rostering. Therefore, an airline's human resources department should be stringent when hiring a candidate for this job position. Besides understanding scheduling processes, following airlines policies, and regulations laid down by aviation authorities, the candidate should meet the following attributes: logical thinking, willingness to self-improvement, excellent communication, analytical and organisational skill, but most important interpersonal skills such as empathy, compassion or being considerate. For that reason, candidates who do not meet these requirements should not be accepted for this position. Airlines' management and scheduling departments should understand that crewmembers are not robots, they have personal life as well.

During a design process of a roster, airlines should consider external factors (e.g. time to get from and to an airport) by adding additional rest time at layovers or home bases, especially in destinations where necessary. Airlines should show an effort to research this kind of destination by using scheduling satisfaction surveys for crewmembers to see their point of views. Last-minute roster changes should be avoided as much as possible to prevent crew's fatigue. If changes should happen, an adequate number of standby crewmembers must be available.

Nevertheless, processes for recovering from disruptions are not well implemented and established for most airlines because many respondents complained about last-minute changes. The impact of external disruptions will be more and more challenging for airlines to deal with. Due to nights shifts, cargo pilots should have an extended rest recovery. For example, an additional local night at the destination because cargo pilots are usually more fatigued, which is hazardous for flight operations. Maybe this suggestion might not be cost-effective, but it will ensure operation safety and prevent potential accidents. Consecutive early morning starts of FDPs can be solved by planning them after the vacation period or on the day that follows the rest day/period.

Older crewmembers with more experience should be allowed to choose whether they would prefer to work shorter hours with pay reduction. This approach would make them satisfied and allow airlines to hire new employees and gradually train them. However, airlines should must ensure a safe, efficient and cost-effective operation. Even though the discrimination of rostering process has not been shown, there is always a potential for improvement in the processes of planning reserve capabilities and implementing innovative bidding systems to further maximise crew satisfaction and productivity.

8. Conclusion

Rostering factors (e.g. timing of flight and duty periods like night shifts, short rest periods, consecutive early morning starts, extended duty periods, consecutive duty days, and others) significantly impact crewmembers' fatigue, representing significant flight operations problems. Rosters affect crew fatigue, which is considered a significant safety issue, leading to increased errors, incidents, and accidents. Lost sleep and disruptions to the circadian body clock due to rostering factors usually lead to degraded alertness and performance. Moreover, crewmembers' mood and communication skills can be affected, and their decision-making or judgment becomes impaired, and reaction time slows down. The fatigue can manifest itself, such as being tired, difficulties in concentrating, sleep disorders, decreased reaction time, irritability, and others. Additionally, the poor rosters can result in crewmembers' health issues, for example depression or their immunity.

Airlines should develop procedures that minimize disruptions of crewmembers' sleep because the key to good quality sleep is uninterrupted non-REM/REM cycles. Protected blocks of time should be included within rest periods (in-flight or on layovers) during which crewmembers are not contacted except in emergencies. Operators should establish procedures to protect crewmember sleep at layovers and appropriate napping facilities, such as quiet hotel room with no interruption.

Interruptions should be minimized during circadian times when sleep is more likely. Before and during FDPs that are unscheduled, the continuous hours of wakefulness should be minimized. A better level of alertness can be maintained if airlines build in some level of schedule predictability.

Provision of a nap during FDP can maintain the crewmembers' performance when extended work periods or during night shifts are applied. Therefore, airlines should educate their crew about mitigating fatigue, the hazard of being fatigued or the benefits of napping. Periodic opportunities for recovery must be included in crewmembers' rosters due to the effects of cumulative sleep restriction. A minimum of two consecutive night of unrestricted sleep is recommended to recover from a sleep debt.

Night shifts should be scheduled to end as early as possible so that crewmembers could get to sleep as soon as possible after a duty. However, the best FDPs for a human body is during a daytime that allow unrestricted sleep at night. Operators should provide breaks during a duty period because they improve crewmembers' performance. Finally, to mitigate fatigue operators must implement FRM practices and fatigue training for all staff directly involved in the flight operations.

Based on the collected data, the paper has shown that age plays a crucial role in crew's fatigue. Older crewmembers suffer more frequent symptoms of fatigue compared to younger crewmembers. Generally, most of the crewmembers are satisfied with their rosters. Cargo pilots are usually more fatigued than passenger pilots due to the FDPs at nights. Therefore, they are more unhappy with their rosters. The research has also shown that older crew members would prefer to work shorter hours in order to have more time with their relatives.

Bibliography

[1] C. Barnhart, A. M. Cohn, E. L. Johnson, D. Klabjan, G. L. Nemhauser a P. H. Vance, „Airline Crew Scheduling," January 2003. [Online]. Available: https://www.researchgate.net/publication/227105914_Airline_Crew_Scheduling. [Cit. February 2021].

[2] P. Belobaba, A. Odoni a C. Barnhart , The Global Airline Industry, Wiley: Chichester, West Sussex, 2009.

[3] M. Deveci a N. Ç. Demirel , „A survey of the literature on airline crew scheduling," 21. June 2018. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0952197618301234?via%3Dihub. [Cit. February 2021].

[4] N. Kohl a S. E. Karisch, „Airline Crew Rostering: Problem Types, Modeling and Optimization," Kluwer Academic Publishers, 2004. [Online]. Available: https://www.inf.utfsm.cl/~mcriff/Tesistas/lista-papers/airline-crew-rostering.pdf. [Cit. February 2021].

[5] A. Brezoňaková, „Realistic scheduling agreement: Defining principles and objectives," 2019. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352146519305976. [Cit. May 2021].

[6] A. Kasirzadeh, M. Saddoune a F.. Soumis, „Airline crew scheduling: models, algorithms, and data sets," 27. February 2015. [Online]. Available:

https://www.researchgate.net/publication/276398916_Airline_crew_scheduling_models_algorithms_and_data_sets. [Cit. February 2021].

[7] Mostert Ploog & Partners, „M2P Study: Trends and Best Practices in Crew Management," 2018. [Online]. Available: https://www.m2p.net/wp-content/uploads/2016/12/190409_Crewstudyresults_DIGITAL_CMYK2.pdf. [Cit. May 2021].

[8] IATA, ICAO and IFALPA, „Fatigue Management Guide for Airline Operators (Second Edition)," 2015. [Online]. Available: https://www.icao.int/safety/fatiguemanagement/FRMS%20Tools/FMG%20for%20Airline%20Operators%202nd%20Ed%20(Final)%20EN.pdf. [Cit. March 2021].

[9] J.-R. Yen, C.-C. Hsu, H. Yang a H. Ho, „An investigation of fatigue issues on different flight operations," 20 February 2009. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0969699709000040. [Cit. March 2021].

[10] ICAO, „Manual for the Oversight of Fatigue Management Appoaches," 2016. [Online]. Available: https://www.icao.int/safety/fatiguemanagement/FRMS%20Tools/Doc%209966.FRMS.2016%20Edition.en.pdf. [Cit. March 2021].

[11] J. A. Caldwell, „Fatigue in aviation," May 2005. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1477893904001012. [Cit. March 2021].