UTJECAJ LJUDSKIH ČIMBENIKA NA SIGURNOST ZRAČNOG PROMETA

Stručni članak

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Sažetak

Ovaj rad istražuje ključni utjecaj ljudskih čimbenika na sigurnost zračnog prometa, uz poseban naglasak na operacije zračnog prometa kao složeni lanac u kojem ljudski čimbenici igraju presudnu ulogu. S obzirom na brz rast i tehnološki napredak u zračnom prometu, operacije postaju sve složenije, što dovodi do povećanog opterećenja na posadu i ostalo osoblje. Ovaj kompleksni lanac uključuje različite faze, uključujući planiranje leta, izvršenje leta, kontrolu leta i operacije na zemlji, gdje ljudski čimbenici igraju ključnu ulogu u svakom koraku.

Operacije zračnog prometa su visoko osjetljive na ljudske greške, posebno u uvjetima visokog stresa, zamora ili emocionalne napetosti. Brzi rast zračnog prometa i tehnološki napredak često dovode do zanemarivanja ljudskih čimbenika, no istraživanja pokazuju da su ti čimbenici i dalje jedan od glavnih uzroka incidenata i nesreća u zračnom prometu. Kako bi se osigurala sigurnost leta u ovom dinamičnom okruženju, ključno je razumjeti i adekvatno upravljati ljudskim čimbenicima, pružajući podršku osoblju i osiguravajući primjenu propisa i najboljih praksi.

*Ključne riječi**:** ljudski čimbenici, zračni promet, sigurnost.*

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1. UVOD

Sigurnost zračnog prometa ključna je komponenta globalne zrakoplovne industrije, a ljudski čimbenici igraju presudnu ulogu u osiguravanju te sigurnosti. Ljudski čimbenici odnose se na različite elemente koji utječu na ljudsko ponašanje i izvedbu u operativnim uvjetima, uključujući psihološke, fizičke, socijalne i organizacijske aspekte. Razumijevanje i upravljanje ovim čimbenicima od suštinskog je značaja za smanjenje rizika od ljudskih pogrešaka koje mogu dovesti do incidenata i nesreća. Sa sve većim razvojem tehnologije raste složenost operacija u zračnom prometu, dok se istovremeno povećavaju i zahtjevi za sigurnošću. Stoga je razumijevanje uloge ljudskih čimbenika u zračnom prometu postalo izuzetno važno.

Ljudske pogreške, stres i učinkovitost operativnog osoblja ključni su elementi koji mogu utjecati na sigurnost zračnog prometa. Piloti, kontrolori leta, zrakoplovno-tehničko i drugo operativno osoblje svakodnevno se suočavaju s izazovima koji zahtijevaju visoku razinu koncentracije, donošenja odluka i koordinacije. Stres, umor i neadekvatna obuka mogu značajno utjecati na njihovu sposobnost da učinkovito i sigurno obavljaju svoje zadatke.

Povećanje kapaciteta zračnog prometa dodatno komplicira ove izazove. Rast broja letova i putnika stavlja veći pritisak na sve segmente zrakoplovne industrije, od planiranja i upravljanja letovima do održavanja zrakoplova i pružanja usluga kontrole leta. Kako bi se održala visoka razina sigurnosti unatoč povećanju prometa, potrebno je kontinuirano istraživanje i unapređenje razumijevanja ljudskih čimbenika.

Ciljevi istraživanja ljudskih čimbenika u zračnom prometu uključuju:

- Identificiranje ključnih uzroka ljudskih pogrešaka i razvijanje strategija za njihovo smanjenje.
- Proučavanje utjecaja stresa, umora i radnog okruženja na izvedbu operativnog osoblja.
- Unapređenje obuke i edukacije kako bi se osigurala visoka razina kompetencije i pripravnosti osoblja.
- Razvijanje tehnologija i procedura koje podržavaju ljudsku izvedbu i smanjuju mogućnost pogrešaka.
- Promicanje kulture sigurnosti unutar organizacija koje djeluju u zrakoplovnoj industriji.

Sustavno istraživanje ljudskih čimbenika i njihova integracija u sigurnosne procese i procedure ključni su za održavanje i unapređenje sigurnosti zračnog prometa, posebno u kontekstu stalnog rasta kapaciteta i složenosti operacija.

2. TEORIJSKI OKVIR I ULOGA LJUDSKIH ČIMBENIKA U ZRAČNOM PROMETU

U ovom poglavlju istražuje se teorijski okvir i uloga ljudskih čimbenika u kontekstu zračnog prometa. Cilj je pružiti dublji uvid u osnovne koncepte, modele i teorije koji oblikuju naše razumijevanje ove ključne discipline. Osim toga, naglašava se uloga ljudskih čimbenika u različitim aspektima zračnih operacija, posebno u područjima odlučivanja, izvedbe, komunikacije i sigurnosti. U ranim danima zrakoplovstva, mnoge su brige bile usmjerene na utjecaj buke, vibracija, temperature i sile ubrzanja na ljude koji su sudjelovali u zračnim operacijama. Često se smatralo da su ljudski čimbenici isključivo područje medicine, pri čemu je uloga fiziologa ili liječnika bila ključna. Međutim, kako su istraživanja napredovala, postalo je jasno da su ljudski čimbenici mnogo više od toga. Oni su multidisciplinarni i uključuju različite znanstvene discipline poput psihologije, fiziologije, antropometrije i biomehanike. (CAP 719, 2002)
Ljudski čimbenici igraju ključnu ulogu u performansama zračnog prometa. Često se etiketiraju kao "pogreške pilota", no ta terminologija ne pruža dovoljno dubok uvid u uzroke problema. Greške koje ljudi naprave mogu biti rezultat nedostataka u dizajnu sustava, nedostatne obuke ili loših pristupa u vođenju zračnih operacija. Razumijevanje ljudskih sposobnosti i ograničenja ključno je za unaprjeđenje sigurnosti u zračnom prometu.
Jedna definicija ljudskog čimbenika, koju je predložio profesor Edwards, navodi da razumijevanje ljudskih čimbenika služi razumijevanju odnosa između ljudi i njihovih aktivnosti, uz sustavnu primjenu humanističkih znanosti, integriranih u okviru sustava inženjeringa. Ciljevi su učinkovitost sustava, što uključuje sigurnost i učinkovitost, te dobrobit pojedinca. Edwards dalje elaborira da „ljudske aktivnosti“ pokazuju interes za komunikacijom između pojedinaca i ponašanjem pojedinaca i grupa. (Marušić, 2014)
Pojam ljudskog čimbenika ubrzano postaje sve poznatiji od kada se u zrakoplovstvu shvatilo da, umjesto mehaničkih ili kompjuterskih otkaza, ljudska pogreška čini temelj većini zrakoplovnih nesreća i incidenata. Zbog velikog značaja koji se pridaje važnosti smanjenju pojavnosti pogrešaka i upravljanju pogreškama, zrakoplovstvo je postalo jedno od vodećih predstavnika razvoja ljudskog čimbenika u svim aspektima izvedbe zadataka zračnog prometa.
U današnje vrijeme ulažu se veliki napori u proširenje svjesnosti o važnosti ljudskih čimbenika, kao i u predanost uzimanja u obzir i iskorištavanja svih mogućnosti dizajniranja novih sustava, čime se smanjuju neželjeni učinci već postojećeg, često zastarjelog dizajna sustava unutar kontrole zračnog prometa, koji ne mogu odmah biti zamijenjeni poboljšanim alternativama. (Martinussen i Hunter, 2010)

2.1. Osnovni konceptualni modeli ljudskih potencijala

Osnovni konceptualni modeli ljudskih potencijala predstavljaju strukturu koja pomaže u razumijevanju uloge ljudskih čimbenika u različitim operacijama i procesima. Ovi modeli obuhvaćaju različite aspekte ljudske izvedbe, uključujući kognitivne procese, percepciju, donošenje odluka, komunikaciju, stres i motivaciju. Također, modeli uzimaju u obzir vanjske čimbenike poput radnog okruženja, organizacijske kulture i tehnoloških alata. Cilj ovih modela je pružiti strukturu za analizu i optimizaciju ljudskih potencijala u cilju poboljšanja sigurnosti, učinkovitosti i uspjeha u različitim industrijskim i operativnim kontekstima.

James Reason i njegov „Model švicarskog sira“ poznati su u krugovima sigurnosti kao korisno sredstvo za opis kombinacija višestrukih manjih neuspjeha, od kojih nijedan pojedinačno nije dovoljan da izazove incident, ali u kombinaciji stvaraju neuspjeh u kompleksnom sustavu.

Latentni uvjeti su oni koji postoje u zračnom sustavu dugo prije što se dogodi štetan ishod. Posljedice latentnih uvjeta mogu ostati neaktivne dugi vremenski period. U početku se ovi latentni uvjeti ne percipiraju kao štetni, ali postaju vidljivi kada se obrane sustava prekrše. Ove uvjete obično stvaraju ljudi udaljeni u vremenu i prostoru od događaja. Latentni uvjeti u sustavu mogu uključivati one stvorene nedostatkom sigurnosne kulture, lošom opremom ili proceduralnim dizajnom; sukobljene organizacijske ciljeve; neispravne organizacijske sustave ili upravljačke odluke. „Model švicarskog sira“ pomaže u razumijevanju interakcije organizacijskih i upravljačkih čimbenika u uzrocima nesreća. (SMM, 2013)

Metodologija sustavne analize događaja (eng. Systemic Occurrence Analysis Methodology – SOAM) sveobuhvatan je proces za analizu podataka prikupljenih kao dio istrage sigurnosnog događaja te za generiranje logičkih zaključaka i preporuka. SOAM je jedna od nekoliko metodologija za istragu nesreća koje se temelje na Reasonovom modelu organizacijskih nesreća. Svrha metodologije sustavne analize događaja je proširiti fokus istrage s ljudske uključenosti na analizu latentnih uvjeta unutar organizacije koji postavljaju kontekst za događaj.

„SHELL model“, po početnim slovima komponenti prvi je razvio profesor Edwards 1972. godine, a modificirani dijagram koji ilustrira model razvio je Hawkins 1975. godine. Komponente su: „program“ (eng. Software), „stroj“ (eng. Hardware), „okruženje“ (eng. Environment) i „čovjek“ (eng. Liveware). Koristi se od strane Organizacije međunarodnog civilnog zrakoplovstva (ICAO) kako bi ilustrirao ljudske čimbenike i njihov utjecaj na operativne sustave i obrnuto te pokušava pokazati da neusklađeni odnos između ljudi i sustava može biti uzrok opasnosti ili rizika. Svrha modela je demonstrirati važnost kontinuiranog fokusa na uspostavljanje odgovarajućih okvira sigurnosti unutar organizacije. (Burling, 2021)

U zrakoplovstvu su se u posljednjih nekoliko godina pojavili razni koncepti koji su usmjereni na poboljšanje suradnje i odnosa među dionicima zračnog prometa.

Ljudski čimbenik ima različite primjene u ovom kontekstu, često se koristi kao sinonim za upravljanje resursima posade (eng. Cockpit Resource Management – CRM) ili upravljanje resursima održavanja zrakoplova (eng. Maintenance Resource Management – MRM). EUROCONTROL je razvio koncept za operativno osoblje Upravljanje timskim resursima (eng. Team Resource Management –TRM), koji ima za cilj smanjiti utjecaj grešaka nastalih kao rezultat timskog rada, razviti pozitivne stavove prema vještinama timskog rada i ljudskom učinku unutar sektora zračnog prometa te smanjiti broj i utjecaj pogrešaka vezanih uz timski rad. TRM je razvijen na temelju principa CRM-a, koje su razvile aviokompanije za pilote i drugo zrakoplovno osoblje. Prepoznata je potreba za obrazovanjem osoblja u zrakoplovnoj industriji kroz mnoge istrage nesreća uzrokovanih ljudskim pogreškama.

3. ZNAČAJ LJUDSKIH ČIMBENIKA U ORGANIZACIJSKOJ STRUKTURI PRUŽATELJA USLUGE

Era ljudskih čimbenika označava razdoblje od početka 1970-ih do sredine 1990-ih, kada je smanjenje učestalosti zrakoplovnih nesreća rezultiralo proširenjem fokusa sigurnosnih napora na ljudske čimbenike, uz naglasak na interakciju između čovjeka i stroja. Unatoč ulaganju resursa u ublažavanje pogrešaka, ljudska izvedba i dalje je ostala čest uzrok nesreća, a primjena znanosti o ljudskim čimbenicima često se usredotočila na pojedinca, ne uzimajući u potpunosti u obzir operativni i organizacijski kontekst. Organizacijska era, koja obuhvaća razdoblje od sredine 1990-ih do danas, donosi promjenu perspektive prema sistemskom pristupu sigurnosti, uz uključivanje organizacijskih čimbenika pored ljudskih i tehničkih. (SMM, 2013)

Sustav za funkcioniranje sigurnosti zračne plovidbe je temeljni okvir koji omogućuje upravljanje sigurnošću u zračnom prometu. Ovaj sustav se oslanja na niz dokumenata i procedura koji su oblikovani kako bi osigurali visoke standarde sigurnosti. Sam sustav funkcionira kroz suradnju između različitih dionika u zračnom prometu, uključujući regulatorne agencije, zračne prijevoznike, zračne luke, zrakoplovne proizvođače i druge relevantne organizacije. Ovi subjekti zajedno rade na uspostavljanju i održavanju visokih standarda sigurnosti kroz implementaciju propisanih procedura, redovito obrazovanje i obuku osoblja te sustavno praćenje i analizu sigurnosnih podataka.

Sustav za upravljanje sigurnosti zračne plovidbe ima za cilj povećanje razine sigurnosti kroz različite pristupe kao što su izvješćivanje, prikupljanje, pohranjivanje, zaštitu, razmjenu, istraživanje, analiziranje, te na propisan način distribuiranje sigurnosnih informacija zainteresiranim stranama, i poduzimanje sigurnosnih mjera i preporuka na osnovu prikupljenih informacija. Pozitivna sigurnosna kultura može značajno smanjiti broj incidenata i nesreća. S druge strane, negativna ili slaba sigurnosna kultura može dovesti do povećanja rizika i

učestalosti sigurnosnih propusta. Primjeri iz prakse pokazuju da organizacije s jakom sigurnosnom kulturom imaju bolje sigurnosne rezultate, manji broj nesreća i incidenata te visoku razinu povjerenja među zaposlenicima.

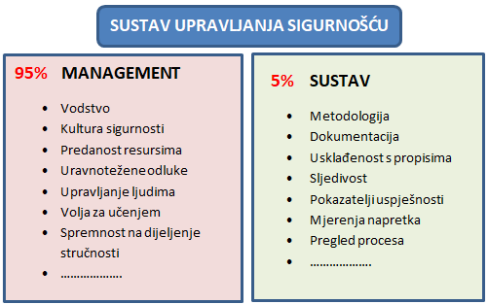
U mnogim državama postoje značajna pravna ograničenja koja sprečavaju nekažnjivo prijavljivanje sigurnosnih događaja. To često rezultira osjećajem inhibicije kod zaposlenika prilikom podnošenja prijava, posebno u situacijama gdje države imaju zakonske propise o "slobodi informacija" i nisu poduzele korake kako bi zaštitile sigurnosne izvještaje od primjene takvih zakona. Osim toga, primijećena je loša komunikacija između različitih subjekata u zračnom prometu i različitih razina upravljanja u brojnim organizacijama koje pružaju usluge u zračnom prometu. Također, uočena je negativna percepcija sigurnosnih regulatora, čija uloga u mnogim državama nije jasno definirana, te su često ograničeni u svom djelovanju.

Da bi se održalo povjerenje zainteresiranih strana, sustavi prijavljivanja sigurnosnih događaja trebali bi sadržavati sljedeće elemente: zaštitu povjerljivosti izvještaja, identifikaciju dobrovoljnih prijava, neponištive odredbe. Važno je istaknuti da nekažnjivo ne znači da osobe odgovorne za sigurnosne događaje izbjegavaju odgovornost za, primjerice, nezakonite radnje, neprikladno ponašanje, grubu nepažnju ili prekršaje. Umjesto toga, cilj je prijavljivanje sigurnosnih događaja u "pravednoj kulturi" u kojoj se iskrene pogreške (tj. manje, rutinske pogreške koje su propusti ili zanemarivanja) analiziraju, izvlače pouke i šire, bez kažnjavanja uključenog osoblja. (EUROCONTROL, 2006)

Za poticanje daljnjeg podnošenja izvješća, organizacija treba jasno komunicirati sa svojim osobljem o tome da su dobrovoljna izvješća vrijedna sigurnosna imovina i priznati trud osoba koje su podnijele izvješće. Informacije primljene preko dobrovoljnog sustava izvješćivanja trebaju biti pravodobno dostupne zrakoplovnoj zajednici. Organizacijska kultura ima ključnu ulogu u oblikovanju sigurnosnih praksi i ponašanja unutar zrakoplovne industrije i predstavlja temelj za stvaranje okruženja u kojem je sigurnost prioritet, a sve aktivnosti i odluke donose se s obzirom na potencijalne sigurnosne implikacije.

3.1 Pravni i regulatorni okvir

Sustav upravljanja sigurnošću znači sustavni pristup upravljanju sigurnošću, uključujući nužne organizacijske strukture, odgovornosti, politike i procedure. Rizik je sastavni dio ljudske aktivnosti. Njime se najbolje upravlja uvođenjem namjenskog sustava za sigurnost. Što je potrebno za postavljanje sustava upravljanja sigurnosti?



Slika 1. Odnos managementa i sustava u SMS-u (Izvor: EUROCONTROL, 2015)

Iz prethodnog prikaza sustava upravljanja sigurnošću u proteklom periodu, mnogi pravni i regulatorni okviri definirali su utjecaj ljudskih čimbenika na sigurnost zračnog prometa. U nastavku će biti navedeni najznačajniji od njih koji regulišu ovu oblast, kao i neki od prijedloga koji bi mogli biti regulirani u bliskoj budućnosti.

3.1.1. Međunarodni i europski propisi

Za funkcionalnije upravljanje organizacijama koje se odnose na avijacijski sektor, a posebno u pogledu sigurnosti koja obuhvaća ljudske čimbenike, usvojeni su važni međunarodni propisi. Prvi značajan dokument koji se bavi ljudskim čimbenicima je International Standard Classification of Occupations ISCO-08, koji je izdala Međunarodna organizacija rada 2012. godine. Međunarodna organizacija rada je specijalizirana agencija Ujedinjenih naroda, osnovana 1919. godine sa sjedištem u Ženevi. Ovi standardi su ljudske resurse, te stoga i čimbenike svrstali u Annex 2. (ILO, 2012)

ICAO[1] specijalizirana je ustanova Ujedinjenih naroda, osnovana Konvencijom o međunarodnom civilnom zrakoplovstvu od 7. prosinca 1944. godine u Chicagu, u svrhu razvijanja načela, tehnologije te poticanja i razvoja međunarodnoga zračnog prometa. (ZOZP, 2009)

Neki od dokumenata i ICAO standarda koji su obavezujući za nacionalna regulatorna tijela, a bave se ljudskim čimbenicima su:

- ICAO Doc 10057 Manual on Air Traffic Safety Electronics Personnel Competency-based Training and Assessment iz 2017. godine. Ovim dokumentom su jasno naznačeni ljudski čimbenici. Dokumentom su obuhvaćene obuke za tehničko osoblje kako bi se unaprijedile njihove performanse. (ATS, 2017)
- ICAO Doc 9868 Procedures for air navigation services iz 2015. godine. Dokument u prilogu C, poglavlje 1, navodi da se TEM (eng. Threat and error management) trebaju što preciznije integrirati sa saznanjima o

[1] Više na: https://www.icao.int/

ljudskim čimbenicima. (PANS, 2015)

- ICAO Doc 10151 Manual on Human Performance (HP) for Regulators iz 2021. godine. Ovaj priručnik koristi izraz HP, ali HP se ne može odvojiti od HF (eng. Human Factors) i ergonomije. (MHP, 2021)
- ICAO Doc 9824 Human Factors Guidelines for Aircraft Maintenance Manual iz 2003. godine. Dokument se u cijelosti bavi utjecajem ljudskih čimbenika kod održavanja zrakoplova počevši od ključnih problema u održavanju pa do treninga i rješenja za nacionalne regulatore. (HFGAMM, 2003)
- ICAO Doc 9683 Human Factors Training Manual iz 1998. godine. Ovaj priručnik predstavlja uvod u najnovije informacije dostupne međunarodnoj zajednici civilnog zrakoplovstva o kontroli ljudske pogreške i razvoju protumjera za pogreške u operativnim okruženjima. (HFTM, 1998)

Agencija Europske unije za sigurnost zračnog prometa (EASA)[2] odgovorna je za osiguravanje **sigurnosti** i **zaštite okoliša** u zračnom prometu u Europi. Osnovana je 2002. godine sa sjedištem u Kölnu. Regulativa koja se bavi i uređuje oblast sigurnosti i ljudskih čimbenika obuhvaća:

- EASA Regulation (EU) 2018/1139 of the European Parliament and of the Council iz 2018. godine. Ova regulativa obuhvaća praktične vještine iz domene ljudskih čimbenika, kao i praktični trening za svjesne situacije. (EPC, 2018)
- EASA – Acceptable Means of Compliance and Guidance Material to Commission Regulation (EU No 1321/2014) iz 2014. godine. Pružatelj usluga kontrole zračnog prometa trebao bi osigurati da cjelokupnim operativnim rizikom koji proizlazi iz stresa, umora i problematične upotrebe psihoaktivnih tvari kod kontrolora zračnog prometa upravlja njegov sustav upravljanja sigurnošću. (AMCGMCR, 2014)

Savezna uprava za civilno zrakoplovstvo (FAA)[3] je agencija američkog Ministarstva prometa zadužena za reguliranje i nadzor svih aspekata civilnog zračnog prometa u Sjedinjenim Američkim Državama. Osnovana je 1958. godine sa sjedištem u Washingtonu. Ljudski čimbenici u okviru FAA su definirani kroz slijedeće dokumente:

- FAA Human Factors Considerations in the Design and Evaluation of Flight Deck Displays and Controls iz 2016. godine. Ovaj dokument utvrđuje smjernice o ljudskim čimbenicima koje treba uzeti u obzir pri projektiranju i procjeni zaslona i kontrola avionike za sve tipove zrakoplova. (HFCDEFDDC, 2016)

[2] Više na: https://www.easa.europa.eu/en

[3] Više na: https://www.faa.gov/

- FAA Human Factors Design Standard iz 2016. godine. Ovaj standard odobren je za korištenje od strane svih odjela FAA. Standard dizajna ljudskih čimbenika (HF-STD-001B) sveobuhvatan je referentni alat koji će pomoći stručnjacima za ljudske čimbenike unutar FAA i ugovornim organizacijama da učinkovito provedu politiku FAA o ljudskim čimbenicima. (HFDS, 2016)

Europska organizacija za sigurnost zračne plovidbe – EUROCONTROL[4] je paneuropska, civilno-vojna organizacija posvećena podršci europskom zrakoplovstvu. Osnovana je 1963. godine sa sjedištem u Briselu. U svojim publikacijama izdao je neke izuzetno bitne materijale koji su od velike važnosti za europsku avijaciju. Neki od tih materijala koji se bave ljudskim čimbenicima su:

- EUROCONTROL Human Factors Module – Stress iz 1996. godine. Cilj ovog modula je dati pregled koji će čitatelju omogućiti prepoznavanje, razumijevanje i upravljanje stresom. (HFMS, 1996)
- EUROCONTROL Human Factors – Critical Incident Stress Management: User Implementation Guidelines iz 2008. godine. Upravljanje stresom u kritičnim incidentima (CISM) odnosi se na programe osmišljene za podršku osobama koje su negativno pogođene kritičnim događajima, kako bi se oporavile i vratile normalnom funkcioniranju i ponašanju. (CISM, 2008)
- EUROCONTROL Fatigue and Sleep Management: Personal strategies for decreasing the effects of fatigue in Air Traffic Control iz 2005.godine. Umor je važan sigurnosni problem unutar sustava kontrole letenja, te postoji regulatorni okvir za provedbu mjera otkrivanja, praćenja i upravljanja. (FSM, 2005)

Razvoj novih strategija koje će unaprijediti ovu oblast i otvoriti perspektive osoblju u avijaciji svakako će predstavljati veliki izazov. Jedno je sigurno, a to je da čovjek nije mašina i da treba postaviti pitanje koliko informacija je dovoljno? Strategija ima za cilj ostvariti dvije glavne funkcije. Prvo, poticati dosljednost u integraciji načela ljudskih faktora u regulativi, upravljanju, dizajnu sustava, obuku, licenciranju, reviziju i osiguranje zrakoplovnih aktivnosti. Drugo, opisuje kako praktično razumijevanje i primjena ljudskih faktora može poslužiti u poboljšanju sigurnosne izvedbe u cijelom sustavu sigurnosti u zrakoplovstvu. (EHFAG, 2012)

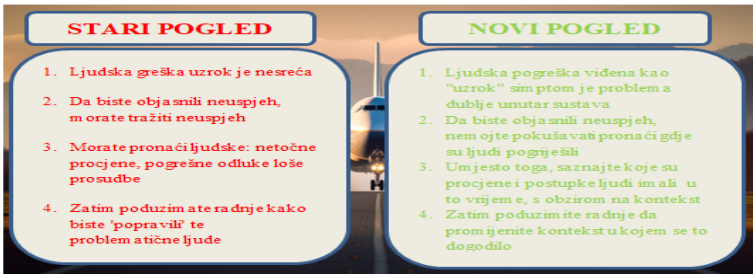
IFATSEA[5] je međunarodna organizacija zrakoplovno-tehničkog osoblja za sigurnost zračne plovidbe. Osnovana je 1972. godine sa sjedištem u Briselu. U svojoj studiji iz 2021. godine pod naslovom "Human Factors of ATSEP" prikazala je jasne buduće korake koje je potrebno poduzeti u vezi s tehničko-

[4] Više na: https://www.eurocontrol.int/

[5] Više na: http://www.ifatsea.org/

operativnim osobljem. Ozbiljne, čak i fatalne nesreće ne mogu se isključiti ako se ne pozabavimo problemima stresa i umora kod ATSEP. (IFATSEA, 2021)

U izradi novih strategija iz domene ljudskih čimbenika bit će važno uzeti u obzir niz iskustava kako bi se pomirila neka ranija i novija stajališta. Razlike između tih stajališta najbolje se mogu sagledati kroz prikaz na u Slici 2.



Slika 2. Dva pogleda na ljudsku grešku (Izvor: EUROCONTROL, 2023

4. ANALIZA NESREĆA I INCIDENATA SA ASPEKTA SIGURNOSTI (SAFETY)

Tijekom povijesti zračnog prometa, bilježi se niz nesreća u kojima je ključnu ulogu odigrao ljudski čimbenik. **Uzrok pada aviona u čak polovini tragedija su pogreške pilota**. Nakon ljudskih čimbenika, mehanički kvarovi su drugi najčešći uzrok pada aviona, što je dovelo do pada 22% ukupnog broja aviona. U 12% slučajeva, vremenski uvjeti su bili faktor avionske nesreće, dok su sabotaža ili teroristički napadi uzrokovali 9% padova.

Navesti ćemo dvije avionske nesreće koje su značajno utjecale na percepciju sigurnosti u zračnom prometu. Također, osim ovih poznatih nesreća, pružit ćemo i analizu slučaja u jednoj od oblasnih kontrola letenja gdje je ljudski čimbenik doveo do opasnog sigurnosnog incidenta. Dvije avionske nesreće zbog kojih su učinjeni veliki iskoraci u oblasti sigurnosti zračnog prometa su:

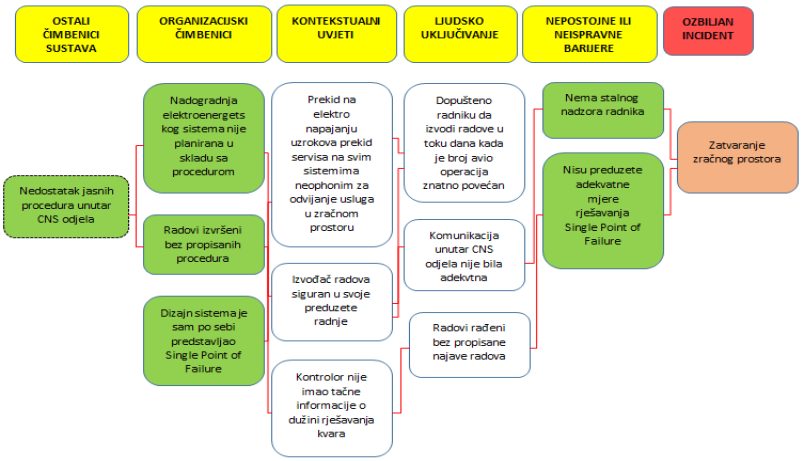
- Sudar na pisti Linate u Milanu, 8. listopada 2001. godine

Završno izvješće o sudaru na pisti između Boeinga MD-87 i Cessne Citation u milanskoj zračnoj luci Linate u listopadu 2001. godine navodi kombinaciju čimbenika, od nedostataka na aerodromu do loše komunikacije između pilota i kontrolora, što je rezultiralo najgorim događajem u Italiji iz domene zrakoplovnih nesreća. Izvješće o nesreći navodi niz nedostataka koji su igrali ulogu u ishodu. Nije postojao funkcionalni sustav upravljanja sigurnošću. Kontrolori aerodromskih tornjeva "izjavili su da su ignorirali postojanje" oznaka. Radiotelefonska frazeologija koju koriste kontrolori i piloti nije bila u skladu s ICAO frazeologijom i utvrđeno je da su odstupanja od standardne frazeologije uobičajena praksa. Kontrolor nije otkrio pogrešku u povratnom čitanju Cessne pilota, a propusti pilota nisu ispravljeni. (EUROCONTROL, 2023)

- AIRPROX u blizini Ženeve, Švicarska, 8. veljače 2007.godine

Incident AIRPROX uključivao je zrakoplov Lockheed C-130 Hercules, koji je održavao FL 250, i Tupoljev Tu-154M, koji se penjao kroz istu razinu leta u suprotnom smjeru. Dva zrakoplova su se križala na bočnoj udaljenosti od 0,4 NM i visinskoj razlici od 100 ft. Ljudski čimbenici koji su involvirani u ovu nesreću su: kontrolor pripravnik je dopustio Tupoljevu da se popne na FL 260, stvarajući sukob s C-130, trener i radarski koordinator nisu primijetili sukob, posada Tupoljeva nije slijedila savjete TCAS-a, kao ni posada C-130 i trener nije intervenirao kako bi spriječio sukob. (EUROCONTROL, 2023)

Analiza SOAM napravljena je od strane autora na temelju događaja koji su se odvijali u jednoj oblasnoj kontroli letenja, uzimajući u obzir dostupnu dokumentaciju o istrazi tog događaja. Specifično, sigurnosni događaj koji je bio predmetom direktnog sagledavanja bio je povezan s ljudskim čimbenikom koji je rezultirao zatvaranjem zračnog prostora. Ovaj događaj dogodio se 2018. godine i bio je kvalificiran kao ozbiljan incident.



Slika 3. Analiza slučaja kroz SOAM grafikon (Izvor: autor, 2024)

5. ZAKLJUČAK

Sigurnost u zračnom prometu je neodvojivo povezana s ljudskim čimbenicima, čija je uloga ključna u osiguravanju bezbjednosti operacija i izvedbe osoblja. Razumijevanje i upravljanje tim faktorima su od suštinskog značaja za minimiziranje rizika od ljudskih grešaka koje mogu prouzrokovati incidente i nesreće. Stoga, stalno istraživanje i unapređenje obuke i edukacije predstavljaju temeljne stupove održavanja visokog nivoa sigurnosti.

Integracija novih tehnologija i procedura podržava ljudsku izvedbu, stvarajući okruženje u kojem osoblje može efikasno i precizno obavljati svoje dužnosti. Analize slučajeva su također od vitalnog značaja jer pružaju duboke uvide u uzroke nesreća, omogućujući primjenu preventivnih mjera radi sprječavanja ponavljanja sličnih incidenata u budućnosti.

Ovaj sveobuhvatan pristup promovira svijest o ljudskim čimbenicima i doprinosi kontinuiranom poboljšanju sigurnosti u zračnom prometu. Kroz konstantno učenje iz prošlih iskustava, primjenu najnovijih tehnoloških dostignuća i osnaživanje osoblja putem obuke i edukacije, aviokompanije i regulatorna tijela mogu zajedno raditi na stvaranju okoline u kojoj se rizici minimiziraju, a putnička bezbjednost postaje apsolutni prioritet.

Ljudski čimbenici i njihov utjecaj na sigurnost u zračnom prometu zauzimaju centralno mjesto na ljestvici prioriteta i postat će među najvažnijim pitanjima u budućnosti. S obzirom na sve veću složenost zračnog prometa, kao i rastuće brojnosti letova i putnika, uloga ljudskih faktora postaje još izraženija. Greške ili nedostatak pažnje osoblja mogu imati ozbiljne posljedice, stoga je ključno razumijevanje, upravljanje i kontinuirano unapređenje u ovom području.

Uz tehnološki napredak koji donosi nove izazove, potreba za fokusiranjem na ljudske čimbenike postaje sve hitnija. Budući da su ljudi ti koji su na kraju odgovorni za donošenje odluka i izvršavanje operacija, njihova sposobnost, motivacija i mentalno stanje imaju izravan utjecaj na sigurnost letova. Stoga će pravilno upravljanje ljudskim resursima i kontinuirana edukacija postati još ključniji elementi u održavanju sigurnosti u zračnom prometu u godinama koje dolaze.

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THE INFLUENCE OF HUMAN FACTORS ON AVIATION SAFETY

Original scientific paper

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Abstract

This paper explores the significant impact of human factors on aviation safety, with a particular emphasis on air traffic operations as a complex chain where human factors play a crucial role. With the rapid growth and technological advancement in aviation, operations are becoming increasingly complex, leading to increased workload on the crew and other personnel. This intricate chain encompasses various phases, including flight planning, execution, air traffic control, and ground operations, when human factors plac a pivotal role at every step. Air traffic operations are highly sensitive to human errors, especially under conditions of high stress, fatigue, or emotional tension. The rapid growth of air traffic and technological advancement often lead to the neglect of human factors. However, research indicates that these factors remain one of the primary causes of incidents and accidents in aviation. To ensure flight safety in this dynamic environment, it is crucial to understand and effectively manage human factors by providing support to personnel and ensuring compliance with regulations and best practices.

Keywords: human factors, air traffic, safety.

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1. INTRODUCTION

Aviation safety is a key component of the global aviation industry, and human factors play a crucial role in ensuring this safety. Human factors refer to various elements that influence human behavior and performance in operational conditions, including psychological, physical, social, and organizational aspects. Understanding and managing these factors is essential to reducing the risk of human errors that can lead to incidents and accidents. As technology advances, the complexity of aviation operations increases, along with the demands for safety. Thus, understanding the role of human factors in aviation has become extremely important.

Human errors, stress, and the efficiency of operational personnel are key elements that can impact aviation safety. Pilots, air traffic controllers, aircraft maintenance technicians, and other operational personnel face daily challenges that require high levels of concentration, decision-making, and coordination. Stress, fatigue, and inadequate training can significantly affect their ability to perform tasks efficiently and safely.

Increasing air traffic capacity further complicates these challenges. The growth in flights and passengers puts greater pressure on all segments of the aviation industry, from flight planning and management to aircraft maintenance and air traffic control services. To maintain high safety standards despite the increase in traffic, continuous research and improvement of human factors understanding is necessary.

The goals of human factors research in aviation include:

Identifying key causes of human errors and developing strategies to reduce them.

- Studying the impact of stress, fatigue, and the work environment on the performance of operational personnel.
- Enhancing training and education to ensure high levels of competence and readiness among personnel.
- Developing technologies and procedures that support human performance and reduce the likelihood of errors.
- Promoting a safety culture within organizations operating in the aviation industry.

Systematic research on human factors and their integration into safety processes and procedures are crucial for maintaining and enhancing aviation safety, especially in the context of the continuous growth in capacity and complexity of operations.

2. THEORETICAL FRAMEWORK AND ROLE OF HUMAN FACTORS IN AVITATION

This chapter explores the theoretical framework and the role of human factors in the context of air traffic. The goal is to provide a deeper insight into the fundamental concepts, models, and theories that shape our understanding of this crucial discipline. Additionally, the chapter emphasizes the role of human factors in various aspects of air operations, particularly in areas such as decision-making, performance, communication, and safety.

In the early days of Aviation, many concerns were focused on the impact of noise, vibration, temperature, and acceleration forces on the people involved in air operations. Human factors were often considered exclusively within the realm of medicine, with physiologists or doctors playing a key role. However, as research progressed, it became clear that human factors are much more than that. They are multidisciplinary, involving various scientific disciplines such as psychology, physiology, anthropometry, and biomechanics (CAP 719, 2002).

Human factors play a crucial role in air traffic performance. They are often labeled as "pilot errors," but this terminology does not provide a deep enough understanding of the root causes of problems. Mistakes made by humans can result from system design flaws, inadequate training, or poor approaches to managing air operations. Understanding human capabilities and limitations is essential for improving safety in air traffic.

One definition of human factors, proposed by Professor Edwards, states that understanding human factors involves understanding the relationships between people and their activities, with the systematic application of human sciences integrated within the engineering framework. The goals are system efficiency, which includes safety and effectiveness, and individual well-being. Edwards further elaborates that "human activities" show interest in communication between individuals and the behavior of individuals and groups (Marušić, 2014). The concept of human factors has rapidly gained

prominence as the aviation industry realized that human error, rather than mechanical or computer failures, is the foundation of most aviation accidents and incidents. Due to the significant emphasis placed on reducing the occurrence of errors and managing them, aviation has become a leading representative in the development of human factors across all aspects of air traffic task performance.

Today, great efforts are being made to raise awareness of the importance of human factors, as well as to commit to considering and leveraging all possibilities in designing new systems. This aims to reduce the undesirable effects of existing, often outdated, system designs within air traffic control, which cannot be immediately replaced by improved alternatives (Martinussen & Hunter, 2010).

2.1. The basic conceptual models of human potential

The basic conceptual models of human potential provide a structure that helps in understanding the role of human factors in various operations and processes. These models encompass different aspects of human performance, including cognitive processes, perception, decision-making, communication, stress, and motivation. They also consider external factors such as the work environment, organizational culture, and technological tools. The goal of these models is to provide a framework for analyzing and optimizing human potential to enhance safety, efficiency, and success in various industrial and operational contexts.

James Reason and his "Swiss Cheese Model" are well-known in safety circles as a useful tool for describing the combination of multiple minor failures, none of which alone is sufficient to cause an incident, but together create a failure in a complex system.

Latent conditions are those that exist in the air traffic system long before a harmful outcome occurs. The consequences of latent conditions can remain inactive for long periods. Initially, these latent conditions are not perceived as harmful but become apparent when the system's defenses are breached. These conditions are usually created by people distant in time and space from the event. Latent conditions in the system can include those created by a lack of safety culture, poor equipment or procedural design, conflicting organizational goals, faulty organizational systems, or managerial decisions. The "Swiss Cheese Model" helps in understanding the interaction of organizational and managerial factors in the causes of accidents (SMM,

2013).

The Systemic Occurrence Analysis Methodology (SOAM) is a comprehensive process for analyzing data collected as part of a safety event investigation and generating logical conclusions and recommendations. SOAM is one of several accident investigation methodologies based on Reason's model of organizational accidents. The purpose of SOAM is to expand the investigation's focus from human involvement to analyzing latent conditions within the organization that set the context for the event.

The "SHELL model," named after the initial letters of its components, was first developed by Professor Edwards in 1972, with a modified diagram illustrating the model developed by Hawkins in 1975. The components are: "Software," "Hardware," "Environment," and "Liveware." It is used by the International Civil Aviation Organization (ICAO) to illustrate human factors and their impact on operational systems and vice versa. It attempts to show that a misaligned relationship between people and systems can be a source of hazards or risks. The purpose of the model is to demonstrate the importance of a continuous focus on establishing appropriate safety frameworks within the organization (Burling, 2021).

In recent years, various concepts have emerged in aviation aimed at improving cooperation and relationships among air traffic stakeholders. Human factors have various applications in this context, often used as a synonym for Cockpit Resource Management (CRM) or Maintenance Resource Management (MRM). EUROCONTROL has developed a concept for operational personnel called Team Resource Management (TRM), which aims to reduce the impact of errors resulting from teamwork, develop positive attitudes towards teamwork skills and human performance within the air traffic sector, and reduce the number and impact of errors related to teamwork. TRM was developed based on CRM principles, which were developed by airlines for pilots and other aviation personnel. The need for educating aviation industry personnel has been recognized through numerous investigations of accidents caused by human errors.

3. THE IMPORTANCE OF HUMAN FACTORS IN THE ORGANIZATIONAL STRUCTURE OF SERVICE PROVIDERS

The era of human factors marks the period from the early 1970s to the mid-1990s when the reduction in the frequency of aviation accidents resulted in an expanded focus on safety efforts towards human factors, with an emphasis on the interaction between man and machine. Despite the investment of resources in mitigating errors, human performance continued to be a frequent cause of accidents, and the application of human factors science often focused on the individual, not fully taking into account the operational and organizational context. The organizational era, covering the period from the mid-1990s to the present, brings a shift in perspective towards a systems approach to safety, including organizational factors alongside human and technical ones (SMM, 2013).

The air traffic safety management system is the fundamental framework that enables the management of air traffic safety. This system relies on a series of documents and procedures designed to ensure high safety standards. The system functions through cooperation among various stakeholders in air traffic, including regulatory agencies, airlines, airports, aircraft manufacturers, and other relevant organizations. These entities work together to establish and maintain high safety standards through the implementation of prescribed procedures, regular training and education of personnel, and systematic monitoring and analysis of safety data.

The air traffic safety management system aims to increase safety levels through various approaches such as reporting, collecting, storing, protecting, sharing, investigating, analyzing, and distributing safety information to interested parties, and taking safety measures and recommendations based on the collected information. A positive safety culture can significantly reduce the number of incidents and accidents. On the other hand, a negative or weak safety culture can lead to an increase in risks and the frequency of safety lapses. Practical examples show that organizations with a strong safety culture have better safety results, fewer accidents and incidents, and a high level of trust among employees.

In many countries, there are significant legal constraints that prevent non-punitive reporting of safety events. This often results in feelings of inhibition among employees when submitting reports, especially in situations

where countries have "freedom of information" laws and have not taken steps to protect safety reports from the application of such laws. Additionally, poor communication has been noted between different entities in air traffic and different levels of management in numerous organizations that provide air traffic services. There is also a negative perception of safety regulators, whose role in many countries is not clearly defined, and who are often limited in their actions.

To maintain the trust of interested parties, safety event reporting systems should contain the following elements: protection of report confidentiality, identification of voluntary reports, and non-revocable provisions. It is important to emphasize that non-punitive does not mean that individuals responsible for safety events avoid accountability for, for example, illegal activities, inappropriate behavior, gross negligence, or violations. Instead, the goal is to report safety events in a "just culture" where honest mistakes (i.e., minor, routine errors that are lapses or neglects) are analyzed, lessons are learned and shared without punishing the involved personnel (EUROCONTROL, 2006).

To encourage further reporting, organizations should strongly communicate with their personnel that voluntary reports are valuable safety assets and recognize the efforts of individuals who have submitted reports. Information received through the voluntary reporting system should be promptly available to the aviation community. Organizational culture plays a key role in shaping safety practices and behaviors within the aviation industry and represents the foundation for creating an environment where safety is a priority, and all activities and decisions are made considering potential safety implications.

3.1. Legal and Regulatory Framework

A safety management system means a systematic approach to managing safety, including necessary organizational structures, responsibilities, policies, and procedures. Risk is an inherent part of human activity, and it is best managed by implementing a dedicated safety system. What is needed to establish a safety management system?

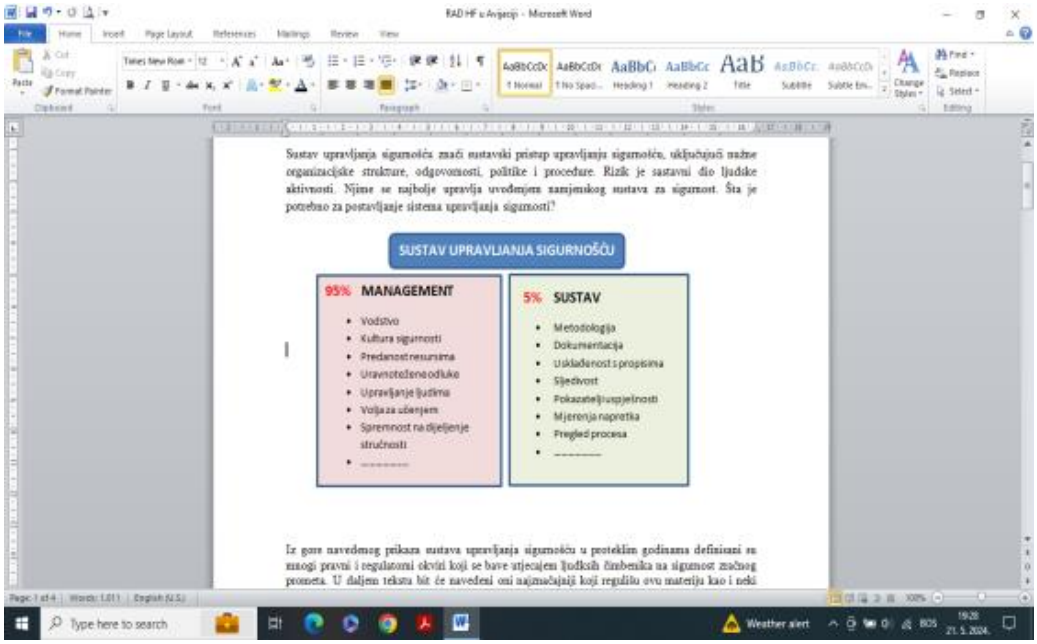

Figure 1. Relationship between management and the system in SMS (Source: EUROCONTROL, 2015)

From the previous overview of the safety management system in recent periods, many legal and regulatory frameworks have defined the impact of human factors on aviation safety. Below, the most significant of these that regulate this area will be listed, as well as some proposals that could be regulated in the near future.

3.1.1. International and European Regulations

To ensure more functional management of organizations related to the aviation sector, especially regarding safety encompassing human factors, important international regulations have been adopted. The first significant document dealing with human factors is the International Standard Classification of Occupations ISCO-08, issued by the International Labor Organization in 2012. The International Labor Organization is a specialized agency of the United Nations, founded in 1919 with headquarters in Geneva. These standards categorize human resources, testing, and factors in Annex 2 (ILO, 2012).

ICAO[3] is a specialized agency of the United Nations, established by the Convention on International Civil Aviation on December 7, 1944, in Chicago, to develop principles, technology, and promote the development of international air transport (ZOZP, 2009).

Some of the ICAO documents and standards that are mandatory for national regulatory bodies and deal with human factors include:

- ICAO Doc 10057 Manual on Air Traffic Safety Electronics Personnel Competency-based Training and Assessment (2017). This document clearly emphasizes human factors. It includes training for technical personnel to improve their performance (ATS, 2017).
- ICAO Doc 9868 Procedures for Air Navigation Services (2015). In Appendix C, Chapter 1, the document states that TEM (Threat and Error Management) should be precisely integrated with knowledge of human factors (PANS, 2015).
- ICAO Doc 10151 Manual on Human Performance (HP) for Regulators (2021). This manual uses the term HP, but HP cannot be separated from HF (Human Factors) and ergonomics (MHP, 2021).
- ICAO Doc 9824 Human Factors Guidelines for Aircraft Maintenance Manual (2003). This document entirely deals with the impact of human factors in aircraft maintenance, covering key maintenance issues to training and solutions for national regulators (HFGAMM, 2003).
- ICAO Doc 9683 Human Factors Training Manual (1998). This manual introduces the latest information available to the international civil aviation community on human error control and countermeasure development in operational environments (HFTM, 1998).

The European Union Aviation Safety Agency (EASA)[4] is responsible for ensuring safety and environmental protection in aviation in Europe. It was

[3] More at: https://www.icao.int/

[4] More at: https://www.easa.europa.eu/en

established in 2002 with headquarters in Cologne. Regulations covering the area of safety and human factors include:

EASA Regulation (EU) 2018/1139 of the European Parliament and of the Council (2018). This regulation includes practical skills in the domain of human factors and practical training for situational awareness (EPC, 2018).

EASA – Acceptable Means of Compliance and Guidance Material to Commission Regulation (EU No 1321/2014) (2014). Air traffic service providers should ensure that the entire operational risk arising from stress, fatigue, and problematic use of psychoactive substances by air traffic controllers is managed within their safety management system (AMCGMCR, 2014). The Federal Aviation Administration (FAA)[5] is an agency of the U.S. Department of Transportation responsible for regulating and overseeing all aspects of civil aviation in the United States. It was established in 1958 with headquarters in Washington, D.C. Human factors within the FAA are defined through the following documents:

- FAA Human Factors Considerations in the Design and Evaluation of Flight Deck Displays and Controls (2016). This document establishes guidelines on human factors to be considered in the design and evaluation of avionics displays and controls for all types of aircraft (HFCDEFDDC, 2016).
- FAA Human Factors Design Standard (2016). This standard is approved for use by all FAA departments. The Human Factors Design Standard (HF-STD-001B) is a comprehensive reference tool that will help human factors specialists within the FAA and contracting organizations to effectively implement FAA's human factors policies (HFDS, 2016).

The European Organization for the Safety of Air Navigation - EUROCONTROL[6] is a pan-European, civil-military organization dedicated to supporting European aviation. It was established in 1963 with headquarters in Brussels. In its publications, it has issued some extremely important materials that are of great importance for European aviation. Some of these materials dealing with human factors are:

- EUROCONTROL Human Factors Module – Stress (1996). The aim of this module is to provide an overview that will enable the reader to recognize, understand, and manage stress (HFMS, 1996).

[5] More at: https://www.faa.gov/
[6] More at: https://www.eurocontrol.int/

- EUROCONTROL Human Factors – Critical Incident Stress Management: User Implementation Guidelines (2008). Critical Incident Stress Management (CISM) refers to programs designed to support individuals negatively affected by critical events to recover and return to normal functioning and behavior (CISM, 2008).
- EUROCONTROL Fatigue and Sleep Management: Personal strategies for decreasing the effects of fatigue in Air Traffic Control (2005). Fatigue is an important safety issue within the air traffic control system, and there is a regulatory framework for the implementation of measures for detection, monitoring, and management (FSM, 2005).

Developing new strategies that will advance this field and open up perspectives for aviation personnel will certainly be a major challenge. One thing is certain: a human is not a machine, and the question must be asked: how much information is enough? The strategies aim to achieve two main functions. First, to promote consistency in the integration of human factors principles in regulation, management, system design, training, licensing, auditing, and assurance of aviation activities. Second, to describe how practical understanding and application of human factors can serve to improve safety performance in the entire aviation safety system (EHFAG, 2012).

IFATSEA[7] is an international organization for aviation technical personnel for air navigation safety. It was established in 1972 with headquarters in Brussels. In its 2021 study titled "Human Factors of ATSEP," it outlined clear future steps that need to be taken regarding technical-operational personnel. Serious, even fatal, accidents cannot be excluded if the issues of stress and fatigue in ATSEP are not addressed (IFATSEA, 2021).

In developing new strategies in the field of human factors, it will be important to consider a range of experiences to reconcile some earlier and newer viewpoints. The differences between these viewpoints can best be understood through the presentation in Figure 2.

[7] More at: http://www.ifatsea.org/

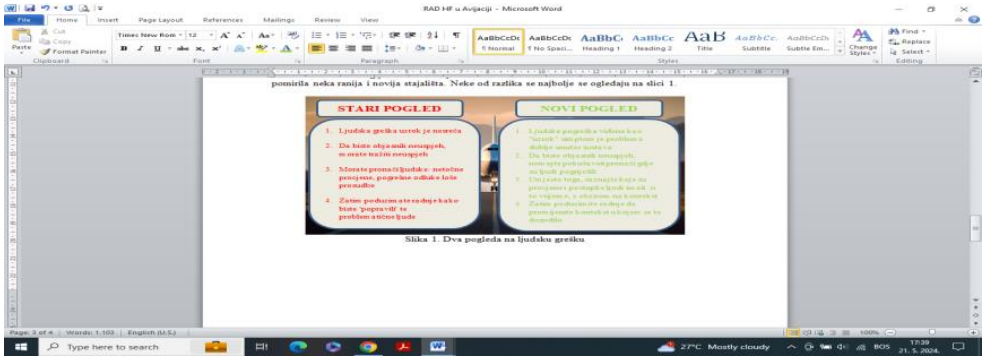

Figure 2. Two views on human error (Source: EUROCONTROL, 2023)

4. ANALYSIS OF ACCIDENTS AND INCIDENTS FROM A SAFETY PERSPECTIVR

Throughout the history of air traffic, numerous accidents have been recorded where the human factor played a key role. Pilot errors account for the cause of airplane crashes in almost half of these tragedies. Following human factors, mechanical failures are the second most common cause of airplane crashes, accounting for 22% of the total number of crashes. In 12% of cases, weather conditions were a factor in airplane accidents, while sabotage or terrorist attacks caused 9% of crashes.

We will highlight two airplane crashes that significantly influenced the perception of safety in air traffic. Additionally, apart from these well-known accidents, we will provide an analysis of a case in an area air traffic control where the human factor led to a dangerous safety incident. Two airplane crashes that led to significant advancements in the field of air traffic safety are:

- Linate Airport Runway Collision, Milan, October 8, 2001

The final report on the runway collision between a Boeing MD-87 and a Cessna Citation at Milan's Linate Airport in October 2001 cites a combination of factors, from deficiencies at the airport to poor communication between pilots and controllers, resulting in the worst aviation disaster in Italy. The accident report points out numerous shortcomings that played a role in the outcome. There was no functional safety management system. Air traffic controllers reported that they "ignored" the existence of signs. The radiotelephony phraseology used by controllers and pilots was not in accordance with ICAO phraseology, and deviations from standard

phraseology were found to be common practice. The controller did not detect the mistake in the Cessna pilot's readback, and the pilots' oversights were not corrected (EUROCONTROL, 2023).

- AIRPROX Near Geneva, Switzerland, February 8, 2007

The AIRPROX incident involved a Lockheed C-130 Hercules aircraft maintaining FL 250, and a Tupolev Tu-154M climbing through the same flight level in the opposite direction. The two aircraft crossed laterally at a distance of 0.4 NM and a vertical difference of 100 ft. Human factors involved in this incident include: the trainee controller allowed the Tupolev to climb to FL 260, creating a conflict with the C-130; the radar coordinator and instructor did not notice the conflict; the Tupolev crew did not follow the TCAS advisories, nor did the C-130 crew; and the instructor did not intervene to prevent the conflict (EUROCONTROL, 2023).

The SOAM analysis was conducted by the author based on events that occurred in an area control center, taking into account the available documentation of the investigation. Specifically, the safety event under direct consideration was related to a human factor that resulted in the closure of airspace. This event occurred in 2018 and was classified as a serious incident.

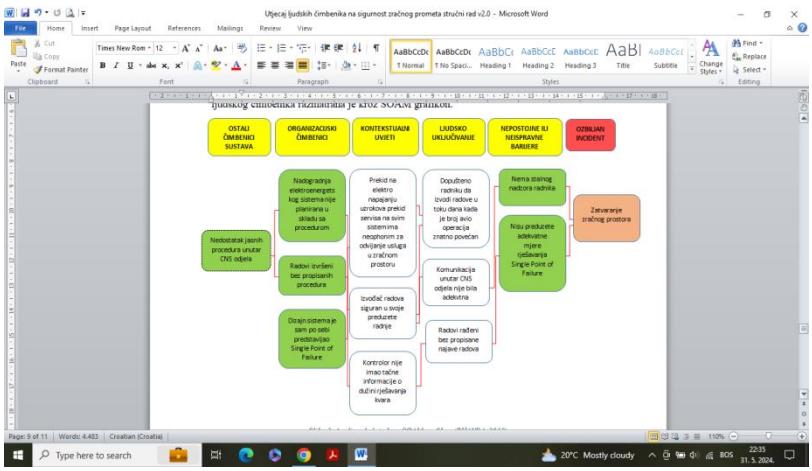

Figure 3. Case Analysis through SOAM Chart (Source: author, 2024)

5. CONCLUSION

Safety in air traffic is inextricably linked to human factors, whose role is crucial in ensuring the security of operations and the performance of personnel. Understanding and managing these factors are essential for minimizing the risk of human errors that can cause incidents and accidents. Therefore, continuous research and improvement of training and education are fundamental pillars of maintaining a high level of safety.

The integration of new technologies and procedures supports human performance, creating an environment in which personnel can efficiently and accurately perform their duties. Case analyses are also of vital importance as they provide deep insights into the causes of accidents, allowing for the application of preventive measures to prevent similar incidents in the future.

This comprehensive approach promotes awareness of human factors and contributes to the continuous improvement of safety in air traffic. By constantly learning from past experiences, applying the latest technological advancements, and empowering personnel Cthrough training and education, airlines and regulatory bodies can work together to create an environment where risks are minimized, and passenger safety becomes an absolute priority.

Human factors and their impact on air traffic safety occupy a central place on the priority list and will become one of the most important issues in the future. Given the increasing complexity of air traffic, as well as the growing number of flights and passengers, the role of human factors becomes even more pronounced. Mistakes or lapses in attention by personnel can have serious consequences, so understanding, managing, and continuously improving in this area is crucial.

With technological advancements bringing new challenges, the need to focus on human factors becomes increasingly urgent. Since it is ultimately people who are responsible for decision-making and carrying out operations, their ability, motivation, and mental state have a direct impact on flight safety. Therefore, proper management of human resources and continuous education will become even more critical elements in maintaining air traffic safety in the years to come.

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