Journal of Agromedicine

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wagr20

Risk Perceptions in Agricultural Aviation

Nishita Sinha, Eva M. Shipp, Tim W. Struttmann, Stephanie C. Payne & Jeffrey D. Borowiec

To cite this article: Nishita Sinha, Eva M. Shipp, Tim W. Struttmann, Stephanie C. Payne & Jeffrey D. Borowiec (2023) Risk Perceptions in Agricultural Aviation, Journal of Agromedicine, 28:3, 393-400, DOI: 10.1080/1059924X.2023.2178570

To link to this article: https://doi.org/10.1080/1059924X.2023.2178570

Published online: 19 Feb 2023.

JOURNAL OF AGROMEDICINE
2023, VOL. 28, NO. 3, 393–400
https://doi.org/10.1080/1059924X.2023.2178570

Taylor & Francis
Taylor & Francis Group

Check for updates

Risk Perceptions in Agricultural Aviation

Nishita Sinha [a], Eva M. Shipp [a], Tim W. Struttmann[b], Stephanie C. Payne[c], and Jeffrey D. Borowiec[d]

[a]Center for Transportation Safety, Texas A&M Transportation Institute, Bryan, TX, United States; [b]Southwest Center for Agricultural Health, Injury Prevention and Education, Tyler, TX, United States; [c]Psychological and Brain Sciences, Texas A&M University, College Station, TX, United States; [d]Jviation, a Woolpert Company

ABSTRACT

Background: Agricultural aircraft operations are an integral part of the agricultural sector. According to the National Agriculture Aviation Association (NAAA), aerial applications are conducted in all 50 states of the U.S. and account for 28% of all treated cropland. A typical application operation consists of an operator (Part 137 certificate holder, permission to apply chemicals to agricultural crops) and one or more pilots. This article explores the risk perceptions of operators (pilots with a Part 137 certificate) and non-operators (pilots without a Part 137 certificate) using data from two industry surveys.

Methods: In an effort to explain the differences between risk perceptions of operators and non-operators, a series of regression analyses were conducted controlling for age, work experience, prior encounters with hazards and history of reported injuries. In addition to exploring the aggregated perceptions across all hazards, perceptions of specific hazards were also examined.

Results: Data indicate that non-operators perceive hazards as significantly more dangerous than operators. Power lines are perceived as the most hazardous, followed by communication towers and meteorological towers. The regression results indicate that risk perception differences remain even after controlling for differences in age, work experiences, prior hazard encounters and injuries between the two groups.

Conclusions: Heterogeneity in risk perceptions within an organization can result in discrepancies over daily decision-making concerning operations. Further research is needed to identify the causal factors behind the observed differences.

KEYWORDS
Agricultural aviation; hazards; pilots; risk perception; safety

Introduction

The agricultural aviation industry is an integral part of the agricultural sector. The industry supports agricultural production through rapid and efficient application of fertilizers and crop protection products without damaging the crop or eroding the essential topsoil. Furthermore, the industry protects forest cover and against diseases caused by mosquitoes carrying West Nile Virus and encephalitis. According to the National Agricultural Aviation Association (NAAA), aerial applications are conducted in all 50 states in the U.S. Approximately 28% of cropland treatment and 100% of forest protection application are conducted by the agricultural aviation industry.

The Code of Federal Regulations (CFR) Part 137 defines "*Agricultural aircraft operation*" as the operation of an aircraft for the purpose of (1) dispensing any economic poison, (2) dispensing any other substance intended for plant nourishment, soil treatment, propagation of plant life, or pest control, or (3) engaging in dispensing activities directly affecting agriculture, horticulture, or forest preservation, but not including the dispensing of live insects. Work is organized largely "on demand" where the operator receives a call from a farmer/client who needs an application on their field. The specific location, product, remuneration, schedule, possible follow up applications are agreed to and the application is conducted. In the U.S., a typical application operation consists of an operator (Part 137 Certificate holder, permission to apply chemicals to agricultural crops) and one or more pilots. The operator is the business owner who has the Part 137 certificate to apply chemicals. The pilot is employed by the operator to fly agricultural aircraft. In some cases, the pilot may be a self-employed contractor hired by operators. Operators and pilots work together to apply treatments to crops or crop land. Many operators start out as pilots and later pursue the

CONTACT Nishita Sinha n-sinha@tti.tamu.edu Center for Transportation Safety, Texas A&M Transportation Institute, Bryan, TX, United States

Part 137 certificate. More than half the operations in the U.S. are based on a private grass airstrip where the operators themselves fly the aircraft.

According to the latest NAAA survey conducted in 2018, of the 550 operators who participated in the survey, 503 (93%) were also pilots. They are referred to as "operators" in this paper. The survey was also completed by 305 pilots who make aerial applications but do not hold a Part 137 certificate themselves. In this paper, they are referred to as "non-operators". According to this same survey, operations have an average of 6.29 employees (*SD* = 8.79). One-half of the operations have three or fewer employees. Most (58%) operate out of a private airport. This non-standard work environment is characterized by rapidly changing and varied work conditions along with a highly trained, contracted workforce in a high-risk setting. According to the Bureau of Labor Statistics, there were 37,870 commercial pilots in the U.S. in 2018. Of these, approximately 3,385 are in agricultural aviation.[1] The Federal Aviation Administration[2] reported in 2019 that agricultural pilots operated 3,100 aircraft and flew 884,000 hours.

Aerial applicators face a set of unique challenges and constraints associated with agricultural aviation operations. For example, there is a risk of collision when operating at low altitudes and of drift when operating dispensing equipment.[3] In aviation, *accidents* is the term used to describe occurrences resulting in a fatality or injury, aircraft damage or structural failure, or a missing or completely inaccessible aircraft.[4] Available data suggest an overrepresentation of accidents in agricultural aviation. In 2019, the overall agricultural aviation accident rate was 6.87 accidents per 100,000 agricultural hours flown, in comparison to 5.43 accidents per 100,000 hours flown for the remainder of general aviation (excluding part 135).[5] Over the last 7 years (2014–2020), the average share of fatal accidents in agricultural aviation has gone up by 118%, compared to the average in the 7 years preceding 2014.[6]

In contrast to the early years of aviation when the primary cause of aircraft accidents was mechanical, the modern era with advanced technology and extremely reliable aircraft has witnessed a rising proportion of accidents that can be attributed to human error.[7] According to Li et al.,[7] who studied 165 crash records from 1983–1997, pilot error was a contributing factor in 73% of the accidents involving younger pilots and in 69% of the crashes involving older pilots. In a detailed assessment of agricultural aviation accidents that occurred in 2017, out of a total of 67 accidents, "collision with objects" accounted for the largest number ($n = 21$) of accidents, including two fatalities.[8] The Federal Aviation Administration Pilot's Handbook of Aeronautical Knowledge[9] identified risk factors and five hazardous attitudes that contribute to poor pilot judgment: anti-authority, impulsivity, invulnerability, macho, and resignation. In agricultural operations, fatal accidents are most often the result of the pilot failing to maintain safe distances from obstacles or failing to see obstacles while maneuvering.[10] In a study of 78 agricultural aviation accidents occurring in 2013 by the National Transportation Safety Board,[3] researchers found four consistent safety issues: lack of guidance for pilot knowledge and skills tests, inadequate aircraft maintenance, lack of agricultural operations-specific fatigue management, and a lack of risk-management guidance. According to the National Transportation Safety Board's special investigation report on agricultural aviation industry,[3] risk management is necessary to help operators and pilots mitigate the unique risks associated with their operation. Risk management refers to a decision-making process through which pilots identify hazards, ascertain the associated degree of risk, and choose their course of action.[3]

Risk perception is a key aspect of risk management and an extensively studied construct in the safety literature. Risk perception is a subjective judgement about the likelihood of encountering hazards.[11] Biased risk perception can lead to underestimation of actual risks and ultimately erroneous decisions. Several models of behavior change such as the Health Belief model,[12] Protection Motivation Theory,[13] the Extended Parallel Process Model,[14] and the Risk Perception Attitude framework include the concept of risk perception.[15] Among factors that shape these subjective beliefs include past experiences, personal communications, and socio-economic factors.

Fraser-Mackenzie et al.[16] stress the importance of including individual background information (domain experience, culture, etc.) when attempting to rectify biases in risk perceptions. Thomson et al.[17] reported a significant negative correlation between hours of flight time in general aviation and risk perceptions, suggesting that more experienced pilots perceive lesser risk.

This study examines the extent to which operators and non-operators perceive hazards the same way. In addition to exploring the perceptions at the aggregate level, perceptions of specific hazards are also examined. Operators, who are often the employers of non-operator pilots are likely to determine the safety climate in an operation, and thereby, the safety behavior of their employees. When operators and non-operators do not perceive hazards similarly, this is likely to result in discrepancies over daily decision-making concerning operations.

Methods

Two waves of web-based survey for Federal Aviation Regulations (FAR) Part 137 operators and pilots were conducted in 2011 and 2018 with support from the National Agricultural Aviation Association (NAAA) and the Southwest Center for Agricultural Health Injury Prevention, and Education. The 2011 web-based survey data were collected between December 14, 2010 and March 31, 2011. The 2018 survey was conducted between January 26, 2018 and April 29, 2018. Participants were recruited from the list of all Part 137 operations purchased from Airpac, Inc. of Edmond, Oklahoma, containing 1,880 names, addresses, telephone numbers, aircraft and company names. To enhance response rates, prior to its roll out, the survey team presented the survey to and gained approval of NAAA and National Agricultural Aviation Research & Education Foundation (NAAREF) boards. The president and executive director of NAAA and board chair of NAAREF agreed to author recruitment postcards and emails to operators and pilots to lend credibility to the survey. The survey was administered during the least busy season for operators and pilots. A "Thank You/Reminder" post card was sent 2 weeks after the initial letter. Response rates were 38% and 35% for the 2011 and 2018 surveys, respectively. This study is based on data from the two surveys and focuses on risk perception items and select socio-demographic variables.

Table 1. Potential hazards listed in the 2018 NAAA Survey*.

Chemicals	Power lines	Adverse weather
Rotating prop	Communication towers	Limited space for maneuvering
Engine noise	Wind turbines	Unmanned aircraft systems
Cockpit clutter	Meteorological towers	Aircraft being shot at
Birds	Mechanical failure	Night application

*The 2011 survey did not include unmanned aircraft systems, aircraft being shot at, and night application.

A total of 717 respondents – 415 operators (387 pilots and 28 non-pilots) and 302 non-operators rated all the risk perception items in the 2011 survey. In the 2018 survey, 607 respondents – 374 operators (351 pilots and 23 non-pilots) and 233 non-operators rated all risk perception items. These items are presented in Table 1. The 2011 survey presented the respondents with 12 hazards, whereas the 2018 survey had 15 hazard items, including unmanned aircraft systems, or UAS aircraft being shot at, and night application.

The aggregate exploratory analyses are based on 717 and 607 respondents from the 2011 and 2018 surveys, respectively, when analyzing the risk perception data, and corresponding subsets of data when examining relationships with other socio-demographic variables. The group level analysis is based on two mutually exclusive sets of pilot respondents from the two waves – operators ($n = 387$ in 2011 and $n = 351$ in 2018 survey) and non-operators ($n = 302$ in 2011 and $n = 233$ in 2018).[1]

Data on select socio-demographic variables were also included in the analysis to explore factors that can contribute to differences in risk perceptions between the operators and non-operators. These variables include age, work experience, prior hazard encounters, and prior injuries.

Measures

Participants were presented with a list of 15 potential hazards (listed below) and asked to rate each one on a 10-point scale.

> *"During the active spray seasons, you [pilots]/your employees/contractors [operators] may be exposed to many hazards. Score each item below where 1 is*

considered "not a risk" and 10 is considered "extremely risky."

Example:

Crossing the street without looking 7

Mowing the lawn with bare feet 7

Running with scissors 2

Table 1 presents the list of hazards for which the survey elicited a risk perception rating. These items did not differ between the operator and pilot surveys.

In the surveys, cumulative work experience was measured using four different variables namely: (i) years in industry, (ii) years as an agricultural pilot, (iii) total hours flown, and (iv) total agricultural hours flown. Due to a high correlation among the measures (in excess of 0.7), only total agricultural hours flown was used as a measure of work experience in the analyses.

Respondents were asked about their prior encounters with unmarked communications towers, wind turbines, and unmarked meteorological towers, and any work-related injuries that required treatment at a hospital or doctor's office in a Yes-No format for the previous calendar year (2010 or 2017). For example, "In 2017 did you encounter unmarked communication tower(s) when making aerial applications?" Information on prior hazard encounters was not collected in the 2011 survey.

Procedures

Survey participants responded to the items online one after another. Items related to socio-demographic variables (age, education, experience) were answered first, followed by risk perception items. All risk perception items were presented at once, and participants were free to complete the ratings in any order. Information on prior hazard encounters and injuries was collected at the end. Participants could return to earlier questions if they wanted to edit their response. Participants were not compensated. On average, respondents completed the surveys in 28 minutes.

Results

A factor analysis of the risk perception items was conducted using STATA (IC 16.1) to determine the dimensionality of this measure. Note that there were 15 such items in the 2018 survey and 12 items in the 2011 survey. Factor analysis suggested that there was a single unobserved construct driving the variation among the items.[2] Accordingly, it was decided to use an average of risk perception ratings as an aggregate measure of risk perception. Only the 12 common risk perception items were used to estimate the average perception rating for each survey.

The mean risk perception rating across all hazards was 4.29 ($SD = 1.63$) in the 2011 survey versus 4.43 ($SD = 1.62$) in the 2018 survey. The mean risk perception ratings for respondents across both surveys were highest for power lines, followed by communication towers and meteorological towers. The mean risk perception rating was lowest for cockpit clutter. Table 2 presents the aggregate and group-level summary statistics for respondents who rated all risk perception items in each survey.

Focusing on pilots alone, it was observed that while both operators and non-operators perceived power lines and communication towers as the most dangerous, those in the non-operator group rated them as more dangerous than operator-pilots. The average risk perception rating for operators was lower than the non-operator group in both surveys. In the 2011 survey, the average risk rating for operators ($M = 4.12$, $SD = 1.57$) was lower than that of non-operators ($M = 4.50$, $SD = 1.70$). The observed difference in perception ratings was statistically significant (Mann-Whitney test $p < .01$). Risk perception ratings from the 2018 survey aligned with this observation. The difference between average risk perception of the operators ($M = 4.28$, $SD = 1.61$) and non-operators ($M = 4.67$, $SD = 1.65$) was statistically significant (Mann-Whitney test $p < .01$).

For individual hazards, non-operators rated power lines, communication towers, mechanical failure, adverse weather, and birds significantly more dangerous than operators in the 2011 survey. In the 2018 survey, non-operators rated power lines, communication towers, adverse weather, mechanical

Table 2. Mean risk perception ratings (Standard deviation in parenthesis).

	Survey 2011			Survey 2018		
	All (*N* = 717)	Operators (*N* = 387)	Non-Operators (*N* = 302)	All (*N* = 607)	Operators (*N* = 351)	Non-Operators (*N* = 233)
Chemicals	3.73 (2.29)	3.64 (2.08)	3.82 (2.50)	4.58 (2.32)	4.63 (2.27)	4.44 (2.41)
Rotating Prop	4.32 (3.08)	4.33 (3.03)	4.23 (3.14)	4.83 (2.95)	4.86 (2.87)	4.71 (3.06)
Engine Noise	3.29 (2.23)	3.16 (2.02)	3.45 (2.46)	3.89 (2.36)	3.85 (2.35)	3.92 (2.38)
Cockpit Clutter	2.11 (1.83)	1.98 (1.66)	2.23 (2.01)	2.44 (2.03)	2.22 (1.87)	2.73 (2.18)
Birds	3.77 (2.18)	3.47 (2.18)	4.19 (2.11)	4.18 (2.19)	4.01 (2.24)	4.40 (2.05)
Power Lines	6.74 (2.41)	6.49 (2.37)	7.04 (2.46)	7.33 (2.12)	7.10 (2.18)	7.70 (1.97)
Communication Tower	6.30 (2.78)	6.04 (2.80)	6.57 (2.75)	6.48 (2.57)	6.31 (2.53)	6.78 (2.59)
Mechanical Failure	4.09 (2.68)	3.87 (2.52)	4.34 (2.86)	4.20 (2.59)	4.72 (3.44)	4.54 (3.36)
Adverse Weather	3.79 (2.57)	3.52 (2.44)	4.12 (2.72)	4.51 (2.69)	6.00 (3.34)	6.06 (3.26)
Limited Space	3.57 (2.59)	3.31 (2.47)	3.91 (2.71)	4.02 (2.59)	3.94 (2.40)	4.62 (2.74)
Wind Turbine	4.18 (3.45)	4.08 (3.44)	4.41 (3.51)	4.61 (3.41)	4.19 (2.54)	5.09 (2.77)
Meteorological Tower	5.59 (3.63)	5.57 (3.60)	5.69 (3.68)	5.97 (3.32)	3.63 (2.43)	4.60 (2.65)
UAS	-	-	-	3.71 (2.83)	3.66 (2.80)	3.88 (2.94)
Aircraft Shot	-	-	-	3.06 (2.71)	2.95 (2.55)	3.29 (2.95)
Night Application	-	-	-	2.59 (2.90)	2.16 (2.54)	3.27 (3.28)

failure, limited space, birds, and cockpit clutter significantly more dangerous than operators.

Among socio-demographic variables, operators have significantly more experience with flying than the non-operators. In the 2011 survey, operators had flown an average of 10,087 ($SD = 9{,}034$) agricultural hours over their career, whereas non-operators had flown an average of 8,548 ($SD = 7{,}992$) hours. In the 2018 survey, operators had flown an average of 9,867 ($SD = 7{,}213$) hours whereas non-operators had flown 7,067 ($SD = 7{,}698$) hours. Additionally, operators are older than non-operators. In the 2011 survey, the mean age of respondents in the operator group was 53 ($SD = 12$) years, in comparison to 50 ($SD = 13$) years for the non-operators. In the 2018 survey, the mean age of operator respondents was 54 ($SD = 12$) versus 47 ($SD = 14$) for the non-operators. Differences in hours flown and age between operators and non-operators were statistically significant (Mann-Whitney Test; $p < .01$) in both 2011 and 2018 surveys.

The 2018 survey elicited information on prior hazard encounters. Among operators, 59% had encountered an unmarked communication tower and 54% a wind turbine. Among non-operators, 55% had encountered an unmarked communication tower, and 57% had prior encounters with a wind turbine. Reported injuries were a rare event in both 2011 and 2018 surveys. In 2011 survey, only 6% of the operators and 2% of the non-operators reported an injury that required treatment at a hospital or a doctor's visit in the year before. In the 2018 survey, these figures were 6% for operators and <1% for non-operators. More operators reported a prior injury than non-operators in both surveys. Using Fisher's exact test ($p < .01$), it is noted that operators are more likely to report injuries than non-operators. The intercorrelations among the study variables for each survey are presented in Table 3.

Table 3. Pearson correlation coefficient estimates.

	2011 Survey				2018 survey				
Variables	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(5)
(1) Risk Perception	1.00				1.00				
(2) Age	0.14**	1.00			−0.14**	1.00			
(3) Total ag hours flown	0.09**	0.49**	1.00		−0.10**	0.57**	1.00		
(4) Prior injuries	0.03	0.05	0.05	1.00	0.14**	0.07	0.12**	1.00	
(5) Prior hazard encounter	-				0.05	−0.06	−0.03	0.01	1.00

Notes: ** $p < .05$.

Table 4. Ordinary least squares regression estimates (robust standard errors in parenthesis).

	(1)	(2)	(3)	(4)
Variables	2011 Survey		2018 Survey	
Age	−0.02**	−0.02**	−0.01**	−0.01
	(0.01)	(0.01)	(0.01)	(0.01)
Total ag hours	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Prior injury	0.30	0.38	1.24**	1.32**
("Yes" = 1)	(0.28)	(0.29)	(0.41)	(0.41)
Prior hazard encounter	-	-	0.14	0.13
("Yes" = 1)			(0.15)	(0.15)
Group		0.34**		0.29**
("Non-operators" = 1)		(0.13)		(0.14)
Constant	5.19**	4.95**	5.41**	5.15**
	(0.28)	(0.28)	(0.29)	(0.30)
N	688	688	584	584
R^2	0.02	0.03	0.04	0.05

Notes: ** $p < .05$.
Prior hazard encounter is a binary variable that equals 1 if the respondent reported a prior encounter with either a communication tower or a wind turbine and 0 otherwise. 71% reported prior encounters with either or both of the two hazards.

To investigate the extent to which differences in risk perceptions between the operators and non-operators exist after controlling for the contributing factors, hierarchical regression analyses were conducted. Average risk perception rating was the dependent variable in all the analyses. The results are presented in Table 4. As can be seen in the table, even after controlling for these variables, the difference in risk perceptions between operators and non-operators remains statistically significant.

Discussion

The analyses in this study highlight several important safety-related concerns in agricultural aviation. In addition to identifying the hazards that are perceived most dangerous by the aerial applicators, this study reveals important differences in risk perceptions between operator and non-operator pilots. These differences were probed further to show that they are not attributable to age and the various experience measures in this study.

A potential factor that could be responsible for the difference in risk perception is different work incentives arising from business ownership of operators versus non-operators' hired employee nature of work. More research, however, is needed to pinpoint the factor(s) responsible for the observed divergence in risk perceptions, as well as the extent to which this influences the interactions between operators and pilots. Another source of Ag Aviation injury and accident data is AgInjuryNews.org. It may be interesting to search this database for information about incidents concerning operators and non-operators as well as the hazards examined in the study.

Whereas the replication of the difference between operators and non-operators across both surveys suggests a robust discrepancy, there is likely some overlap between the two samples that cannot be determined. Future research might gather respondent identification information to allow for such determinations and to enhance the research questions that could be tested. For example, given the positive relationship between age and risk perceptions, how do individual risk perceptions change over time?

Despite its limitations, this study fills important gaps in the agricultural aviation and occupational safety literature. This study is the first to formally analyze risk perceptions in agricultural aviation. Furthermore, contrary to the findings of Zohar[18] and Hallowell,[19] the results suggest there can be heterogeneity in risk perceptions within organizational levels. Knowledge about risk perceptions and heterogeneity has the potential to guide safety training programs and minimize perception inaccuracies. Safety training programs take an even more important role in mitigating accidents in the U.S. where Unmanned Air Vehicles (UAVs) are unlikely to replace manned vehicles for mass application. Given the large average acreage (441 acres) in the U.S. and small chemical capacity of UAVs, the widespread use of UAVs is not attainable at present. UAVs are also significantly smaller in size and can be invisible to other low flying manned aircrafts such as emergency medical helicopters, firefighting, and law enforcement, posing safety concerns.[20] Currently, NAAA is of the view that proper risk and drift assessment need to be performed before UAVs can be recommended for pesticide spraying in future.

Conclusions

The aerial application industry is critical to modern agriculture. The industry supports the nation's growing demand for food and fiber by increasing crop yields, in turn, promoting efficient land use. Given the increase in fatalities within this industry, it is paramount to determine opportunities to improve pilot safety, which begins with the relatively fundamental perception of hazards and risks. Future studies may focus on identifying factors that cause the observed divergence in the risk perceptions between operators and non-operators and identify ways to ensure those perceptions are valid.

Notes

1 A third mutually exclusive group of non-pilot operators; $n = 28$ in 2011 and $n = 23$ in 2018 has not been included in the results due to its small sample size.

2 Kappa's coefficient alpha (measure of internal consistency between the items) of 0.88 and 0.85 were observed between the items in 2018 and 2011 surveys, respectively.

Acknowledgments

Authors are grateful to the Southwest Center for Agricultural Health Injury Prevention, and Education for supporting the research.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Southwest Center for Agricultural Health, Injury Prevention, and Education through Cooperative Agreement # U54-OH007541 from CDC/NIOSH.

Disclaimer

No financial interest or benefit has arisen from the direct applications of this research.

ORCID

Nishita Sinha http://orcid.org/0000-0002-8247-6867
Eva M. Shipp http://orcid.org/0000-0002-4034-8031

References

1. agaviation.org [Internet]. Alexandria, VA: NAAA. Available from : https://www.agaviation.org/naaaindustrysurveys. [cited 2022 Apr 20].
2. faa.gov [Internet]. Washington (DC): FAA. Available from : https://www.faa.gov/data_research/aviation_data_statistics/general_aviation/CY2019/ [cited 2022 Apr 20].
3. ntsb.gov [Internet]. Washington (DC): NTSB. Available from : https://www.ntsb.gov/safety/safety-studies/documents/sir1401.pdf [cited 2022 Apr 20].
4. aviation-accidents.net [Internet]. Aviation Accident Database; [cited 2022 Apr 20].Available from: Accidents and Incidents Aviation Accident Database (aviation].Available from: Accidents and Incidents Aviation Accident Database (aviationaccidents.net)
5. agaviation.org [Internet]. Alexandria, VA: NAAA. Available from: http://news.agaviation.org/naaa/issues/2021-02-04/index.html [cited 2022 Apr 20].

6. agaviation.org [Internet]. Alexandria, VA: NAAA. Available from:https://www.agaviationmagazine.org/agriculturalaviation/winter2017/MobilePagedArticle.action?articleId=1068392#articleId1068392 [cited 2022 Apr 20].
7. Li G, Baker SP, Lamb MW, Grabowski JG, Rebok GW. Human factors in aviation crashes involving older pilots. *Aviat Space Environ Med*. 2002;73:134–138.
8. agaviation.org [Internet]. Alexandria, VA: NAAA. Available from : https://www.agaviationmagazine.org/agriculturalaviation/winter_2018/MobilePagedArticle.action?articleId=1311121#articleId1311121 [cited 2022 Apr 20].
9. Duncan JS. *Pilot's Handbook of Aeronautical Knowledge*. US Department of Transportation Federal Aviation Administration Flight Standards Service; 2016, pp. 25–32.
10. van Doorn Rr. Accidents in agricultural aviation in the United States. *Aviat Psychol Appl Hum Factors*. 2014;4(1):33–39. doi:10.1027/2192-0923/a000053.
11. Gierlach E, Belsher BE, Beutler LE. Cross-cultural differences in risk perceptions of disasters. *Risk Anal*. 2010;30(10):1539–1549. doi:10.1111/j.1539-6924.2010.01451.x.
12. Rosenstock IM. Why people use health services. *Milbank Meml Fund Q*. 1966;44(3):94–124. doi:10.2307/3348967.
13. Rogers RW, Prentice-Dunn S Protection motivation theory. Handbook of health behavior research 1: Personal and social determinants. 1977;113–132.
14. Witte K. Putting the fear back into Fear Appeals: the Extended Parallel Process Model. *Commun Monog*. 1992;59(4):329–349. doi:10.1080/03637759209376276.
15. Paek HJ, Hove T Risk perceptions and risk characteristics. In: Oxford Research Encyclopedia Of Communication. 2017 Mar 29.
16. Fraser-mackenzie P, Sung MC, Johnson JE. Toward an understanding of the influence of cultural background and domain experience on the effects of risk-pricing formats on risk perception. *Risk Anal*. 2014;34(10):1846–1869. doi:10.1111/risa.12210.
17. Thomson ME, Onkal D, Avcioğlu A, Goodwin P. Aviation risk perception: a comparison between experts and novices. *Risk Anal*. 2004;24(6):1585–1595. doi:10.1111/j.0272-4332.2004.00552.x.
18. Zohar D. A group-level model of safety climate: testing the effect of group climate on microaccidents in manufacturing jobs. *J Appl Psychol*. 2000;85(4):587–596. doi:10.1037/0021-9010.85.4.587.
19. Hallowell M. Safety risk perception in construction companies in the Pacific Northwest of the USA. *Constr Manage Eco*. 2010;28(4):403–413. doi:10.1080/01446191003587752.
20. agaviation.org [Internet]. Alexandria, VA: NAAA. Available from : https://www.agaviation.org/uasefficency [cited 2022 Nov 6].