Method to study risk perception in aircraft maintenance

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SUMMARY

In this article, we present the methodology we developed to propose an original model of mechanics' risk perception adapted to the aircraft maintenance field. We have identified 20 concepts that can be mobilised to build the model. To focus our study on a limited number of targeted concepts, we carried out a 4-stage selection process. As a result, the model was reduced to 4 factors and 3 measures of risk perception.

KEYWORDS

Safety, aircraft maintenance, hazards, taxonomy.

Introduction

Why study risk perception of aircraft mechanics?

The aircraft maintenance activity is governed by numerous rules and procedures which require maintenance organisations to have the human and material resources necessary to maintain safety. More specifically, aircraft maintenance organisations must implement a continuous safety management process that makes it possible to identify hazards, to assess risks to equipment and/or people and to establish appropriate safety measures (ICAO, 2018). In this context, our question is to know the role that the aircraft mechanic plays in maintaining safety.

Even before starting to work as aircraft mechanics, the latter must prove to the relevant authorities that they have the necessary theoretical knowledge and practical skills. Theoretical knowledge is acquired in organisations certified by the European Aviation Safety Agency (EASA) (valid only for European member states which can be different in other countries). This means that during their initial training, mechanics students are expected to have the knowledge required to carry out the maintenance operations completely safely. For example, a module entitled "Human Factors" must be validated, implying that students are aware of the risks associated with human error. In this context, we also wanted to know the real impact of this initial training on mechanics' perception of risk.

During their initial theoretical training, the students choose a speciality between aircraft structure, systems, or avionics. Depending on their speciality, they will therefore be exposed to different risks. In addition, during their initial practical training (which lasts between 3 and 5 years and must take place in an EASA-certified maintenance centre), the students will be specialised in a particular type or family of aircraft. Once this step is complete, they apply for their licence to the relevant authority. The licence is validated if the EASA requirements are fulfilled. Note that the speciality and the type of aircraft determine the tasks the mechanic will be able to perform, and therefore the hazards to which he/she will be exposed. For example, a B2 (Avionics) mechanic on an A320 will only be able to carry out the maintenance tasks related to the A320 family's electrical systems. Thus, we need to consider the impact that the specialties chosen can have on mechanics' perception of risk.

Once in service, mechanics receive training or refresher courses every two years as required by the EASA and covering very specific risks. For example, Electrical Wiring Interconnection System (EWIS) training covers electrical risks. Thus, mechanics' knowledge and on-going training would present a high importance for the authorities. Consequently, we also need to consider the impact of this additional knowledge on mechanics' perception of risk. Similarly, over the years, mechanics will gain experience and be faced with incidents or even accidents that could potentially impact their health and/or the airworthiness of the aircraft. We therefore need to consider in our study the impact of this experience of risk. Our approach also needs to identify which one, between training and personal experience, has the greatest impact on risk perception.

From a theoretical point of view, mechanics are responsible for performing the maintenance task in accordance with the documentation (procedures) which will inform them, through warnings, of the risks to their health and, through the cautions, of the risks to the equipment (mainly the aircraft). In this respect, these procedures are a safety barrier which must be followed step by step, and which ensure the quality of the work performed. Paradoxically, mechanics are not asked to make any judgments about risks. Indeed, if a hazard has been identified by the employer or mentioned in the procedure and associated with a safety measure, then the risk is present. In this case, mechanics must apply the appropriate safety measures. However, even though safety is a top priority, and that mechanics are trained, made aware and informed of the risks, incidents and accidents occur. For example, health insurance in France tells us that 75% of occupational accidents in aircraft maintenance are caused by working at height (L'assurance maladie, 2019). Regarding aircraft airworthiness, studies show that human error plays a major role in the occurrence of incidents and accidents (Hobbs, 2008). This highlights the importance of considering the human factors in improving safety. However, despite the efforts to understand and anticipate human error, incidents and accidents still occur. For this reason, we would like to conduct a study of risk perception to be able to understand the day-to-day risk management by aircraft mechanics.

What is risk perception?

Risk perception is a multidimensional concept (Slovic, 2000), subjective (Orasanu et al., 2002) and composed of rational and intuitive elements (Slovic et al., 2013). Numerous models and theories have emerged, such as the theory of expected utility, which models an investor's decision-making as a function of his or her attitude through "the utility function" (Kouabenan et al., 2007, p40), an attitude characterised either by risk aversion, a neutral attitude or risk-taking. Also, the cultural theory, which stresses the importance of considering the culture or social context in which an individual is situated (Douglas & Wildavsky, 1983). And the psychometric paradigm which is based on the idea that risk perception can be measured using a set of risk characteristics such as immediacy of effect, severity of consequences, dread, etc. (Fischhoff et al., 1978).

Apart from these models, other factors have been identified as explaining a greater or lesser share of the variance in risk perception. For example, risk experience (Kummeneje & Rundmo, 2018), age (Trillo-Cabello et al., 2021) or gender (Rundmo & Nordfjærn, 2017), anger and fear (Lerner & Keltner, 2001), anxiety (Rahn et al., 2021), worry (Wolff et al., 2019), trust (Siegrist et al., 2005), safety climate (Oah et al., 2018), belief (Sjöberg & Af Wåhlberg, 2002), personality (Le & Arcodia, 2018), expertise (Martínez-Fiestas et al., 2020) and training (Namian et al., 2016). However, from our knowledge, there is no consensus on how risk perception can be defined and measured. Thus, to study the perception of risk by aircraft mechanics, some preliminary reflection has been done with the aim of building a model suited to the field of study. More specifically, we aim to identify the concepts that influence the way aircraft mechanics perceive and assess risks on a daily basis.

Method

The methodology used in this study should enable us to answer two questions: 1) How can we measure the risk perception of aircraft mechanics? 2) What factors could explain a significant part of the variance in risk perception?

Construction of the model

The literature review enabled us to identify 20 concepts that can be grouped into 5 dimensions: "Socio-cultural", "Cognitive", "Affective", "Individual" and "Demographic". Figure1 shows a graphical representation of the complete model.

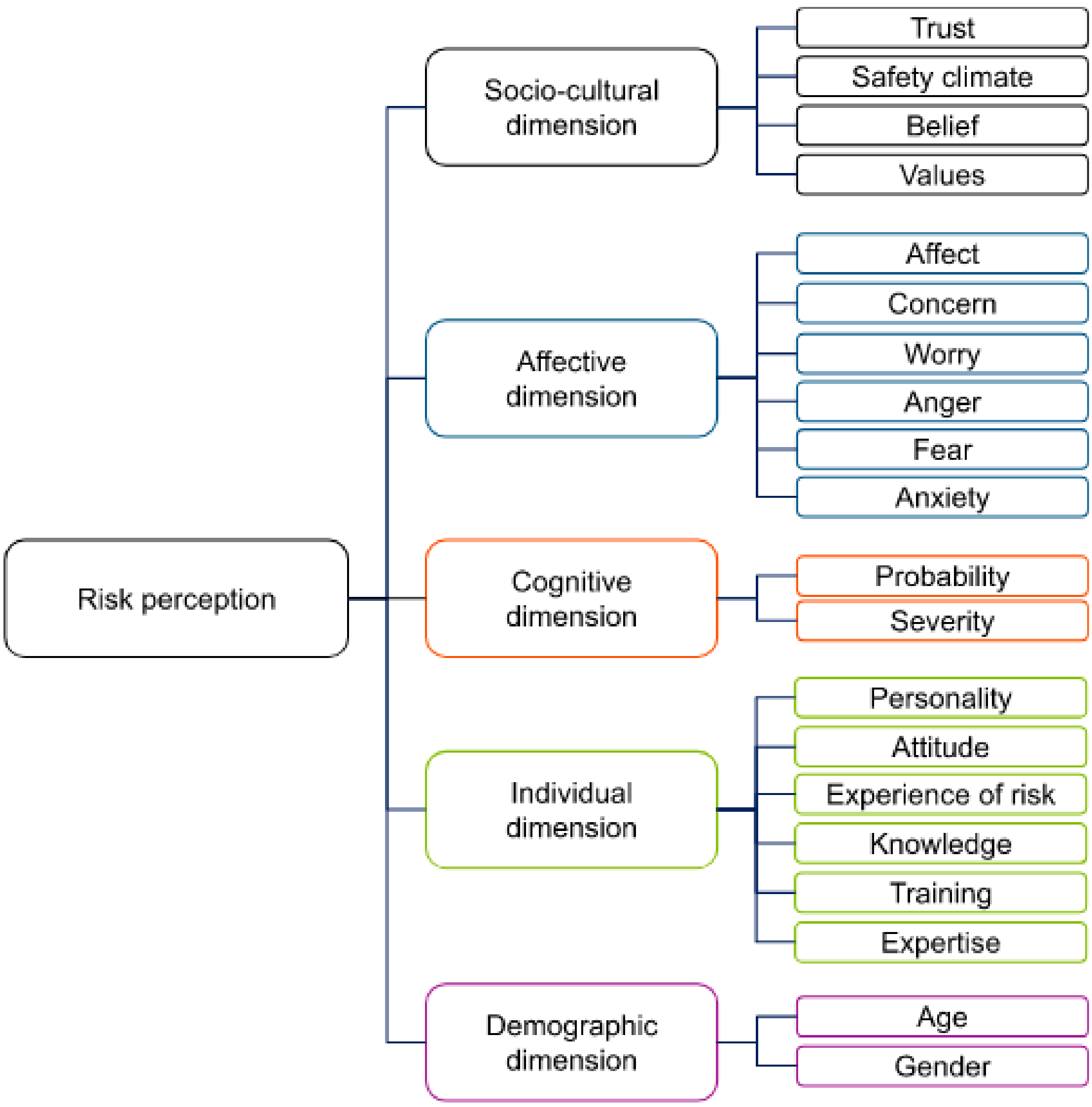

Figure 1: The 20 concepts identified through the literature.

To focus our study on a limited number of targeted concepts, we carried out a 4-step selection process: 1) To define the 20 concepts. 2) To establish selection criteria. 3) Weight the criteria. 4) To prioritise the concepts. The next step was to identify the concepts that would enable risk perception to be measured, and those that would be studied as explanatory factors for variance in risk perception. The concept selection process was carried out by experts familiar with in-the-field and operational issues. Three experts were involved: a former aircraft mechanic and two trainers in the field of aircraft maintenance.

To define the concepts

As a first step, we attempted to specify each of the 20 concepts that could be considered in our study. For example, the concept of "knowledge" which, as previously mentioned, is crucial to maintain safety, may correspond to the knowledge that mechanics possess concerning the hazards present in a task, or the associated consequences, or the safety measures to be applied.

To establish the selection criteria

Once the concepts have been defined, three selection criteria were used:

- C1: "Applicability to aircraft maintenance", which identifies if a concept can meet the need for day-to-day risk management. It also enables us to write accurate and applicable recommendations.
- C2: "Importance of the concept in the literature" which corresponds to the need to select factors for which there is a certain consensus in the literature.
- C3: "Ease of measurement" is related to the need to carry out experiments in a relatively limited timeframe, of one hour maximum, to optimise the chances of access to working mechanics. Indeed, the current shortage of manpower in the aircraft maintenance field makes it difficult to recruit participants for our study.

Each concept will be evaluated through the three criteria using a 5-point Likert scale rated from 1 (Strongly Disagree) to 5 (Strongly Agree).

To weigh the criteria

To weigh the importance of each criterion, we used Saaty's (1987) multi-criteria analysis method. First, we constructed a comparison matrix to assign an importance score between two criteria. This allows us to establish that the criterion C1 "Applicability to aircraft maintenance" has a low importance compared to C2 "Importance of the concept in the literature". Indeed, although the study of risk perception must be applicable to our field of study, it is also important to consider the results of the literature. Criterion C1 has a very high importance compared to C3 "Ease of measurement", as it is preferable for the concept to be applicable to the field of study rather than easily measurable. The maximum "extreme importance" was not used, as we also need to create a study that is feasible in terms of duration. Criterion C2 has a higher importance than C3, as it is more important to consider results in relation to ease of measurement. It should be noted that the importance scores were assigned based on the authors' judgement.

Using various calculations described by Saaty (1987), the comparison matrix provides weights for each criterion, as follows: WC1 = 0.64, WC2 = 0.28, WC3 = 0.07. The consistency ratio is R = 0.06 and less than 10%, so the assessment is deemed consistent.

To prioritise the concepts

To rank the concepts, a Final Score (FS) for each concept "i" named "FSi" was calculated. Each FSi is the weighted sum of the scores of each concept "i" on each criterion. This gives the following formula: FSi = 0.64*SC1i + 0.28*SC2i + 0.07*SC3i, with SC1i being the score assigned to concept i for criterion C1, SC2i for criterion C2 and SC3i for criterion C3. Once the scores had been calculated, the 20 concepts were ranked from highest to lowest. We chose to select the first 6 concepts, which we consider as accurate to provide an initial understanding of risk perception. The model composed of the selected concepts is shown in figure2.

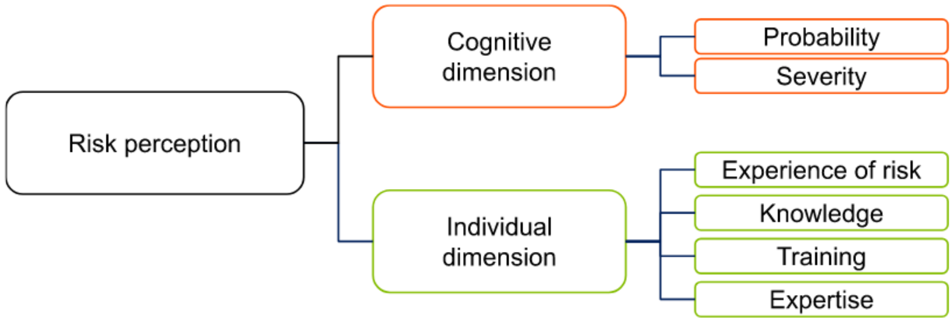

Figure 2: Risk perception model.

Distinction between measure and explanatory factors

The final methodological step was to distinguish between the concepts we will use to measure risk perception and those that will be considered as explanatory factors. According to Wilson et al (2019), probability and severity are two concepts frequently used to measure risk perception. In addition, those are two concepts that are integral to the definition of risk. We will therefore use them as a measure of risk perception. The notion of probability will enable us to identify whether mechanics consider the potential for consequences on the health or airworthiness of the aircraft during maintenance operations. The same applies to the severity of the consequences. However, the study carried out by Fischhoff et al, (1978) using the psychometric paradigm informs us that risk perception can be measured using 9 characteristics. So, should we consider other risk characteristics in addition to probability and severity to represent mechanics' risk perception? To be selected, each of the 9 risk characteristics had to meet two requirements: 1) Is the characteristic applicable to the field of aircraft maintenance? 2) Is the characteristic already considered in our model? For example, the "voluntariness" characteristic measures the degree to which participants voluntarily expose themselves to hazard. We don't consider it suitable for the maintenance domain, as mechanics don't choose to be exposed to hazards that are characteristics of the equipment used (i.e., the aircraft, etc.). Among the 9 risk characteristics, we have chosen to retain only the "immediacy of effects". Indeed, aircraft mechanics are exposed to hazards that can have both an immediate impact on their health or on the equipment (cutting tools, chemicals, etc.) and a long-term impact (carcinogens, heavy objects, etc.). We therefore consider risk perception as a combination of the probability of occurrence of consequences on the mechanic's health or the airworthiness of the aircraft, the severity of the consequences and the immediacy of the consequences. The other concepts ("risk experience", "knowledge", "training" and "expertise") will be considered as explanatory factors. Only the individual dimension has been retained.

Discussion

The decision to study risk perception of aircraft mechanics has arisen from several observations. The first is that, despite strict regulations and a high level of safety, accidents and incidents do occur, impacting both the health of mechanics and the airworthiness of aircraft. The second observation is that these accidents and incidents are analysed primarily from the human error point of view. Authors such as Hobbs (2008) have stressed the importance of understanding the origin of these errors to take a systemic approach to a safety problem. The third observed fact considers that aircraft mechanics are trained and have the knowledge and equipment (if the organisation is certified) needed to maintain safety. Thus, mechanics would not have to judge the risk, but must apply the procedure provided by the manufacturer and the safety measures. However, from our point of view, the mechanic, as a human and through human decision-making process analyses, judges work situations and makes decisions because the procedure (provided by the manufacturer) cannot be representative of all working situations.

Initially composed of 20 concepts, the model we propose has been reduced to 4 factors and 3 measures of risk perception. This was based on the expertise of 3 experts. The ranking, based on a multi-criteria analysis methodology (Saaty, 1987), helped us in our choice of concepts to select. However, it is important to stress the subjective aspect of establishing scores and the importance of criteria. Regarding the factors, we selected: "risk experience", "expertise", "training" and "knowledge". These highlight the "evolution" of individual notions essential to mechanics to ensure safety during maintenance operations. More specifically, initial training is designed to impart knowledge so that mechanics can perform their jobs straight from school. As they gain experience, this knowledge will be modified, and the mechanic will become an expert. Continuous or recurrent training will help maintain and adjust certain skills. In addition, experience of incidents or accidents will help to adjust knowledge of a specific risk. However, we have not identified any previous work that explains the contribution of each factor to risk management by aircraft mechanics. For this purpose, we intend to test our model with a population already in operations and aircraft mechanics trainees. It would help to establish the evolving nature of the factors influence on aircraft mechanics' perception of risk.

We chose to exclude factors such as attitude and safety climate despite the interest they could represent. Indeed, the mechanic's attitude, which would refer to his tendency to take risks or not during the activity, could highlight differences in day-to-day risk management. For example, a tendency not to wear personal protective equipment is a risk-taking behaviour that could have an impact on risk perception. However, the lack of consensus on definition and measurement led us to exclude it. Safety climate refers to the way in which individuals perceive the safety culture within the company in which they work (Zohar, 1980). However, this factor appears complex to study and define. We have therefore chosen not to consider it. In addition, the cultural aspect has not been considered, as we will be carrying out the experiments in France with French mechanics. However, as aeronautical maintenance is carried out all over the world, it would be relevant in the future to study differences in risk perception and the impact of factors such as knowledge, training, or risk experience. This would highlight the importance of risk management that is as close as possible to the reality of the activity and the socio-cultural context. However, safety culture is also a complex concept, which would have considerably lengthened the time required to complete the questionnaire in our study and made this one more complex. We then excluded it.

We chose to consider risk perception as a combination of probability, severity, and immediacy of consequences. This is because mechanics are exposed to numerous hazards, all of which are associated with uncertainty regarding probability, severity, and immediacy. For example, when installing a fuel pump, the risk of spillage is probable, but extremely low if all safety measures are followed. If it does happen, the severity of the impact on the mechanic's health may differ according to the extent of the spillage, even though he or she is wearing all the protective equipment. Just like the immediacy of the consequences, which will depend on whether the fuel has come into contact with the eyes, the skin, been ingested, etc. Thus, despite the variable nature of risk, we want to understand how these three notions are considered in relation to each other, and thus attempt to clarify the notions manipulated by aircraft mechanics to manage risk on a day-to-day basis. At the same time, we want to identify the factors that may influence this judgement.

Conclusion

This preliminary work is essential for our research project, as it establishes the methodology used to design a model that would be testable in our study. Indeed, even if the selection of factors remains based on a globally subjective approach, this work will enable us to explore a part of aircraft maintenance that remains unknown and unexplored while providing answers concerning risk perception.

References

Douglas, M., & Wildavsky, A. (1983). Risk and Culture: An Essay on the Selection of Technological and Environmental Dangers. University of California Press.Fischhoff, B.,

Slovic, P., Lichtenstein, S., Read, S., & Combs, B. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. Policy Sciences, 9(2). https://doi.org/10.1007/BF00143739

Hobbs, A. (2008). An Overview of Human Factors in Aviation Maintenance. Analysis, December. http://www.atsb.gov.au/publications/2008/AR2008055.aspx

ICAO. (2018). Safety Management Manual.

Kouabenan, D. R., Sastre, M. T. M., Cadet, B., & Hermand, D. (2007). Psychologie du risque. Dans *De Boeck Supérieur eBooks*. https://doi.org/10.3917/dbu.kouab.2007.01

Kummeneje, A. M., & Rundm, T. (2018). Subjective assessment of risk among urban work travel cyclists. Safety and Reliability – Safe Societies in a Changing World – Proceedings of the 28th International European Safety and Reliability Conference, ESREL 2018, 459–466. https://doi.org/10.1201/9781351174664-57

L'assurance maladie. (2019). NAF3316Z – Réparation et maintenance d'aéronefs et d'engins spatiaux.

Le, T. H., & Arcodia, C. (2018). Risk perceptions on cruise ships among young people: Concepts, approaches and directions. International Journal of Hospitality Management, 69(September 2017), 102–112. https://doi.org/10.1016/j.ijhm.2017.09.016Douglas,

Lerner, J. S., Gonzalez, R. M., Small, D. A., & Fischhoff, B. (2003). Effects of fear and anger on perceived risks of terrorism: A national field experiment. Psychological Science, 14(2), 144–150. https://doi.org/10.1111/1467-9280.01433

Namian, M., Albert, A., Zuluaga, C. M., & Behm, M. (2016). Role of Safety Training: Impact on Hazard Recognition and Safety Risk Perception. Journal of Construction Engineering and Management, 142(12), 1–10. https://doi.org/10.1061/(asce)co.1943-7862.0001198

Oah, S., Na, R., & Moon, K. (2018). The Influence of Safety Climate, Safety Leadership, Workload, and Accident Experiences on Risk Perception: A Study of Korean Manufacturing Workers. Safety and Health at Work, 9(4), 427–433. https://doi.org/10.1016/J.SHAW.2018.01.008

Orasanu, J., Fischer, U., & Davison, J. (2002). Risk perception: A critical element of aviation safety. IFAC Proceedings Volumes (IFAC-PapersOnline), 15(1), 49–58. https://doi.org/10.3182/20020721-6-es-1901.01639

Rahn, M., Tomczyk, S., & Schmidt, S. (2021). Storms, Fires, and Bombs: Analyzing the Impact of Warning Message and Receiver Characteristics on Risk Perception in Different Hazards. Risk Analysis, 41(9), 1630–1642. https://doi.org/10.1111/risa.13636

Rundmo, T., & Nordfjærn, T. (2017). Does risk perception really exist? Safety Science, 93, 230–240. https://doi.org/10.1016/j.ssci.2016.12.014

Saaty, R. W. (1987). The analytic hierarchy process-what it is and how it is used. Mathematical Modelling, 9(3–5), 161–176. https://doi.org/10.1016/0270-0255(87)90473-8

Siegrist, M., Gutscher, H., & Earle, T. C. (2005). Perception of risk: The influence of general trust, and general confidence. Journal of Risk Research, 8(2), 145–156. https://doi.org/10.1080/1366987032000105315

Sjöberg, L., & Af Wåhlberg, A. (2002). Risk perception and New Age beliefs. Risk Analysis, 22(4), 751–764. https://doi.org/10.1111/0272-4332.00066

Slovic, P. (2000). Perception of risk. Science, 236(4799), 280–285. https://doi.org/10.1126/science.3563507

Slovic, P., Finucane, M. L., Peters, E., & Macgregor, D. G. (2013). Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk and rationality. The Feeling of Risk: New Perspectives on Risk Perception, 24(2), 21–36. https://doi.org/10.4324/9781849776677

Trillo-Cabello, A. F., Carrillo-Castrillo, J. A., & Rubio-Romero, J. C. (2021). Perception of risk in construction. Exploring the factors that influence experts in occupational health and safety. Safety Science, 133(August 2020), 104990. https://doi.org/10.1016/j.ssci.2020.104990

Wilson, R. S., Zwickle, A., & Walpole, H. (2019). Developing a Broadly Applicable Measure of Risk Perception. Risk Analysis, 39(4), 777–791. https://doi.org/10.1111/risa.13207

Wolff, K., Larsen, S., & Øgaard, T. (2019). How to define and measure risk perceptions. Annals of Tourism Research, 79(March). https://doi.org/10.1016/j.annals.2019.102759

Zohar, D. (1980). Safety climate in industrial organizations: Theoretical and applied implications. Journal of Applied Psychology, 65(1), 96–102. https://doi.org/10.1037/0021-9010.65.1.96