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Pilot Workload Questionnaire as a Self-Improvement Tool for General Aviation Organizations in the Context of Sustainable Development

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Abstract:

Purpose: *Pointing out the important problem of the human factor in flight safety in general aviation. Introduction of the idea of post-flight pilot load questionnaires as a tool to identify the most burdening workload categories for the pilot.*
Approach: *The study emerges the original post-flight workload questionnaire and presents the survey conducted with it on general aviation pilots.*
Findings: *The most challenging and the easiest workload areas were identified. As the most demanding ones, surveyed pilots pointed to the tasks that require high perceptual activity related to visual and auditory perception, and high concentration and precision.*
Practical Implications: *Proposing the implementation of questionnaires on a wider scale in order to help contribute to reducing flight operating costs, the risk of accidents and human error in general aviation.*
Originality/Value: *This study deals with general aviation, which is often in the background, but is responsible for the overwhelming majority of accidents in civil aviation. The research can contribute to pointing the direction of work on general aviation flight safety and increasing the awareness of its importance.*

Keywords: *Risk management, flight safety, sustainable development, human factor, pilot, general aviation, workload.*

JEL codes: *J28.*

Paper Type: *Methodological paper.*

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1. Introduction

The development of new methods and technologies, as well as the improvement of existing systems in all branches of aviation, is not only an expression of continuous technical progress, but can also contribute to the practice of sustainable development (Ramasamy *et al.*, 2015; Bailey *et al.*, 2023). The study aims to show how the idea of post-flight pilot load questionnaires may have a positive impact on reducing flight operating costs, the risk of accidents and human error in general aviation.

Knowledge obtained through such questionnaires can be used to develop practices leading to reduce unscheduled changes in flight routes, probability of an accident and other circumstances that have a negative impact on the environment. Subsequently, once these practices are implemented, it will be possible to make general aviation flights more environmentally friendly and sustainable. The importance of this issue is based mainly on the actuality of sustainability and the need to implement it not only in commercial, but also general aviation (Stiebe, 2023).

The research seeks to determine which areas of improvement can be most contributed to by assessing selected pilot loads after a flight. An original post-flight questionnaire was proposed, as a tool to determine the load in six separate categories. The tool can be used in general aviation to assess pilot workload more broadly. The comprehensive approach represented by the author provides a better understanding of the impact of pilot workload on developing potential changes in the organization of general aviation and individual flights, the introduction of which can contribute to the goals of sustainable development.

2. Literature Review

Sustainable development based regulations are appearing in more and more national and global regulations regarding aviation (Sengur and Altuntas, 2023). The greatest emphasis is placed on commercial aviation, due to its predominance in civil aviation (Stiebe, 2023). That much attention is not paid to general aviation, even though this sector has an alarmingly low safety record, being responsible for 94% of civil aviation fatalities (Boyd, 2017). Such accidents generate large costs, both in terms of coping with damage they caused and repairing or disposing of the crashed aircraft, that have a negative impact on the environment.

General aviation encompasses all civil aviation excluding communications aviation. This sector will include, for example, school flights, business flights, specialized operations, rescue flights, firefighting flights, photogrammetric flights, or sports and recreational flights. This branch of aviation also uses a very wide fleet that includes many different types of aircraft are aircraft, helicopters, gliders, motor gliders balloons, hang gliders, paragliders and others (Turnbull, 1999).

Despite efforts at various organizational levels, general aviation still is the sector with the highest number of fatal accidents. It is distinguished by a low safety culture, limited budgets, high pilot turnover and an often outdated fleet (Huang *et al.*, 2020). This sector is dominated by recreational and training flights, which are particularly risky due to the low experience of pilots and the nature of training involving simulated dangerous situations (Sun *et al.*, 2023).

Based on observations, literature analysis and interviews with experts, it was concluded that the weakest link in the flight safety system remains the human being (Berlik, 2023). People are responsible for about 80% of adverse incidents (Szopa, 2015). At the same time, the biggest challenges related to safety culture, risk management and security are in general aviation. In training flights in particular, a significant factor leading to operator errors is workload (Hsu *et al.*, 2022).

There are several areas considered when evaluating the success of a flight, and one of them is pilot workload. The most accurate definition of it was proposed by G. Cooper and R. Harper, who understand pilot workload as the integrated physical and mental effort required to perform a specific task. The physical effort is described as the effort exerted by the pilot to move or exert forces on the controls during the performance of a specific task, and mental load as not subject to quantitative analysis other than pilot assessment or through indirect methods using physical workload (output data) and task performance measurements (Cooper and Harper, 2013).

Examples include solutions that reduce the normally occurring mental workload of the pilot, such as those associated with maintenance or analysis of flight-director flight parameters (Cooper and Harper, 2013). From the point of view of the conducted research, it was considered most befitting to define the load using the areas identified by the authors of the Task Load Measurement Questionnaire (Nur et al., 2020). They identify six basic areas that will be considered components of workload:

- mental load,
- physical load,
- time pressure,
- productivity,
- effort,
- frustration.

Mental load represents the strain caused by the mental activity that is necessary to perform a task. It includes activity processes such as remembering, thinking, performing mathematical operations, as well as activity related to the perception of visual and auditory impulses. Mental load is also affected by the level of focus and accuracy required, as well as the level of complexity of the task. The level of mental load for these processes can depend on the pilot's level of training and experience, among other factors (Bailey *et al.,* 2009).

Physical load determines the level of physical effort required to perform a task. The level of physical load is influenced by performing activities such as pulling, pushing, twisting, making steering movements or maintaining their position and other manual activities, as well as by the musculoskeletal load resulting from, for example, maintaining a forced body position. The load is also influenced by factors such as how fast and precise the activities must be performed. The level of task load for the same task can depend on, among other things, the subject's muscular strength or fitness (Bailey *et al.*, 2009).

Time pressure determines the subject's perception of the time available to complete the task: whether it was sufficient, or whether the subject was deficient in time, resulting in discomfort due to excessive speed. Perceptions of time pressure can also be influenced by the degree to which activities are assimilated and the ability to perform them quickly (Bailey *et al.,* 2009).

Productivity determines the extent to which one succeeds in meeting the goals of a task. It provides a response regarding satisfaction with the task, which indicates the degree to which a person is prepared for it and feels confident. The level of performance on the same task can depend, among other things, on the pilot's level of training and whether he or she is in current training (Bailey *et al.*, 2009)

Effort represents the amount of energy expended to perform a task. It results from the physical and mental work that must be put in to achieve the highest level of performance (Bailey *et al.*, 2009)

Frustration results from the feelings of the examinee while performing the test. These consist of feelings of stress, irritation, weariness, discouragement, uncertainty, but also self-satisfaction and satisfaction (Bailey *et al.,* 2009; Na, 2021).

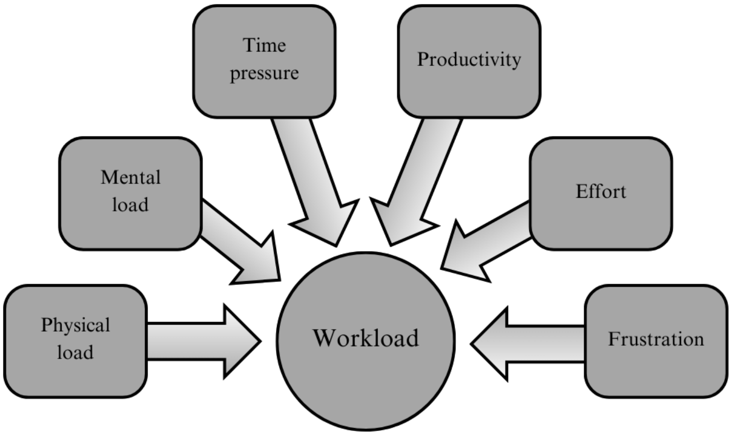
Based on the above, workload can be defined as the sum of the burdens of mental strain, physical strain, time pressure, productivity, effort and frustration (Berlik, 2023). Specific components of the pilot's workload are shown in Figure 1.

The developed definition of workload was the starting point for creating its evaluation questionnaire for general aviation usage.

3. Research Methodology

Considering workload as a critical determinant of operational risk, a questionnaire for pilots was developed as a research tool, to assess its actual level as precise as possible. According to the assumptions, the designed tool should require as little effort from the pilot as possible, so that it would not contribute to the pilot's workload. At the same time, it was important to identify the areas in which there is the greatest burden, which would be the basis for the implementation of corrective measures to reduce the pilot workload. The reason for developing the questionnaire was that, in the author's opinion, the available questionnaire methods for assessing workload did not indicate the specific factors causing it (Berlik, 2024).

Figure 1. *Components of workload*



Source: *Own elaboration based on Berlik, 2023.*

Taking into account the presence of the above factors, the reduction of the pilot's workload can significantly contribute to increasing the level of flight safety. At the same time, increase the correctness of his tasks. This can result, for example, in better planning of the route or maintaining the course, which reduces the flight time or avoids the need to go around in the event of a critical error during the approach to landing.

This can make a significant contribution to reducing costs, fuel consumption, carbon dioxide emissions and noise. At the same time, the fact that general aviation is the least invested branch of aviation, where relatively primitive solutions are often used, makes the case that there is ample room for continuous improvement, and makes it possible to achieve relatively large effects with a small financial outlay.

The workload assessment questionnaire was developed according to the accepted definition of workload, based on the workload categories defined in method NASA Task Load Index (NASA-TLX). Several questions were developed for each load category. It was assumed that the content of the questions was intended to increase the pilot's awareness of factors that may occur during the flight and to help assess the workload as accurately as possible.

The questionnaire consisted of 32 questions, divided into sections according to load categories based on the definition of workload developed for the purpose of the work. The separate sections were:

- mental load (9 questions),
- physical load (6 questions),
- time pressure (4 questions),
- performance (4 questions),
- effort (4 questions),
- frustration (5 questions).

The difference between the number of questions in each section is due to the level of detail of the questions and the type of tasks performed by the pilot. Questions on mental and physical workload form the core of the questionnaire, as they deal with the most specific issues. Moreover, these components account for the largest part of task workload.

The questionnaire includes the following questions:

Mental load:

- The task requires a lot of mental activity (thinking, remembering, deciding, performing mathematical operations).
- The task requires high perceptual activity related to visual and auditory perception.
- The task requires great concentration and precision.
- The task is very complicated.
- Basic preparation for flight (e.g. analyzing the meteorological situation, completing aircraft documentation) requires a lot of work.
- Preparing for a flight due to the task (e.g. preparing the route, submitting a flight plan, etc.) requires a lot of work
- The flight environment (operational procedures, traffic intensity, knowledge of the airport, etc.) requires a lot of mental activity.
- Performing a flight on this aircraft (taking into account, among others, use of equipment, technical condition, experience with the type, and current training) is very difficult for the pilot.
- The pilot's preparation for flight leaves much to be desired.

Physical load:

- Performing activities such as pushing, turning, pulling, operating, and controlling the position of the controls requires the use of large forces.
- Performing activities such as pushing, turning, pulling, operating, and controlling the position of the controls requires high precision.
- Performing activities such as pushing, turning, pulling, operating, and controlling the position of the controls requires a high pace of action.
- The pilot feels very tired due to maintaining his body position in the cabin.
- The pilot feels a heavy load resulting from the conditions in the cabin (e.g. temperature, humidity, sunlight).

- Performing activities related to preparing the aircraft for flight (e.g. performing pre-flight inspection) requires a lot of effort.

Time pressure:
- The pilot must perform activities in a great hurry.
- The pilot feels great discomfort due to lack of time to perform all activities.
- The task is completed with a long delay.
- The task is started with a long delay.

Performance:
- The pilot is very happy and satisfied with the extent to which he correctly performs activities during the task.
- The pilot will carry out the tasks that occur during the task with very good result.
- The pilot will perform all activities while performing the task very precisely.
- The pilot's well-being (taking into account: fatigue, hunger, time of day, health condition, etc.) is very conducive to the correct and safe execution of the flight.

Effort:
- The task is very demanding.
- The pilot has to put in a lot of effort to cope with the activities while performing the task.
- The pilot is very tired and exhausted after completing the task.
- Carrying out a flight due to weather conditions (wind, turbulent atmosphere, etc.) requires a lot of effort from the pilot.

Frustration:
- While performing the task, the pilot experiences great stress.
- While performing the task, the pilot feels extremely irritated.
- While performing the task, the pilot feels extremely discouraged.
- While performing the task, the pilot feels extremely complacent.
- The crew composition is very conducive to a good atmosphere and cooperation in the cockpit.

Responses were given on a seven-point Likert scale, expressed as follows (Tarka, 2015):

1 = Strongly Disagree
2 = Disagree
3 = Partially Disagree
4 = Neutral
5 = Partially Agree
6 = Agree

7 = Strongly Agree

The questions were related to the pilot's workload. They were divided into categories and constructed in such a way to help the pilot increase his situational awareness of the burden caused by the flight and the factors affecting him during the flight. At the same time, efforts were made to keep the questionnaire as short as possible, avoiding excessive detail. The purpose of doing so was to optimize the time and burden required for the pilot to complete the assessment. Each question dealt with several different groups of factors affecting the pilot and generating his load in flight.

A series of flights was taken as the sample size. Questionnaires were completed after each flight series. More flights than one may have been made in a flight series, but the entire series was evaluated. This is due to the common practice in aviation, especially in the case of training flights, that a series of flights are made in a single task. This is most often the case in flights where takeoffs and landings are practiced. If there is no engine shutdown between flights, they are considered to be flights made in a series, which is reflected in entries, for example, in the aircraft's Technical Log or in the Pilot's Book. The entire series of flights is entered as a single entry with an annotation detailing the number of flights made in the series.

The load rating applied to a series of flights in which multiple flights may have been made. This applies primarily to the assessment for a series of flights during which landings were practiced. In this case, the load was evaluated for a series of multiple flights consisting of takeoff, circle flight and landing. This was for practical reasons. In aviation, it is very common (especially in training flights) to perform flights in series without shutting down the engine. Similarly, the entirety of a task involving, for example, a destination-return flight to a foreign airport, where the takeoff from the home airport, en route flight, landing at the foreign airport and return to the home airport were treated as the entirety of the task, could be evaluated.

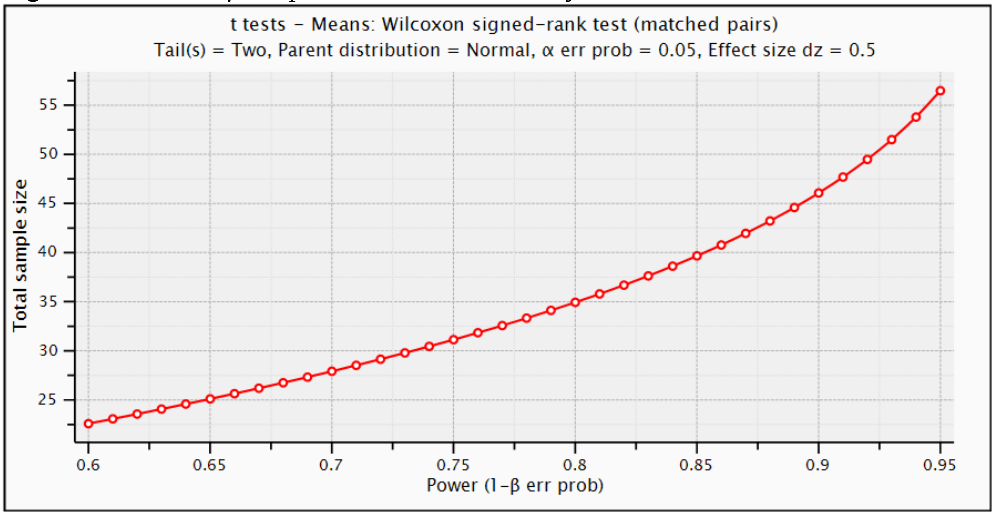
Minimum sample size estimation was carried out using the G*Power package (Faul *et al.*, 2007). Assuming an expected effect size (effect size) of $d=0.5$, a significance level of $\alpha=0.05$ for the dependent sample test used, a test power level of 0.8, which is considered satisfactory (Jarmakowska-Kostrzanowska, 2021), will be achieved with a group size of $N=35$, which was shown in Figure 2.

In the study, the sample of the pilot flight series was $N=63$, giving a test power level of more than 0.9 and meeting the minimal requirement.

The surveys were conducted between June 15, 2022 and July 15, 2023. They included 348 flights with a total time of 91 hours and 23 minutes, conducted in 63 series. Eighteen pilots between the ages of 18 and 43 participated in the study. The flights were conducted as part of flight training for licensing or new qualifications. The participants' general airfare obtained on aircraft ranged from

4 to 130 hours. The pilots were informed about the purpose of the study and its conduct. During the flights in which the study was conducted, the pilots performed standard tasks carried out in flight training. The flight series accounts for the sample size (63 flight series).

Figure 2. *Results of sample size evaluation analysis*



Source: *Own elaboration using G*Power package (Berlik, 2023).*

The tasks included:

- circle flights (learning and perfecting takeoff, climb, descent, landing);
- flying to the pilotage area (learning and perfecting the performance of maneuvers such as straight flight and horizontal turns, on descent and ascent, performing maneuvers based on instrument indications, flying at low speed, stalls and preventing entry into a tailspin);
- route navigation flights;
- handling post-failure situations (in circle, pilot zone and en route flight).

4. Research Results

The results obtained are presented in the Table 1. M represents average points given, Me shows the median, and SD the standard deviation. The results for questions 20., 21., 22., 23., 31., and 32. are presented after inverting the scale.

The highest average scores (5.44 and 5.29, respectively) were given to questions 3. and 2. concerning the concentration and attention required from the pilot during the task, and activities related to auditory and visual perception. The remaining questions (11., 1., 24., 12., 25., 4., 16.), which received average scores above 4, indicate the presence of a high workload associated with the need to perform complex and demanding tasks involving high mental activity and steering movements requiring high precision, performed under time deficit conditions.

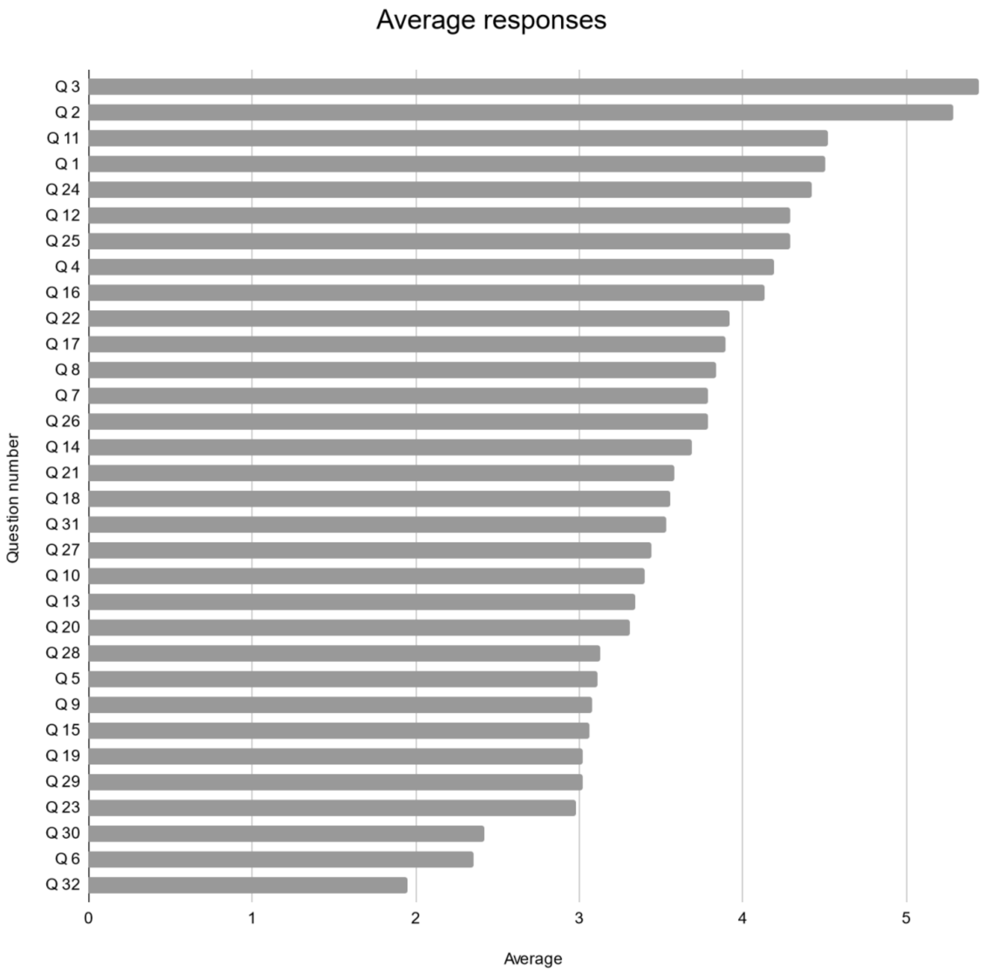
Table 1. *Results from the post-flight questionnaire*

	Post-flight measure average		
	M	***Me***	***SD***
Q1	4.50	5.00	1.49
Q2	5.29	5.00	0.86
Q3	5.44	5.50	0.92
Q4	4.19	5.00	1.41
Q5	3.11	3.00	1.33
Q6	2.35	2.00	1.29
Q7	3.79	4.00	1.45
Q8	3.84	4.00	1.43
Q9	3.08	3.00	1.06
Q10	3.40	3.00	1.18
Q11	4.52	5.00	1.26
Q12	4.29	5.00	1.49
Q13	3.34	3.00	1.33
Q14	3.69	3.50	1.39
Q15	3.06	3.00	1.37
Q16	4.13	4.00	1.40
Q17	3.89	4.00	1.38
Q18	3.56	3.00	1.35
Q19	3.02	3.00	1.08
Q20	3.31	3.00	1.20
Q21	3.58	3.00	1.11
Q22	3.92	4.00	1.21
Q23	2.98	3.00	1.00
Q24	4.42	5.00	1.33
Q25	4.29	5.00	1.31
Q26	3.79	4.00	1.52
Q27	3.44	3.00	1.50
Q28	3.13	3.00	1.43
Q29	3.02	2.00	1.57
Q30	2.42	2.00	1.33
Q31	3.53	3.00	1.35
Q32	1.95	2.00	0.84

Source: *Own elaboration based on Berlik, 2023.*

The average response points are shown in Table 2, sorted from those with the highest scores.

Figure 3. *Average responses to each question*



Source: *Own elaboration based on Berlik, 2023.*

Associated with the occurrence of the lowest burden were the questions in question 32. on crew composition and cooperation in the cockpit (1.95) and questions 6. (2.35) and 30. (2.42) relating to issues related to preparation for the flight and feelings of discouragement occurring during the task.

At the same time, it can be observed that most of the questions for which the average score was below 3.5 points (27., 10., 13., 20., 28., 5., 9., 15., 19., 29., 23., 30.) relate to issues not directly related to the pilot's performance during the flight. They concern, among other things, issues related to the preparation for the flight, the psychophysical state of the pilot (satisfaction of basic needs such as sleep, sense of hunger) and meteorological conditions.

5. Discusion

The results show that the greatest workload on pilots is related to the performance of activities in the aircraft cabin already during the flight. Surprisingly, to a relatively small extent, respondents pointed to external factors as generating a large burden. From a management point of view, this is positive, as it indicates the possibility of significantly influencing the actual state of affairs by undertaking appropriate shaping of the work environment. Particularly in the case of general aviation, which is characterized by a relatively low level of automation and the implementation of solutions to reduce the pilot's workload, there are great opportunities to influence the pilot's work environment with fairly little financial outlays.

Based on the responses, basic courses of action can be proposed to reduce the pilot's workload. Firstly, it is noteworthy to take measures to relieve the pilot's mental workload, especially attention concentration. One solution could be to equip crews with tablets that have applications dedicated to preparing for the flight and conducting navigation activities during the flight. In the flights conducted during the research, navigation was done in the traditional way, i.e. based on a paper map. The use of apps could reduce the crew's workload associated not only during flight execution, but also related to flight preparation.

Integrated flight preparation based on dedicated tools for this purpose avoids the need to analyze meteorological data, information related to airspace availability, verification of NOTAM (Notice To Air Missions) dispatches, based on various sources usually available on different websites. At the same time, flight preparation time would be significantly reduced, as the pilot would not have to perform calculations using a mechanical calculator, which would significantly reduce the flight preparation time and fatigue created during the route preparation process.

At the same time, the use of the device during the flight could significantly reduce the load level during the flight. Indicating the current position of the aircraft based on GPS indications and displaying fixed and time-active airspace elements could significantly contribute to reducing the pilot's workload during the flight. In addition, conducting navigation based on electronic devices significantly increases its precision, which contributes to a significant reduction in the deviation of the aircraft's flight path from the planned path.

This has an impact on reducing flight time, fuel consumption, oil consumption, carbon dioxide emissions or noise. Dedicated applications also include information on arrival and departure procedures from individual airports, radio frequencies, runway lengths, etc. The use of this data contributes to an increase in the level of safety, as the pilot can at any time familiarize himself with the conditions at any airport, which is particularly important, for example, in a situation where there is a sudden need to modify the planned route and use a different airport than the one planned.

At the same time, it avoids the need to print out each time a lot of data and maps dedicated to each airport, in paper form.

Based on the results, one can also see the need to reduce the physical load, which is mainly due to the precise movements of the controls, which requires the use of large forces. For cross-country flights in particular, the installation of an autopilot system could be a solution. It could significantly reduce the need for the pilot to react to the aircraft's deviations arising during flight.

In addition to reducing the physical workload, the use of such a solution would also contribute to reducing the mental workload, as performing the task would require the pilot to focus less attention and less activity related to visual perception. The implementation of such a solution would also have a beneficial effect on the environment, due to the fact that automatic systems are more effectively and accurately able to maintain preset flight parameters than humans.

Due to the high cost of using an autopilot system, it is worth noting that a similar, though less effective, effect can be achieved by properly trimming the aircraft. High forces occurring on the rudder may result from insufficient use of trim tabs. These are devices mounted on the rudder surfaces whose task is to generate aerodynamic forces that keep the rudder in the desired position at the set speed.

Thus, when the trim tabs are in the correct positions for a given speed, the aircraft is able to maintain a reasonably stable position and flight parameters. Importantly, in such a condition, the pilot does not need to apply forces to the controls or the forces required to maintain the aircraft's position are minimal. Proper use of trim tab contributes not only to the reduction of forces that the pilot has to apply to the rudders, but also has a positive effect on piloting precision and maintaining stable flight parameters such as altitude and heading, as well as reducing the number of additional movements with the rudders, which also contributes to reducing flight time and additional air resistance associated with the turbulent flow of leaning rudder surfaces, which has a positive effect on fuel consumption, for example.

The ability to use trim tabs is primarily due to the pilot's awareness and the extent to which this skill was acquired during practical training. The key here is the contribution of instructors who pay attention to the fact of using and changing the trim balance for each change in position and speed of the aircraft (e.g., for descent, climb, level flight, takeoff or landing).

The above solution is practically cost-free and does not require interference with the aircraft structure and equipment. The problem of inadequate or insufficient use of trim tab primarily concerns inexperienced pilots and pilots who perform flights irregularly. It is the pilots who meet these criteria who are the pilots most frequently performing operations in the General Aviation sector (Dapica *et al.*, 2022).

6. Limitation of the Study

The sample size depended on many factors, primarily the research environment. Research conducted on pilots in flight is difficult because of the general reluctance of the environment to conduct it. This applies to both pilots and organizations. Both groups fear the exposure of possible misconduct. In the case of pilots, the concern is about possible health problems or possible infirmity during flight operations. Similarly, in the case of organizations, a very small portion of them look favorably on conducting research during flights. A second complication is the scarcity of time, especially when performing flights.

The proposed questionnaire can be useful to diagnose the factors generating the highest fatigue of crews relevant especially from the point of view of personnel management and assignment of type and amount of tasks to be performed and planning of rest time (Ewertowski and Berlik, 2020).

From the point of view of further research, it would be interesting to expand the study to include other organizations and other types of flights. The research presented here mostly covered school flights, which have their own peculiarities. It would also be noteworthy to conduct a broader study, where route flights, flights over the flight pattern, and flights from imitation hazardous situations would be analyzed separately.

7. Conclusions

The proposed questionnaire method can be a tool to help diagnose the factors that generate excessive task load on the pilot. Identification of these factors can be beneficial for many reasons. It can provide a lot of information relevant to risk management. Based on the information obtained, it is also possible to implement improvements to increase the reliability of the pilot and the correctness of his task performance.

This is important not only from the point of view of increasing the level of safety of flight operations, but also from the point of view of environmental benefits. Examples of benefits include, for example, reduced fuel or oil consumption, as well as reduced noise or carbon dioxide emissions.

The tool can also be helpful in planning and organizing the training course, as well as their selection of flight crews by pointing out the areas causing the most difficulties.

The problem may be the reluctance of crews to fill out questionnaires. Very important here is the transparency of the purposes of obtaining information and the organization of the survey process in such a way that it requires the least possible involvement on the part of the pilot.

Importantly, taking steps to reduce the pilot's workload can bring multiple benefits in different fields. It can contribute not only to increasing the comfort of aircraft crews' operations, but also to increasing the safety of operations, reducing losses and costs, and, most importantly, reducing the adverse impact of aviation on the environment.

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