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OBJECTIVE MEASUREMENT OF HUMAN FACTORS FOR SUPPORTING THE OPERATOR’S LOAD SIMULATION AND MANAGEMENT

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Abstract

The HungaroControl and Budapest University of Technology and Economics (BME) work on improving the operator’s load simulation and developing the load management. The objective measurement system has developed that is based on sensors usage and integration into the working environment of operators. Measurements were realized in flight simulator of the Department of Aeronautics, and Naval Architecture at BME, and air traffic controllers simulation at HungaroControl. The paper will (i) introduce the measurement systems and models, (ii) discuss the major measurement results, and (iii) describe the applicability of the measurement in operator’s load simulation and load management.

Keywords: human factors, operator loads, pilot, ATCO, load measurement

1. Introduction

Air transportation is going through an accelerated and continuous growth specifically in the human (operator)-vehicle conflict level, considerably over the next two decades. In dealing with this growth, it is essential to ensure the highest level of safety and security to reach sustainability.

As the level of technology advances and the avionics system becomes more complex, evaluation of the performance of operators requires, such as situation awareness, decision-making, and operator load. Operators need viable constructs, principles, and aviation systems to promote a better understanding of automation and balancing their loads in complex systems. This highly complex and dynamic environment measures operator performance more complicated than in the early time of aviation. Despite all the advancements in aviation technology and cockpit automation, aviation accidents continue to occur. With the continuous evolution of flight systems, including aircraft capabilities, radar, and sensor systems, operators are supported by vast amounts of available data and relevant information. Available too much information confuses operators during operation, particularly while the decision-making process in abnormal/emergencies. In parallel with these changes, the operator load system also has been significantly changed. This highly automated system may be accompanied by unbalanced operator load systems vary from under load to overload, unintended reductions in situation awareness, decrease in the quality of decision-making, and increased level of stress.

This research aims to measure the human errors factors based on load monitoring systems in operators ‘working environments and managing their total loads. To achieve this, three main steps were investigated: (i) the role of operators in future aviation systems, such as operators’ roles, human factors, and models. (ii) the new operator models will be developed, such as “situation awareness and decision-making model” and “information model”, (iii) the load monitoring systems will be developed such as eye movement and eye blink rate. Finally, the summary, and major results will be presented.

2. Human Factors in Aviation

The human factor is the study of the relationship between (i) humans (body and mind), (ii) human beings and systems, human beings and technology, and (iv) human beings and working environment by focusing on improving efficiency, productivity, safety and security to minimize human errors. Within the context of aviation, studies include the interactions and effects among operators, their working environments, equipment, and systems. The field of human factors dates back to World War II in the area of aviation, and its importance has grown increasingly up until today. Human factors in aviation deal with operator performance, behavior, abilities, limitation, stress, anxiety, fatigue, cognitive loads (work, task, information, communication, and mental load), and culture. It is necessary to manage human aviation factors and their effects on flight crews and among others, in order to reduce operator mistakes. Human factor awareness in aviation is critical to optimize the fit between operators and the systems in which they work in order to improve safety, security, and performance. Aircraft accidents and incidents almost always result from a series of events, each of which is a combination or interaction of several factors. An example might be when an aircraft accident was made to avionic causes, severe weather, and unbalanced operator load. As in most aircraft accidents involving humans and systems, there were a number of human errors that caused severe air disasters. According to Boeing [1] today, approximately eighty per cent of aircraft accidents were caused by operator error, and the other twenty per cent is mainly due to mechanical failure and weather-related flying conditions. Back in the early days of aviation, it was the reverse, close to eighty per cent of aircraft accidents were caused by the machine and the other twenty per cent were caused by operator error (Figure1).

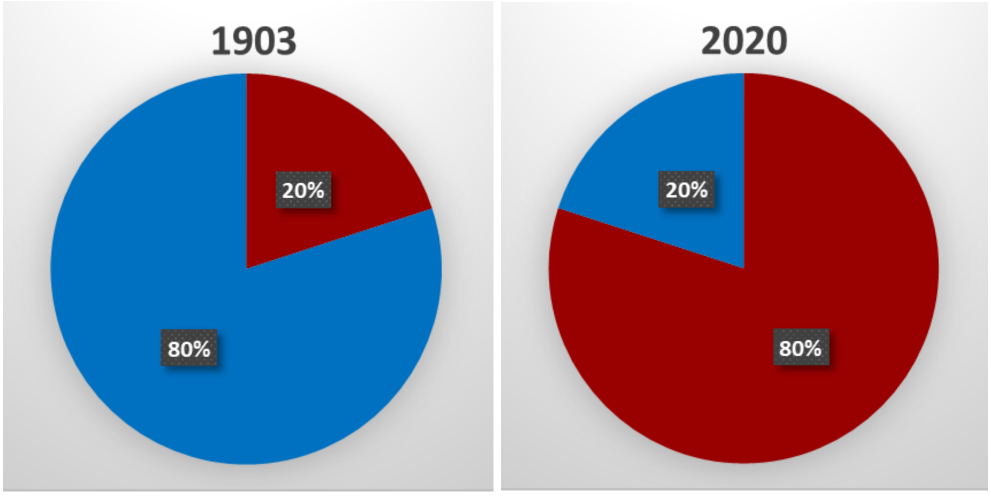

Figure 1- Causes of Accidents (Blue: Machine Causes, Bordo: Human Causes- data taken from [1])

Petersen [4] is among many who believes that human error is the fundamental cause behind all accidents. Human error is now the primary risk to flight safety (Civil Aviation Authority - CAA [5]). Accident investigations have been shown that human factors could be divided into three groups depending on their origins.

Figure 2 shows that operator interactions get more critical over the years. Today, this means that over time situation awareness, decision-making process and operators' total loads become the main driver. There is a change in focus and priorities of human factors in aviation over time: human workload in aviation became a priority between the 1940s and 1970s. From the 1970s through the 1990s, situation awareness received the highest focus. With continually changing aviation technology, organizational safety and as well as supervision of human mistakes were the main driver from the 1990s through the 2010s.

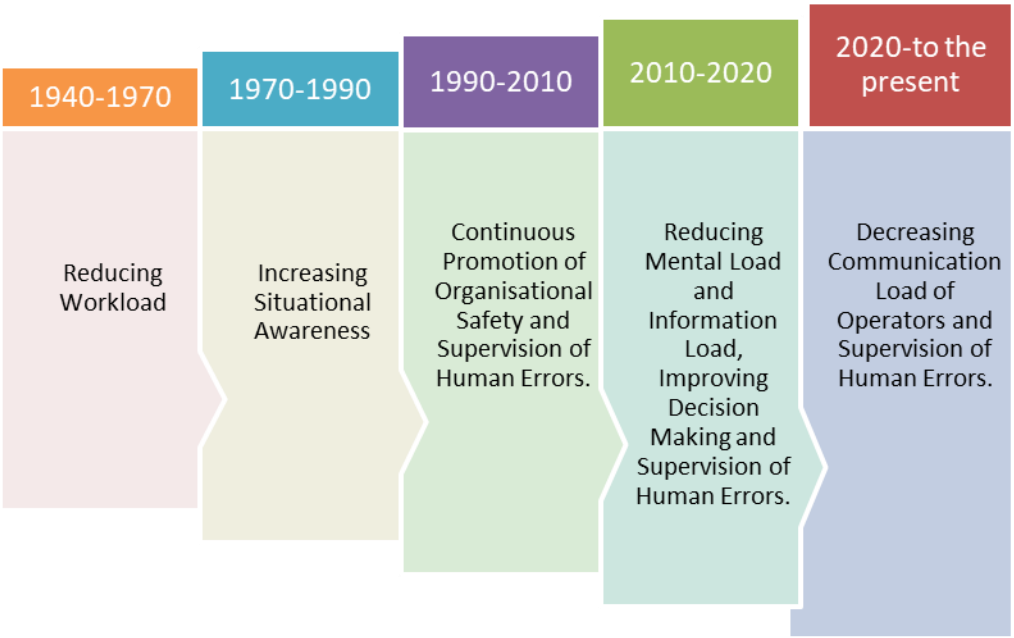

Figure 2- Human Factor Priorities evolved over time (the data partly taken from [2] and recreated and improved by the current researcher [3])

From the 2010s to 2020, mental load and information load, and operator decision-making process have been a driver. From 2020 to the present time, operator communication load, mental load, and information load are the main focus.

3. Human (Operator) Load Models

3.1 Situation Awareness Model

Many previous researches focused on different approaches for the operator model specifically situation awareness and decision-making model, and information model. In aviation, most safety issues are resulted from a lack of situation awareness and are attributed as the cause of negative safety outcomes. For decades, loss of situation awareness (SA) has been cited as the cause of accidents attributable to human error in operators [6]; [7]. Benton J. Underwood can give one of the earliest references to the situation awareness concept in his classic book of “Psychological Research” [8]. However, situation awareness did not receive enough attention until its use in military communities necessitated an operational definition. The first sign of the development of the situation awareness construct by Endsley [9], and other researchers such as [10]; [11]. Now, many scientific descriptions can be found in this field [12]; [13]; [14], and [9]. Endsley defined situation awareness as “perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” [15]. Endsley [9] suggested a component model where a simulation-based tool was developed, known as the Situation Awareness Global Assessment Technique (SAGAT). This tool was used to measure the situation awareness of pilots [16]. Taylor [13] proposed measuring situation awareness using a somewhat similar method known as the Situation Awareness Rating Technique (SART). Figure 3 provides a model of the role of “situation awareness” in the decision process adapted from Endsley [6].

Situation awareness is affected by environmental factors, individual characteristics, workload, and pre-conceptions and objectives. In this model, situation awareness contains three different levels: (i) Level 1 is the critical factors in the environments, (ii) Level 2 is, understanding what those factors mean, and (iii) Level 3 is, understanding what will happen with the system soon. This model was one of the well-used models up to date and clearly described situation awareness and its connections well.

However, situation awareness factors and the type of problems are continuously changing in parallel to the rapid technological changes. With the current aviation systems, automation has been altered the role of operators from active control to passive monitoring. Due to this change, the workload of operators tends to balance with some of the tasks that rely on automation; however, on the other hand, operators have been started to receive high information and mental load. The Endsley "Situation Awareness Model" was improved upon, by the current researcher, by including the "Present Situation", total load systems and as well as extending the "Task/System Factors" and "Individual Factors". This situation awareness model allows researchers to evaluate and determine the most appropriate actions according to the stipulated objectives.

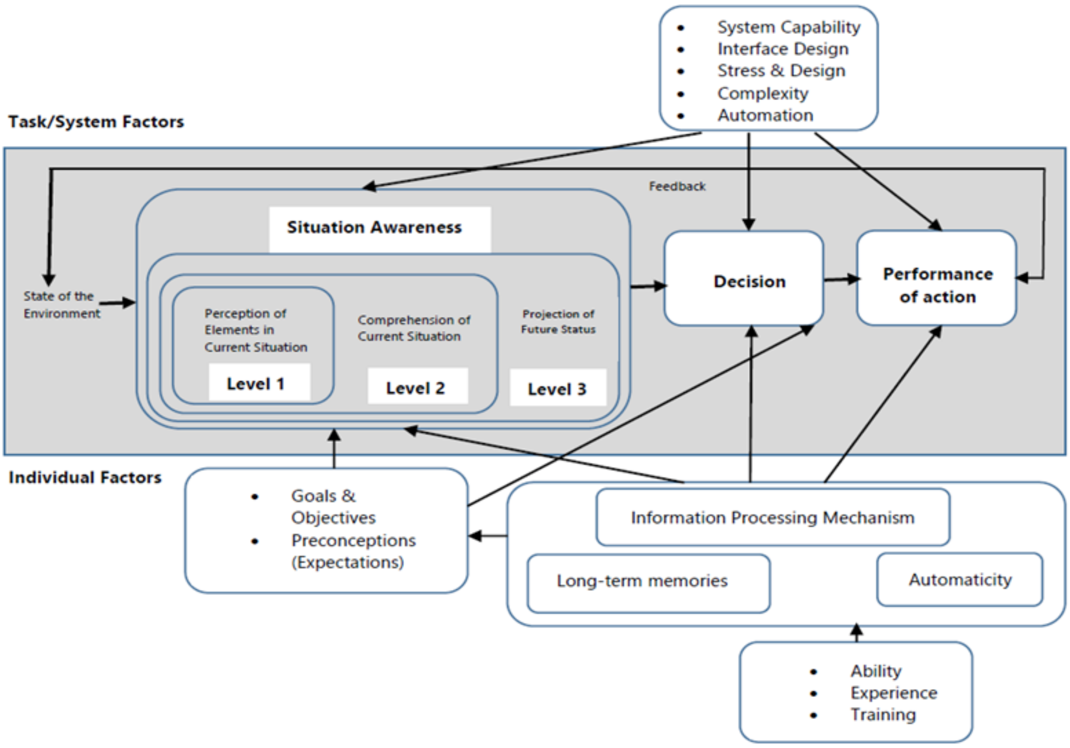

Figure 3- Role of situation awareness in the decision process presented by Endsley [15]

The NASA Task Load Index (NASA-TLX) is a multi-dimensional rating procedure that provides an overall workload score based on a weighted average of ratings on six subscales: Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort, and Frustration [17]. In the dynamic flight environment, the decision-making process of operators is highly dependent on situation awareness. Operators use subjective decisions [18]; namely, they apply subjective situation awareness, situation analysis, and decision process in aircraft controls. Firstly, the level and type of problem need to be defined, and after they must choose the best solution from a set of available resources (methods or technologies). Resources can be divided into two categories: (i) "active resources" which can be related to aviation systems such as finance, information, materials, and (ii) "passive resources" which can be connected to operators such as physical, psycho-physiological behaviors, and possibilities of subjects. Subjects (system operators) can develop their active resources or competencies with theoretical studies and practical lessons [19]; [20]. However, the ability to choose and use the right resources in optimal time is highly dependent on (i) information support, (ii) tacit knowledge, (iii) way of thinking, and (iv) skills of the subject. Such decisions are the results of subjective analysis. Secondly, operators make a decision on control after evaluation of the flight situation awareness.

3.2 Information Load Model

The quality of the decision depends on the available information of the operator. The aircraft conventional control systems including "operators in the loop" are called active endogenous systems, because the operators react actively to real situations evaluated by them, and their solutions origin from their minds, from the nervous system. Over the past years, there has been much talk about operator workload. The operator workload plays an essential role in the flight environment, and most of the operator errors and performance decrements can result from causes beyond a loss of situation awareness and overload. The workload can be defined in a variety of ways. The various definitions and theories of workload agree on the statement that workload is an interaction between the operator and their tasks. Thus, elements of the task and characteristics of the operator are contributors to workload. According to Huey and Wickens [12], the workload of operators contributes in a complex circumstance (cockpit and ATCOs workstation) from four factors: (i) performance criteria, (ii) task structure, (iii) human system interface, and (iv) individual factors. According to his statement, operators are under pressure because they are expected to perform high with minimum errors. Multi-tasking, the complexity of tasks and information, and time pressure can be addressed such factors that lead to increase workload. Individual factors, such as tacit knowledge, stress level, and experience of operators, have the potential to overload. According to Huey and Wickens [12], all the load systems were included in the calculation of workload. Sarno and Wickens [21] state that the main contributor to operator workload is task load. Moreover, Watson et al. [22] have a similar statement that task difficulty has a significant influence on operator workload. Numerous researchers have reported that mental workload is a crucial factor in determining operator performance in the working environment. Most of the previous researchers were tried to calculate workload in connection with operators' tasks and mental conditions. However, due to rapid technological changes in aviation technology, operators receive too much and partly not harmonized information from different sources than the early days of aviation. These changes have introduced a new type of operator load system, namely information load.

According to a study by Endsley [6], eight per cent of them involving human error could be linked to issues with situational awareness. In an abnormal or emergency situation, flight safety does not only depend on available information, but the whole picture including space, time, tacit knowledge, experience, and loads of operators on the emergency situation plays the central role. Operator training can also be a useful mechanism for improving situational awareness abilities. In order to understand how to monitor and measure a total load of an operator, it is crucial to have a clear understanding of how operators acquire and analyze information for "decision-making" and "performance action". Various studies in the literature try to model human information processing systems such as [23]; [24]; [25]. One of the most recognized and clear explanations of the human information processing model has been given by Wickens [25] (Figure 4). This information model has been framed around five key components: (i) initial sensors (eyes, ears), (ii) perception, (iii) human memory (working and long-term memory), (iv) decision and response selection, and (v) response and execution.

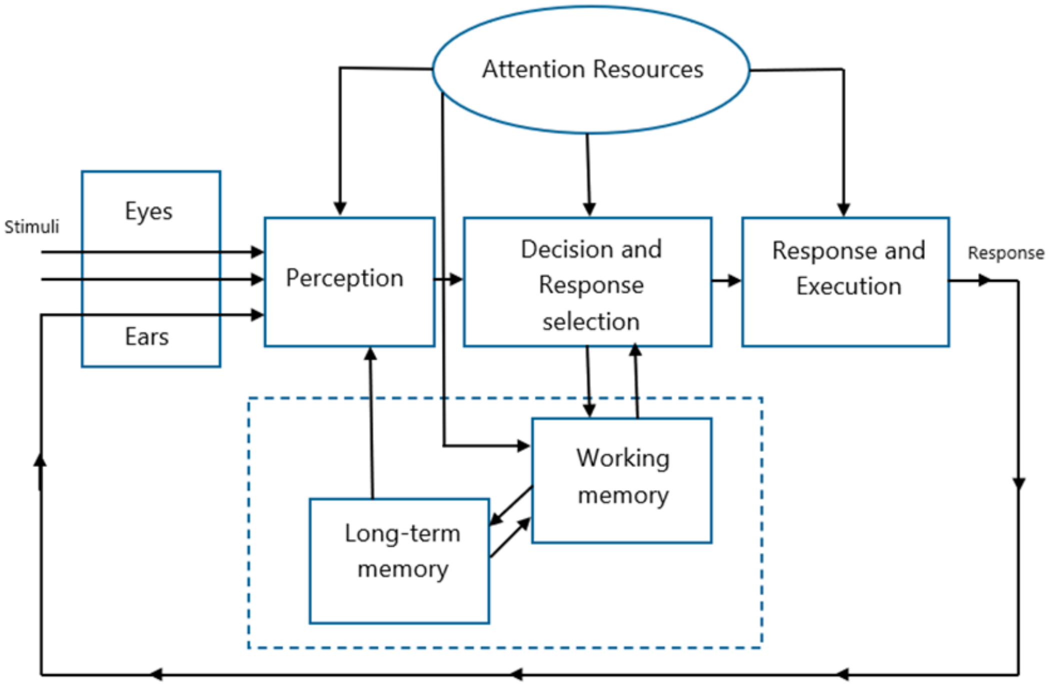

Figure 4- The human information processing model presented by Wickens [25]

According to this model, as shown in Figure 4, the start point of the information process is the initial sensors, namely the eyes and ears. The human brain then processes the detected information. Working memory is a short-term (recent) memory that maintains some amount of information in mind to enable its manipulation for further information processing while long-term memory is used for storing information and knowledge. The processed incoming information can be temporarily stored and manipulated in the working memory for supporting the human decision-making process. This stage can be described as “main thinking” according to Wickens [25] and also connected with long-term memory where information and knowledge can be stored for more extended periods of time. The most appropriate response, finally, can be executed, and respectively, the decision can be made in the last stage. This information model of Wickens was adapted to operators by the current researcher. There are several essential factors, directly or indirectly involved with the decision-making process of the operator in their working environment, such as the degree of attention, situation awareness, psychological conditions, experience, tacit knowledge, and skill.

4. Measurement and Results

Developing an objective measurement system is based on five groups of indicators. (i) Measuring the supporting information (like traffic complexity, defined type of sectorisation in case of air traffic control, type of aircraft and its controllability, meteorological conditions, etc.) give information on task load as inputs. (ii) Measuring the situation recognition and situation awareness includes the time delay in recognition of the changes in situations, understanding and selecting the required actions, deconflicting, and so on, more or less evaluate the workload. It is depending on the information load, too. (iii) Distance measurements, as eye movement, eye blink rate, and eye-tracking are implemented for estimating the work and mental condition. For example, attention dissipation or changes in eye characters, face blushing, or motion (un)coordination are warning signals for work overload or hard mental load. Finally, (v) measuring or collecting data on results of operator’s actions by using the data on flight or aircraft motions, changes in air traffic situations may show the total quality of the operator’s work.

4.1 Dynamic Sectorization and Airspace Configuration

Nowadays, several international projects are launched, aimed at modernizing the coming air traffic management to cope with the present problems, including, e.g. airspace capacity, efficiency, air traffic complexity, and environment [26]; [27]; [28]; [29]. The SESAR project develops a new method for sector design and airspace configuration. One of the large projects in SESAR deals with the investigation of ATCOs workload management. And one of the possible management when sectors, the airspace is usually divided into smaller regions referred to as sectors, are dynamically changed to make the configuration of the airspace less complex in terms of both its uncontrolled/controlled airspace classification and its international boundaries. This is the so-called “Dynamic Airspace Configuration”. Introducing dynamic airspace configuration will significantly decrease total operator load, and the complexity of the overall route structure and airspace system. A special workshop was organized by the Budapest University of Technology and Economics for validation of the exercise performed in the scope of the SESAR program in France. During the workshop, a series of questionnaires were used for the evaluation of the opinions of experts. The current researcher took part in this project in the assessment of results. In the framework of a SESAR project, a concept of dynamic sectorization was developed as well (Figure 5).

The main goals of the project were: (i) balance the sector workload for ensuring safety, (ii) decrease operator total loads, (iii) better use of the availability of airspace, (iv) offer the maximum capacity to the incoming air traffic, (iv) best meet traffic demand at peak times operate with less staff, (vi) reduction in fuel burn and emission, and (vii) minimizing all costs.

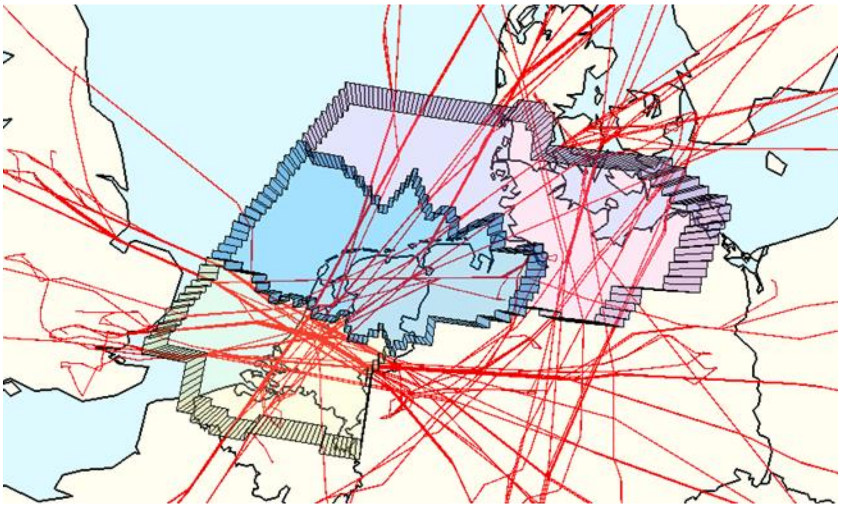

Figure 4- Dynamic sectorization and airspace configuration [39]

As seen in Figure 5, depend on the air traffic complexity, the total airspace can be divided dynamically into small "sectors". The complexity of the traffic has a direct influence on the total load of operators. According to the results, the dynamic sectorization and air space configuration may eliminate the task overload and reduce the actual load by 30-40 per cent [30]. The large size international projects, such as SESAR and Next-Gen, plan to shift aircraft separation task from the ground-based air traffic control to the airborne self-separation, as well as the "situation awareness" and "conflict avoidance" to the aircraft. These two aspects introduce a paradigm change in the ATCOs' roles [31]. Next-Gen envisions [32] the five types of personal roles of the navigation service provider: (i) capacity managers in collaboration with airspace users and flight operators, (ii) flow contingency providers in cooperation with flight operators, (iii) trajectory managers in a collaboration with flight operators, (iv) separation managers (maybe flight crew depending on the airspace and the operation), and (v) automated dissemination to operators and flight crews, flight operation centres, third-party service providers.

4.2 Developing New Operator Models

The operator makes decisions every day in many situations where s/he must have a selection of a course of action from among multiple alternatives. The decision-making process of the operator strongly depends on many factors, such as total load systems, mental condition, experience, tacit knowledge, and skills. Unfortunately, some decisions lead to the loss of lives of hundreds of people and have extraordinary economic consequences. On the one hand, the "situation awareness" and "decision-making" is the central element of the model, seen in Figure 6. This figure demonstrates the operator model [33]; [34] developed by adaptation of the well-known and probably the most used model created by Endsley [33]; [9]. According to this model, situation awareness is made at three different levels:

- Level 1. Encompass and awareness of specific critical elements of a situation,
- Level 2. Comprehension of a current situation, integration of that information in the light of operational goals,
- Level 3. An ability to project future states of the systems.

In this model, the situation is evaluated from the "present situation" instead of the state of the environment as defined by Endsley. The "current situation" is continuously changing depending on the environmental effects (such as weather), real air traffic situation (including the individual aircraft performance), operator behaviors or working quality, and applied controls. This operator model is improved, by the current researcher, by including the actual (present) mental condition of operators into the "individual factors" because, in highly automated systems, the role of the psycho-physiological state of the operators is increasing. Moreover, another modification in this model is that operators apply “control actions” and then they face with new “present situation”. This model starts with a “present situation”; after having the “control action”, operators will have a new situation depend on the previous state. Depending on situation awareness, operators make decisions on how to control aircraft most safely. “Performance actions” do not only depend on the skills of the operator but also highly dependent on human aspects including operator behavior, practice, personal habits, personal characteristics (mental condition), physical and psychophysical conditions. For example, if an operator is tired or under being in a stressful situation, the reaction time of the operator is increasing. Operators may know absolutely what to do in a situation; however, if s/he does not have enough practice and experience, then this would create an accident as well.

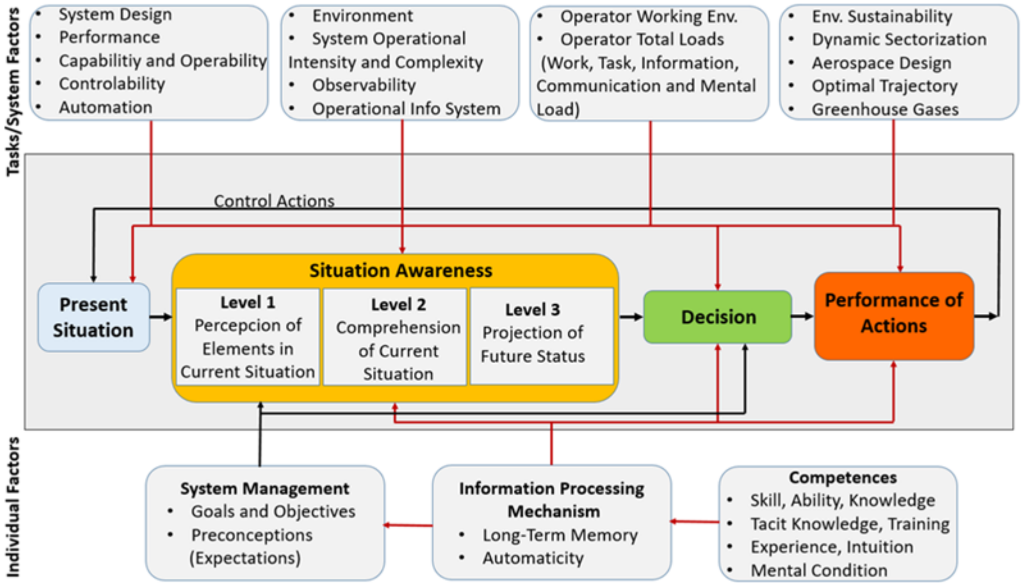

Figure 5- The created model of situation awareness and decision making in future dynamic ATM environment [34]

The (i) system functions, (ii) operational characteristics, and (iii) operator-system interface (working environment) compose the system factors. The developed model includes some new system factors as (i) system operability (including interoperability), controllability and automation, (ii) system operational intensity and (traffic) complexity, observability and operational (flight) information system, and (iii) improving the working environment of operators to increase the level of situation awareness. The underlined new element and incorporated into the traditionally applied situation awareness model adapt the model to the future air transport system, and future air traffic management. As it is investigated and well-known, the success of situation awareness and decision-making highly depends on human behavior (skill and performance) and operator loads (work, task, information, communication, and mental load). As Rasmussen ([35]; [36]) defined thirty years ago, situation awareness and decision-making might be realized on three different levels. The first level, so-called “skill-based control” is applied by the operators when the situation is normal, and the operator can easily recognize the situations and can work “automatically”. At the second level, the operators must recognize and identify the situation and apply the “rule-based” solutions to reach the expected situations. In case of abnormal flight situations or possible flight conflicts, the operators must derive the solution with their knowledge and practice. This level is called the “knowledge-based level”.

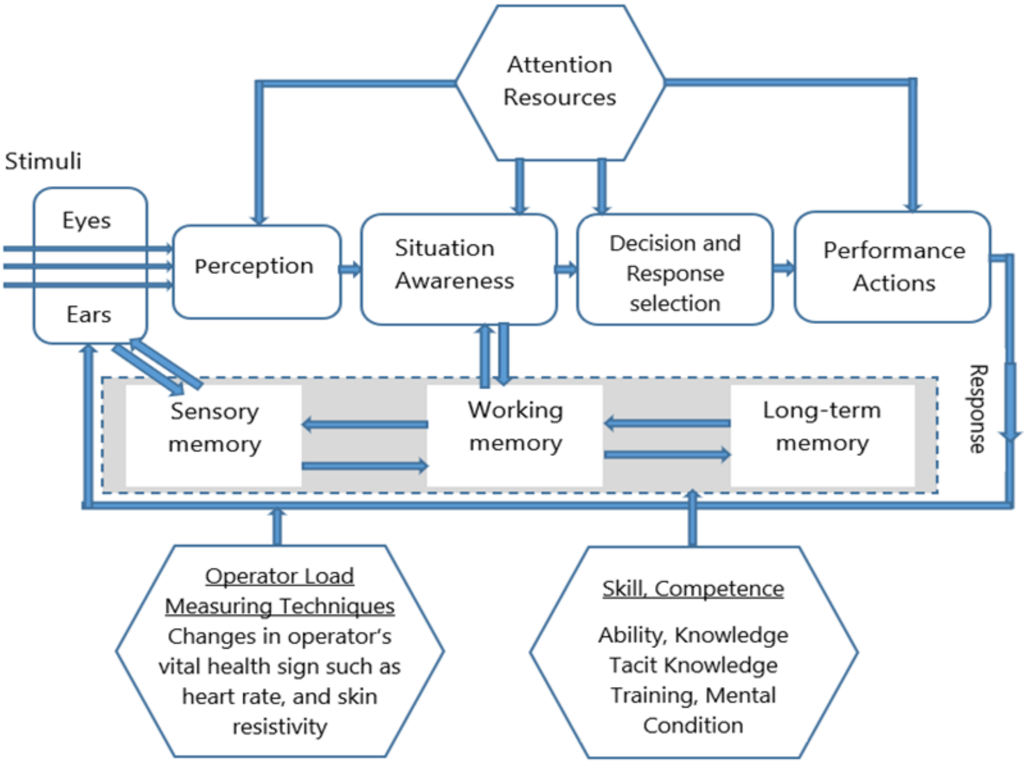

Figure 7- The improved model of human information processing and decision-making [25]

The information model of Wickens [25] was improved and adapted by the current researcher, to operators by including (i) sensory memory, (ii) situation awareness, (iii) skill and competence, and (iv) load measuring techniques (Figure 7). According to this model, after receiving information by the operator senses, receptors encode stimuli from the external environment. Thereafter, the collected information might transmit through sensory memory which limited a certain amount of information that can be processed for a concise time, about half a second to three seconds, and forwards to working memory. Finally, this information might be encoded and stored in long-term memory.

This information process highly depends on the operator's skill, competence, experience, physical and physiological condition. On the other hand, the total load of operators can be monitored from their responses during "situation awareness", "decision-making" and "performance actions". The information processing is linked with the reaction time of operators. Due to highly automated systems, information load increases some phases of flight such as take-off, approach, and landing particularly. It is, therefore, these flight phases that can generate a high metal state which can, in turn, lead to increased "reaction time", and reduced "decision-making time". According to Cummings [37], a person is capable of processing three bits of information per second on average without error. In case if an operator receives higher than three bits per second, the occurrence of unavoidable errors and loss of information can be expected. However, the rate of information processing highly depends on the operator's characteristics such as operator skills, competence, experience, total load, physical and physiological condition.

4.3 Eye Movement and Eye Blink Rate of Pilots

Given the importance of eye movements for visual perception, there has been a surge of interest in eye movements with numerous studies being conducted to clarify what kind of information can be derived from eye movements. A number of studies have suggested that eye movement, blinking rate, and fixation duration can be linked to the task, information processing, stress level, fatigue, and loads [38]; [39]. Many investigators have reported that an increase in eye movement when the task increases in difficulty [40]; [41]. Rui Fu et al. [40] reported that as the complexity of the task increases, an operator's mental load increases, which leads to an increase in the eye movement of operators. However, some investigators have reported otherwise; they found, an inverse relationship, a decrease in eye movement with task difficulty. For example, May et al. [42] indicated that eye movements were restricted as counting complexity increased. When the level of task difficulty increases, the total load of operators is also increasing, mainly work, task, and mental load.

In order to examine the number of eye movement and eye blink rate during different flight tasks, three flight scenarios were designed: (i) Visual Meteorological Conditions (VMC), (ii) Instrument Meteorological Conditions (IMC), and (iii) IMC with ADI (Attitude Directional Indicator) failure (Figure 8). According to the results, the number of eye movements of the experienced pilot was found (i) 1.31 per second under Visual Meteorological Conditions (VMC) scenario, (ii) 1.82 per second under Instrument Meteorological Conditions (IMC) scenario, and 2.38 per second under IMC with Attitude Directional Indicator (ADI) failure.

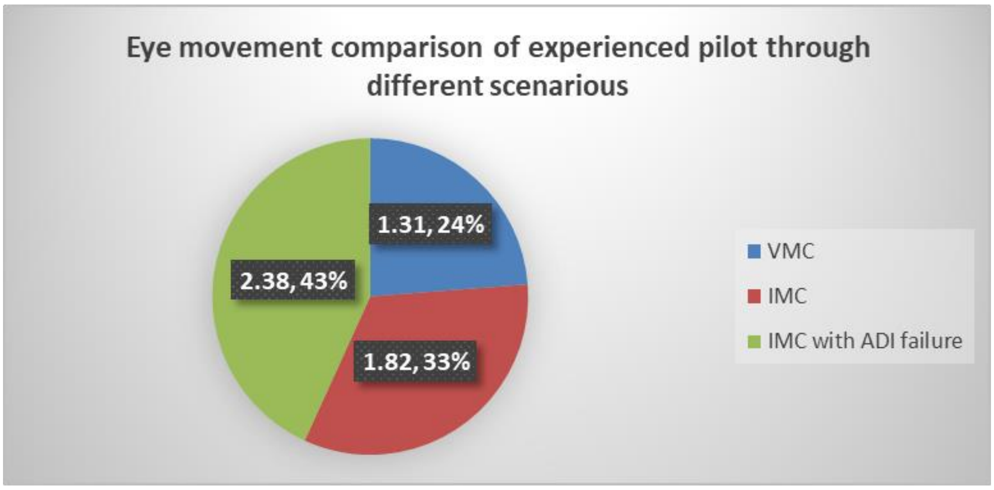

Figure 6- Eye movement comparison of the experienced pilot through different scenarios

In this research, eye blink rate was used as a measure of studying the connection between the mental state and the complexity of flight tasks. The human eye blinks once every four or five seconds on average – that is approximately 15-20 times per minute [44]. Eyeblink rates can be affected by a variety of different factors such as human behaviours, experience level, task (nature, difficulty, and engagement) and endogenous state (mental activity, psychological state, and state of attention). Several studies have shown that an increased level of task difficulty results in less frequent eye blinking [45];[46]; [47]. According to Jyotsna and Amudha [45], a constant increase in the level of task difficulty will increase the cognitive load and which results in a reduced number of eye blinks. In contrast to these researchers, some other studies reported that the blink rate is increasing as the task difficulty increased; [38]; [39];[40]. Tanaka & Yamaoka studied the relationship between blink rate and task difficulty and reported the more difficult the task became, the higher was the blink rate [38]. Additionally, a limited number of studies found no relationship between the degree of task difficulty and the blink rate. For example, Pauline Cho [41] reported that the level of task difficulty did not affect the blink rate in primary gaze and downward gaze. In this research, the eye blink rate of an experienced pilot was investigated through three flight scenarios: (i) Visual Meteorological Conditions (VMC), (ii) Instrument Meteorological Conditions (IMC), and (iii) IMC with Attitude Directional Indicator (ADI) failure.

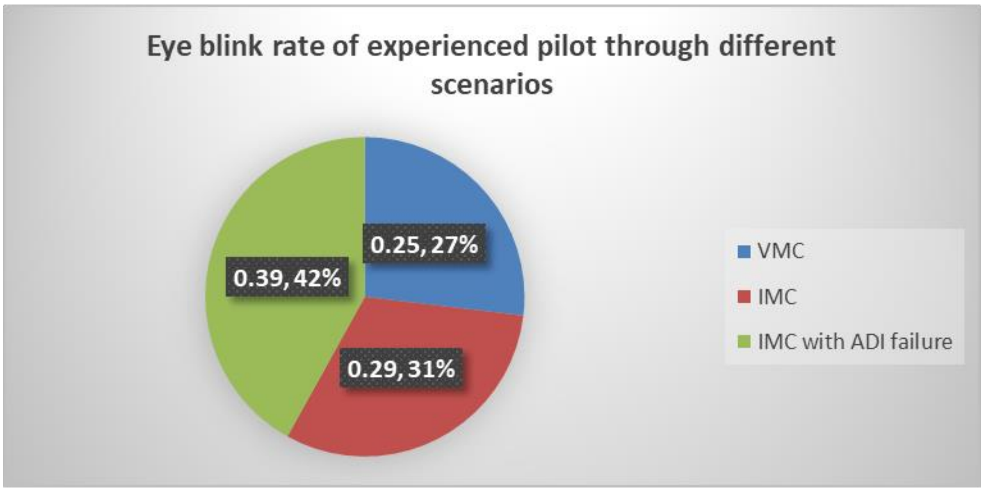

Figure 9- Eyeblink rate of the experienced pilot through different scenarios

The number of eye blink (full blink and half blink) of experienced pilot increased significantly in parallel to the task complexity: (i) 0.25 per second under Visual Meteorological Conditions (VMC) scenario, (ii) 0.29 per second under Instrument Meteorological Conditions (IMC) scenario, and 0.39 per second under IMC with Attitude Directional Indicator (ADI) failure (Figure 9). In addition to this, it is also noticed that eye flutters (rapid muscle movement in the eyebrow area) also increased.

According to the outcomes of these experiments, direct relationships were found between task difficulty and both eye movement and eye blink rate. As discussed earlier, a number of studies support the outcomes and methodology of the experiments. On the other hand, some others against these results. However, in my newly built concept, the autonomous system recognizes the operator in the loop and after start to continuously measure and store all the parameters on the subject in the operator environment including eye movement, blink rate, skin resistivity, and heart rate, etc. The autonomous system will have the ability to know what is the normal or abnormal value for each of the vital health parameters for a specific subject from the continuously stored data. In the case, if the system detects any sharp changes in the operator’s vital health parameter(s), the autonomous system will automatically be reported to the control managers and supervisors, and generate some suggestions to the operators.

4.4 Pilot Decision Support System

The new operator load monitoring and management concepts were developed for pilots in order to improve their working environment and decision support system. The decision support system of pilots has three layers: (i) ground controlling system, (ii) onboard central processing unit, and (iii) smart cockpit screen. The ground controlling system includes ATM, aircraft remote control, S/PATS support centre, and S/PATS management. The onboard central processing unit contains (i) pilot load management, (ii) situation awareness, and (iii) decision support. The onboard central processing unit collects and analyses the available data, including the information provided by cooperating with other aircraft and ground systems. The cockpit screen provides (i) the four types of pilot loads (work, task, information, and mental load) are presented in forms of colored lines (left-bottom side), (ii) the tasks of pilots are displayed (central part), (iii) advice of pilots are given in a text form (right bottom), and (iv), the screen contains the more than 180-degree view of ahead and side of the aircraft (upper hand). The view on the left and right sides are shown as synthetic vision pictures. The central view is the real view, but the head-up display shows the recommended flight path (in predicted tunnel forms) and gives some other recommendations, measured information (Figure 10).

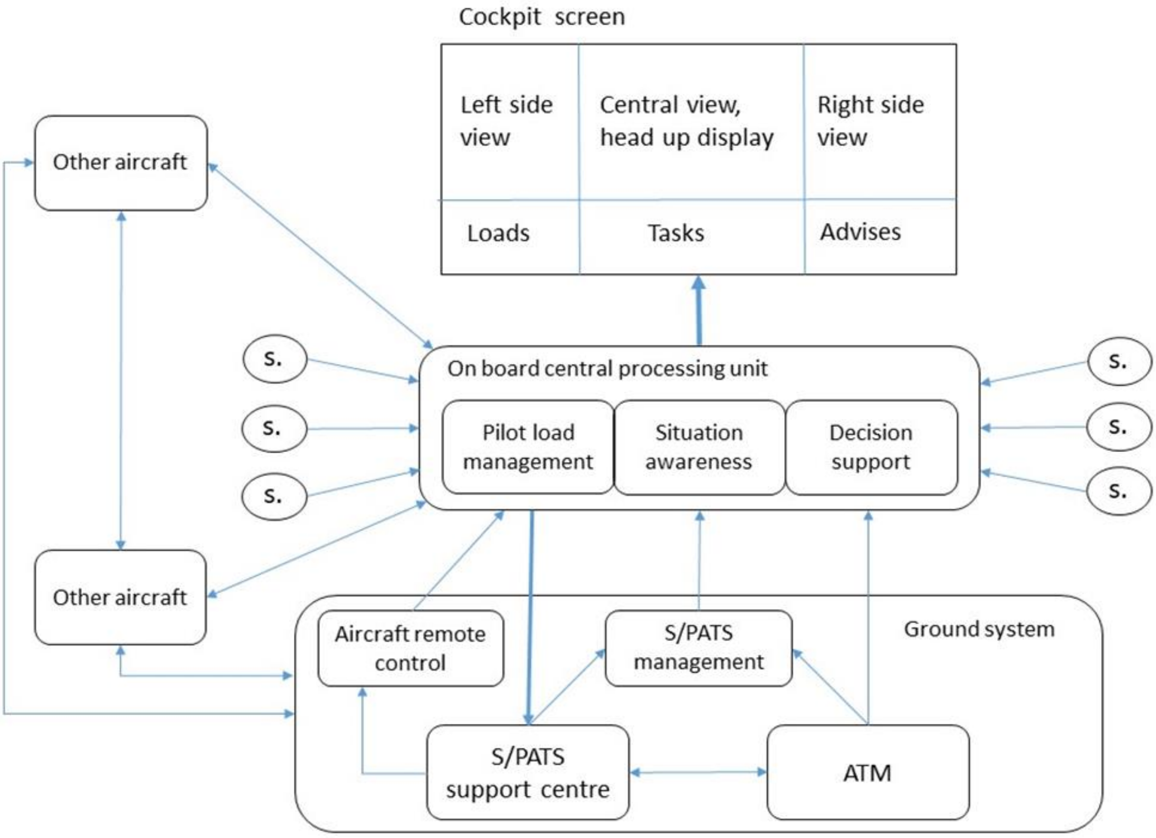

Figure 10- Functional model of the pilot decision support system (s. – sensors) [43])

For example, the ground sensed information on the wind and wind shear under the landing trajectory. The supporting systems include all the possible methods that may help in reaching better flight performance and better stability, flight dynamics, and control characteristics of the aircraft. The recommended pilot decision support system is based on (i) environment, (ii) technology, and (iii) solution (software) developments.

5. Conclusion

Air transportation is expected to continue growing considerably over the next two decades. In dealing with this growth, it is essential to ensure the highest level of safety and security. After analyzing the well-known situation awareness models of Endsley and the information model of Wickens, new situation awareness and operator load model have been created. These operator models had been used for developing general ideas on load management taking into account the interaction of identified loads reducing the work quality of operators. In addition to this, in the framework of a SESAR project, a concept of dynamic sectorization was developed. The dynamic sectorization and air space configuration concept may eliminate the task overload and reduce the actual load by 30-40 per cent.

The complexity of the task found directly proportional to the number of eye movements per second in this research. In other words, if the complexity of task increases, the number of eye movement per second also respectively increase. Concerning this, the number of eye movements of the experienced pilot measured as (i) 1.31 per second under Visual Meteorological Conditions (VMC) scenario, (ii) 1.82 per second under Instrument Meteorological Conditions (IMC) scenario, and 2.38 per second under IMC with Attitude Directional Indicator (ADI) failure.

According to the results of the eye blink rate, the number of eye blink (full blink and half blink) of experienced pilot increased significantly in parallel to the task complexity: (i) 0.25 per second under Visual Meteorological Conditions (VMC) scenario, (ii) 0.29 per second under Instrument Meteorological Conditions (IMC) scenario, and 0.39 per second under IMC with Attitude Directional

Indicator (ADI) failure. In addition to this, it is also noticed that eye flutters (rapid muscle movement in the eyebrow area) also increased.

With the developed models and concepts, the load of operators can be continuously monitored and managed in the working environment. If the operators in the loop are incapable of dealing with the routine tasks (such as strip marking, transferring an aircraft to the next sector) or failure, the control of aircraft will able to take over from the pilots in the loop by ground operators or the fatigue ATCOs can be replaced with the fresh ones. According to the test results system balance operator total load, thereby increasing the safety of operators' action, particularly in an abnormal /emergency situation.

6. Copyright Statement

7. References

[1] Boeing, "Boeing Aero Magazine," 2007.
[2] EUROCONTROL,*" Human Factor Strategy," Skybrary*.
[3] U. Kale, "'Role of Operators in Future Highly Automated Aviation,'(ISSA-2019)," in *in Proceedings of International Symposium on Sustainable Aviation*, 2019, pp. 20–24.
[4] D. Petersen, "Human error reduction and safety management," *Van Nostrand Reinhold, New York, USA, and Chapman & Hall, 2-6 Boundary Row, London SE1 8HN, United Kingdom, 3rd ed., 1996. xvii, 397p. Illus. Bibl.ref. Index. Price (in Europe): GBP 45.00.* 1996.
[5] CAA, "Global Fatal Accident Review 1980-96 (CAP 681)," London, 1998.
[6] M. R. Endsley, "Toward a theory of situation awareness in dynamic systems," *Human Factors*. 1995.
[7] M. Khazab *et al.*, "Evaluating pilot situation awareness using multi-agent systems," *Intell. Decis. Technol.*, 2013.
[8] B. J. Underwood, *Psychological research. Englewood Cliffs*. United State: Prentice-Hall, 1957.
[9] M. R. Endsley, "Measurement of situation awareness in dynamic systems," *Hum. Factors*, vol. 37, no. 1, 1995.
[10] J. M. Flach, "Situation awareness: Proceed with caution," *Human Factors*. 1995.
[11] N. B. Sarter and D. D. Woods, "Situation Awareness: A Critical But Ill-Defined Phenomenon," *Int. J. Aviat. Psychol.*, 1991.
[12] B. M. Huey and C. D. Wickens, *Workload Transition: Implications for Individual and Team Performance*. Washington, D.C.: National Academy Press, 1993.
[13] E. Salas, A. S. Dietz, and R. M. Taylor, "Situational Awareness Rating Technique (SART): The Development of a Tool for Aircrew Systems Design," in *Situational Awareness*, 2018.
[14] K. Smith and P. A. Hancock, "Situation awareness is adaptive, externally directed consciousness," *Human Factors*. 1995.
[15] M. R. Endsley, "Design and Evaluation for Situation Awareness Enhancement," *Proc. Hum. Factors Soc. Annu. Meet.*, 1988.
[16] M. R. Endsley, "Situation Awareness Global Assessment Technique (SAGAT)," in *IEEE Proceedings of the National Aerospace and Electronics Conference*, 1988.
[17] S. G. Hart, "NASA-task Load Index (NASA-TLX)," *Proc. Hum. Factors Ergon. Soc.*, 2006.
[18] U. Kale and M. B. Tekbas, "Operator's Subjective Decisions-Improving the operator's (Pilot and Air Traffic Control) decision making," *Sci. Coop. Int. J. Mech. Aerosp. Eng.*, vol. 3, no. 1, pp. 43–51, 2017.
[19] V. Kasyanov, *Subjective analysis*. Kyiv/Ukraine: National Aviation University of Kyiv, 2007.
[20] J. Rohacs and V. A. Kasyanov, "Pilot subjective decisions in aircraft active control system," *J.*

Theor. Appl. Mech., vol. 49, no. 1, 2011.

[21] K. J. Sarno and C. D. Wickens, “Role of Multiple Resources in Predicting Time-Sharing Efficiency: Evaluation of Three Workload Models in a Multiple-Task Setting,” *Int. J. Aviat. Psychol.*, 1995.

[22] A. R. Watson, C. Ntuen, and E. Park, “Effects of task difficulty on pilot workload,” *Comput. Ind. Eng.*, 1996.

[23] M. Flach, J. and Mulder, “Putting Humans Into Control,” 2004.

[24] D. Marr, “Vision: a computational investigation into the human representation and processing of visual information.,” *Vis. a Comput. Investig. into Hum. Represent. Process. Vis. information.*, 1982.

[25] C. D. Wickens, *Engineering psychology and human performance, 2nd ed.* 1992.

[26] S. Kinzhikeyev, A. Wangai, and U. Kale, “Influence of state management on environment sustainability,” in *Materials of International practical science conference ” Ualikhanov Readings-21*, 2017.

[27] A. Wangai, U. Kale, S. Kinzhikeyev, and M. B. Tekbas, “Influence of e-mobility on total impact on transport means,” in *IFFK 2017*, 2017, pp. 94–100.

[28] A. Wangai, U. Kale, S. Kinzhikeyev, and M. B. Tekbas, “A method for comparison of impacts of the transportation means,” in *Transport Means 2017 (21st International Scientific Conference)*, 2017.

[29] K. Tánczos and Á. Török, “Impact of transportation on environment,” *Period. Polytech. Transp. Eng.*, 2008.

[30] J. Rohacs, R. Daniel, I. Jankovics, and U. Kale, “Sector Design and Dynamic Airspace Configuration,” in *Repüléstudományi Közlemények XXIX. Évfolyam*, 2017.

[31] J. Rohacs, D. Rohacs, and I. Jankovics, “Conceptual development of an advanced air traffic controller workstation based on objective workload monitoring and augmented reality,” *Proc. Inst. Mech. Eng. Part G J. Aerosp. Eng.*, vol. 230, no. 9, 2016.

[32] FAA, “Concept of Operations for the Next Generation of Air Transportation System,” *Tech. Rep.*, 2010.

[33] I. Jankovics and U. Kale, “Developing the pilots’ load measuring system,” *Aircr. Eng. Aerosp. Technol.*, vol. 91, no. 2, 2019.

[34] U. Kale, I. Jankovics, J. Rohacs, and D. Rohacs, “Load monitoring for operators’ load management,” in *31st Congress of the International Council of the Aeronautical Sciences, ICAS 2018*, 2018.

[35] J. Rasmussen, “Skills, Rules, and Knowledge; Signals, Signs, and Symbols, and Other Distinctions in Human Performance Models,” *IEEE Trans. Syst. Man Cybern.*, 1983.

[36] J. Rasmussen, *Information processing and human-machine interaction*. 1986.

[37] R. . Cummings, “The analysis of driving skills.,” *J.Aust. Road Res. Board*, vol. 1(9), pp. 4–14., 1964.

[38] R. Zargari Marandi, P. Madeleine, O. Omland, N. Vuillerme, and A. Samani, “Reliability of Oculometrics during a Mentally Demanding Task in Young and Old Adults,” *IEEE Access*, 2018.

[39] R. Zargari Marandi, P. Madeleine, Ø. Omland, N. Vuillerme, and A. Samani, “Eye movement characteristics reflected fatigue development in both young and elderly individuals,” *Sci. Rep.*, 2018.

[40] R. Fu *et al.*, “Research on heart rate and eye movement as indicators of drivers’ mental workload,” in *Road Safety and Simulation*, 2011.

[41] K. Rayner, *Eye Movements in Reading: Perceptual and Language Processes*. New York: Academic Press, 1983.

[42] J. G. May, R. S. Kennedy, M. C. Williams, W. P. Dunlap, and J. R. Brannan, “Eye movement indices of mental workload,” *Acta Psychol. (Amst).*, 1990.

[43] I. Jankovics, U. Kale, and D. Rohacs, “‘Modernizing the tasks of ATCO for reducing the total environmental impact of aviation,’ (ISSA-2018).,” in *in Proceedings of International Symposium on Sustainable Aviation 2018*, 2018.

[44] E. Wascher, H. Heppner, T. Möckel, S. O. Kobald, and S. Getzmann, “Eye-blinks in choice response tasks uncover hidden aspects of information processing,” *EXCLI J.*, 2015.

[45] A. Nagy and I. Jankovics, “‘Tanszéki repülésszimulátor laboratorium modernizálása _ (Modernization of the departmental flight simulator) repüléstudományi közlemények,’” 2012.

[46] National Transportation Safety Board, “‘Aviation accident database synopsis,.’”

[47] Federal Aviation Administration,*“ Instrument flying handbook,.”* New York,.