

## TRANSPORT DEVICE OPERATOR STRESS FEATURES ANALYSIS

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### **Abstract**

*The paper is focusing on known publications review concerning the transport device operator stress features and identification possible and their influence at man decision making process. The paper composition include: stress phenomenon analysis, human features and stress interaction analysis, human availability models including stress factors, and stress analysis tools analysis. Stress has been recognized as a major influential factor to affect the operator's health, safety, and productivity. Stress is subjective and express man reaction from external to potential reactions. The operator stress is often expressed as quality of life indicators related to satisfaction with a given domain of functioning and have influence at the human operation potential (health). Studies on the role of the state of mental and physiological functions are an important part of the theory of operators working reliability and a cause-and-effect relationship between the functional state and their availability. The review on known selected publications concerning the transport device operator stress features and others, including own research, helps to identify possible stressors acting at man and their influence at decision making process. The measure possible stress parameters: physiological, subjective and behavioral types have also been discussed. The transport devices' operator fatigue remains to be one of the important factors that contribute to possible accidents accompanying transportation processes. The problem of availability and reliability of human operators activities are today more practically oriented crucial and a branch of applied psycho-physiological research.*

**Keywords:** *man operator, stress, availability, anthropocentric system*

### **1. Introduction**

Today evolution of technical devices is driving at improvement not only devices, but also sets of man/ operator – automated devices (anthropocentric sets) [69]. Development of anthropocentric sets is forcing greater attention at their identification (with taken into consideration property and critically), as well as shaping and designing possibilities of adequate information type connections for decision - making needs. The important problem of anthropocentric set (from reliability point of view) is their resistance at surroundings (external) actions that have weaken and deformation impact at decision-making process. The focus will be done on man - operator of the transport device.

Equivalent of device safety losing (e.g. offence of critical stress of the construction) is losing of operation capacity of the operator (e.g. health, as the result of stressors impact, mostly time type during decision making activities so called controls), moreover finally system availability will not meet with user needs.

Availability is uncertain and is typically defined and measured as the probability of the system (in particular operator) being available for use (to undertake control activities) at a given surroundings conditions and time. A system might be unavailable if it has failed (device or operator) and is waiting to restore needed operation potential. Over a given time period, a system might therefore be available or unavailable depending not only on the system set reliability but also on how well the support transportation organisation/ business might affect needed renewals activities [57].

The paper is focusing on known publications review concerning the transport device operator stress features and identification possible and their influence at man decision making process.

## 2. Stress phenomenon

Stress is a condition of the organism, which is independent or dependent on a human being [8], and a result of a process with changeable relationship [11] between a human and the environment [9].

Stress has been recognized as a major influential factor to affect the operator's health, safety, and productivity. Stress refers to some undesirable condition, circumstance, task, or other factors that impinge upon the individual. For each man – device – surrounding set it is necessary to predict the levels and effects of the ergonomic workload stress in the workplace and provide recommendations to solve the problem [6]. The stress levels can legitimately be defined as permissible or not permissible. The workload can be expressed by the following parameters [67]: with the imposed load or stressor, internal stress response without loss of homeostasis, intensity of homeostatic disturbance or strain, the stress response associated with disturbance of homeostasis.

Much of stress research is founded on description of the General Adaptation Syndrome which identifies the three components of the stress response as being the alarm reaction, followed by the phases of resistance and exhaustion [20, 48].

Stress can have either external or internal origins or some combination of these. Possible sources of stress are [6]:

- physical job demand stressors ( $s_1$ ): the stresses that come from the physical activities which are the manual part of materials handling, such as weight of load, frequency of handling load, duration of physical activity, and moving distance of load [6],
- environmental stressors ( $s_2$ ): the stresses from working environment, including improper temperature, lighting, noise, vibration, and exposure to chemicals (including dust and fumes) [17],
- body motion and postural stressors ( $s_3$ ): the stresses which are induced by improper body motion and posture (e.g.: standing, stooping, squatting, twisting) [17],
- mental demand stressors ( $s_4$ ): caused by the mental and perceptual activity that is required in performing a job (e.g.: calculating, thinking, deciding, communicating, remembering, looking, and searching) [47].

Stress is subjective and express man reaction from external stressors (e.g.: job stress, adverse life events, financial problems) to potential reactions (e.g.: depression, vital exhaustion, sleeping difficulties or anxiety) [64]. For example known models of job stress include a stressor that can either arise from the individual, the organization, or extra-role (non-work) factors that induce a series of physiological and psychological outcomes [14, 22].

Stressors can be physical or psychological types or both [70]:

- physical stress is caused by long-term exposure to negative factors such as: physical overload, an irregular lifestyle, environmental toxicity, cigarette or alcohol or drug use, improper diets, etc.,
- psychological stress can be caused by factors such as: psychological overload, insecurity, negative emotions, confusion, rejection on a social level, home/ family problems, etc.

The complex relationship nature between physical and psychological health is well known [41].

Psychological stress refers to the emotional and physiological reactions when an operator confronts a working situation in which the demands go beyond their existing/ access available

potential/ resources [41, 59]. The stressful situations or psychological stressors are major life events (e.g.: health disorders, environmental problems in the home and/ or workplace, financial needs) [41, 45].

The psychological stress has been linked to illness and alterations in physiological functioning [21] and would be expected to have a direct impact on quality of life indicators such as psychophysiological symptoms: job satisfaction, and life satisfaction. Psychological stress plays an important role in the physical and emotional well-being of low-income hypertensive patients [1].

Psychological stress affects the body in many ways [41]. It is known that psychological stress can affect the immune system, the body's defence against infection and the disease, including cancer [59]. However, it is not yet known whether stress increases a person's susceptibility to disease.

Stress can influence also eating patterns in humans [61]. The stress response can induce following stressors: physical stressors (trauma, surgery, intense heat or cold); chemical stressors (reduced oxygen supply, acid-base imbalance); physiologic stressors (heavy exercise, hemorrhagic shock, pain); psychological or emotional stressors (anxiety, fear, sorrow); and social stressors (personal conflicts, change in lifestyle) [50].

### **3. Human features and stress interaction**

The stress term is widely considered to result from noxious events [29, 30]: one would anticipate that stress would have a negative impact on one's quality of life. The operator stress is often expressed as quality of life indicators related to satisfaction with a given domain of functioning. Compared to other lifestyle risk factors, stress is different because no consensus exists with respect to either definition or measurement.

In the sociological papers [51], there has been a particular interest in measuring chronic strain, as it is believed to play a more influential role in mediating the relation between socioeconomic status (SES) and physical health than acute stress [43, 62]. There is substantial evidence that people of lower SES are more likely to experience high job strain, low job control, financial strain, and other forms of chronic life stress than are higher SES individuals [32, 35, 52].

Hearing problems are the most common sensory deficit in human populations, with hearing loss alone affecting more than 250 million people worldwide [36].

While the deleterious effects of mechanical stress (noise), on hearing have been studied extensively in animal models [42] and human populations [24, 58], the notion of emotional stress as a modulator of the auditory system is rather novel [18]. It also needs be considered that long-term hearing problems can be stressful.

Stress is associated with coronary disease [19, 34].

Researchers have suggested that psychological factors may affect disease progression in cancer patients [59]. The hypothesis that there is a causal link between psychological factors and cancer has been widely debated in the scientific literature [10, 15]. Studies done over last dozen years, that examined the relationship between psychological factors, including stress and cancer risk, have produced conflicting results [10, 15, 41]. Although the results of some studies have indicated a link between various psychological factors, a direct relationship between psychological stress and the development of cancer has not been scientifically proven [10, 15, 41].

There is evidence linking psychological stress to exacerbation of certain skin diseases [25]. Both the clinical and the basic science evidence however can be hard to interpret in light of the difficulty of defining and quantifying psychological stress as well as the questions regarding the etiologic significance of neuroimmunologic findings in skin diseases.

Emotion affects human performance through influencing individuals' judgment and behaviour [5] and can accompany undertaken actions by man operator under the device operation. Negative impacts of negative emotions are generally well known, but currently impact of various emotions on human performance is still not clear. In order to discuss the relationship between operators'

emotions and task performance, it is necessary to first describe and quantify emotions.

In paper [26] author pointed out that stressed operators could not achieve their optimal performance in complex task environments, as well as an anger and frustration have a similar negative influence on operators' performance. Other authors [33] indicated that human operators might be inattentive and unproductive due to boredom in highly automated systems: human operators are unable to resume control quickly enough in frightening situations. In paper [55] suggested that delays in human - computer interaction negatively affect the emotional state and cause a significant deterioration of task performance, work satisfaction, and health-and-safety. In order to discuss the relationship between operators' emotions and task performance, it is necessary to first describe and quantify emotions [5].

Results the investigation has been pointed, that between stress and aggression of non-human and in particular the hormonal changes, association with them are highly complex in the relationships [20].

#### 4. Human availability model

The problem of availability and reliability of human operators activities are today more practically oriented crucial and a branch of applied psycho-physiological research [28, 56]. Studies on the role of the state of mental and physiological functions are an important part of the theory of operators working reliability and a cause-and-effect relationship between the functional state and working reliability [4, 27].

Four approaches to modelling the reliability of man-machine systems have been identified [13]:

1. the discrete failure combinatorial model based on technique for human error rate prediction (THERP) [37, 54] based on standard combinatorial mathematics together with artful use of tabled human error rates,
2. the time-continuum failure human model based on mean time between failure approach (MTBF) [2],
3. the Monte Carlo man-operator failure simulation probability based model expressing human behaviour under operation [71],
4. the man behavioural model [49].

The discrete failure combinatorial model based on technique for human error rate prediction (THERP) is based on standard combinatorial mathematics together with registered from practice possible human error rates results operation with use any device [49].

The time-continuum failure human model is based on mean time between failure (of human - H) approach (MTBFH) consequence man undertaken actions and consider system reliability is in terms of time until failure. The possible man failure results with losing human potential which is a subject of re-create or/ and upgrade resulting possible processes [56] in so-called mean time to repair of human (MTTRH) and generate statistics for fraction of time a given system is available (A):

$$A = \frac{MTBFH}{MTBFH + MTTRH} \quad (1)$$

Other a general formula for the system steady-state availability is developed with the aid of the Markov approach and Laplace transforms, which demonstrate the impact of critical and non-critical human errors on system steady-state availability [12].

The Monte Carlo man-operator failure simulation probability based model expressing human behaviour under operation. Probabilities of error are assumed for human behaviour elements such as: obtained from device sensors right data interpretation, reading and interpreting the operation data display correctly, making the right decision based on own knowledge and practice and achieved data, finding the right device controls or operating it correctly [71].

The man behavioural model [49] is based on outputs variables characterize what the human operator with particular potential capacity does in time and operation space to what characteristics of

response make it a success or a failure. The criteria of success or failure can be specified individually to device type and undertaken operations. The probability of success is determined by the performance resulting from the inputs and initial conditions based on set of man operator (hardware/ body, software/ brain and health, in-built knowledge results education and training) - device (hardware, software, automation/ in-built knowledge) – surrounding (conditions).

The reliability of an operator’s work should be determined based on not only integral working parameters but also individual psychological and physiological characteristics [27]. Psychophysiological stress index (PSI) is one of possible characteristic. Psychophysiological stress index is a specific characteristic of the functional state of the human body representing its reactions to conditions, character, and result of activity.

Psychophysiological stress index is measured quantitatively using special psychophysiological tests [28]. Functional correlation between PSI and an aggregate of determining factors is described by the following equation:

$$PSI = F(c_1, c_2, \dots, c_n), \quad (2)$$

where:

- PSI - psycho-physiological stress index value of the operator,
- $c_i$  - the estimate of the  $i$ -th psycho-physiological parameter of the operator,
- F - the function transformation operator,
- n - the number of psycho-physiological characteristics taken into consideration.

Equation (1) solving matter contains two problems should be taken under consideration: selection of psycho-physiological parameters associated with PSI and determination of the transformation F function.

Selection of psycho-physiological parameters associated with PSI should be solved taking into consideration that values of psycho-physiological parameters and indices are indirect characteristics of psycho-physiological reactions determined not only by simulation parameters (complexity, testing conditions, etc.) but also by internal factors (initial functional state of the body, level of training, etc.) determining the operator’s reactions [29]. The psycho-physiological parameters provide information about integral effects of a combination of factors, including the effect induced by the individual operators’ working features (e.g.: environmental conditions, level of training).

Determination of the type of transformation of psycho-physiological parameters into PSI must be based on measurements results coming from operator features monitoring operation in real conditions with use suitable sensors.

The stress influences on human performance and behaviour have been studied in several papers [16, 38]. To predict the existence and level of the ergonomic workload stress in the workplace the concept of the fuzzy sets theory has been developed and the Ergonomic Workload Stress Index (EWSI) model [6]. The model is based on the linguistic values (e.g.: heavy, uncomfortable) of the tasks and workplace variables (e.g.: physical job demand, environmental stressors) which have most influential factors on stress.

## 5. Stress analysis tools

Three different levels of analysis have been used to measure stress: physiological, subjective and behavioural [40]. Stress can either be measured: before the aversive event occurs during the anticipatory period; or while the aversive event occurs; or during the impact period; or after the aversive event has occurred during the post-impact period.

On the physiological level, skin conductance and heart rate have been the most popular measures [40]. For skin conductance two main measures can be derived: tonic skin conductance level (SCL) which refers to gradual long-term shifts in conductance and phasic skin conductance responses (SCRs) which refer to abrupt changes in conductance. On the subjective level

anticipatory arousal is measured by self-report ratings of anxiety and tension; behavioural measures usually refer to choice of a controllable or an uncontrollable aversive event.

The existence of stress can be directly found by measuring the strain, e.g.: chemical measures (heart rate, blood volume, etc.), electrical measures (electroencephalography (EEG), electromyography (EMG), etc.), physical measures (blood pressure, temperature of body, etc.), activity measures (work rate, errors, etc.; attitudes measures: boredom, etc.).

The autonomic nervous system (ANS) plays an important part in the overall man body's control system focused for overlooked useful functions (e.g.: driving by car). Physical and psychological stresses effective physiological responses through the autonomic nervous system [70]. The ANS is both man major defence against stress and the system that demonstrates principal symptomatic of stress in its early stages. The ANS is responsible of beat to beat variations in heart rate (HR) and is controlling most of organs in human body including heart.

The ANS is divided into two parts in a parasympathetic and sympathetic balance [53, 70]: the sympathetic, which activates organs, getting them ready to cope with exercise or other physical stress, and the parasympathetic, which controls background *housekeeping* functions in the body. The balance between these two systems is an indicator of the body's reaction to external and internal demands.

Stress involves change of autonomic function and the secretion of several hormones such as cortisol, corticosterone and adrenal catecholamine [63]. Blood pressure and heart rates during stress increase reflecting the predominance of sympathetic nervous system activities [46]. The psychological stress decreased high frequency component of HRV and increased low frequency component of HRV [3].

Heart rate variability (HRV) is a physiological phenomenon where the time interval between heart beats varies. The analyzing data of the heart rate possible variability (HRV) data can provide a tool to understand the mechanisms of ANS and it is the most frequently used method for ANS test using combining electrocardiography (ECG), blood pressure, and pulse analyzer functions into one integrated measuring device. The example electrocardiogram (ECG) methodology is useful for operators stress detection and analysis to help them understanding how to reduce their own risk by showing their stress states correlation with heart health.

The specified parameters measurement with suitable sensors put together the powerful non-invasive methodology having enormous practical advantages with a minimum of technical constraints, which makes it useful everywhere. The portable set parameters measurement device can help to collect monitored data on-line and analyze them for the decision making process focusing on man physiological responses under particular working conditions.

To detect and investigate stress in humans, questionnaires and interviews may be used. In animals, stress mostly has been quantified via physiological parameters, such as the measurement of adrenocortical response through the detection of cortisol levels either in the plasma, faeces, urine or saliva [39, 60] or monitoring autonomic responses such as changes in heart rate or blood pressure [7, 44]. Both routes of investigation have problems but benefit over questionnaires and interviews.

The behaviour of device operator has been an active field of study for decades [31]. The operator fatigue remains to be one of the important factors that contribute to traffic accidents. One of the key steps towards developing a fatigue monitoring system is to consider the features that could be effectively used for fatigue recognition, which can be classify into four categories [23, 66, 68]: causal/ contextual features, physiological features, performance features, and multi-features.

Physiological features of the operator may be classified into: contact features, including the brain activity, heart rate variability, and skin conductance – these can be easily detected by EEG (electroencephalogram), ECG (Electrocardiograph), and EMG (electromyogram); and contactless features, including the eye movements (EM), head movement, and facial expressions – these can be easily observed from the dynamic images provided by a CCD camera and others contactless

feature based method.

Performance features include operator's fatigue contributes to the deterioration in the operational performance such as for example: the reaction time, lane position deviation/ trajectory movement, hand movement of controlling the steering device. The above measuring needs have been reached by the fuzzy set-based method involving the small movement of controlling the steering car wheel to calibrate and predict the driver's fatigue [65].

## 6. Conclusion

Stress has been recognized as a major influential factor to affect the operator's health, safety and productivity, and express man reaction from external to potential reactions. The operator stress is often expressed as quality of life indicators related to satisfaction with a given domain of functioning and have influence at the human operation potential (health). Results studies the role of the state of mental and physiological functions of an operators, working reliability and a cause-and-effect relationship between the functional state and their availability model have been presented. To express human availability the data archived from operator measure stress system have been also discussed: physiological, subjective and behavioural types.

The review on known selected publications concerning the transport device operator stress features and others possible including own research helps to identification possible stressors and their influence at man decision making process. Future works will include both quality and quantity analysis of the problem in practice.

## Acknowledgements

The research project is financed from the Polish Science budget for the years 2008-2011.

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