

ERGONOMIC ASPECTS OF RELIABILITY AND SAFETY IN TRANSPORT - NATURE, PROBLEMS, PROBLEMS OF THEORY AND PRACTICE

Assoc. prof. Eng. Georgiev N. D., Senior. assist. Hadjiev E. N.
Todor Kableshkov University of transport, Sofia, Buglaria

Abstract. *Indisputable desire to improve the quality of services is an essential feature of modern transport. This trend has led to development activities in order to realize the reliable movement of vehicles. Ergonomic aspects of reliability (and all the problems associated with it) is a particularly important recent trend in this area, the essence of which is related to the provision of adequate conditions for reliable operation and effective use of relevant and specific to a transport system for man-machine systems. In this montgomery, this article provides systematic problems, tasks and directions for research and analysis of the role of man-machine systems to provide reliable transport process.*

Keywords: ERGONOMIC ASPECTS, RELIABILITY, RESEARCH, ANALYSIS, HUMAN-MACHINESYSTEMS, TRANSPORTS PROCESS.

1. Intorduction

There is a lack of uniform definition for ergonomics and the comparative analysis of the multiple definitions shows evolution of ideas from "adaptation of machine and labor to man" to "system approach". Ergonomics (from gr. Ergon "act" and nomos "law") is the science for creation of the best possible labor conditions, though adaptation of labor tools to man's milieu. In the most general case the ergonomics is defined as a complex scientific way for optimizing the man-machine system in order to achieve maximum techno-economic and bio-medical labor efficiency. Practically, ergonomics executes the synthesis of biological, psychological, anthropological, labor-hygiene, technical, economical and other knowledge. In the Russian-language literature it is called "эргономика" (ergonomika), in Germany- anthropo-technique and in the USA- human engineering or human factor engineering design.

The ergonomics is a science for the human factor and it studies mainly the human labor activity. The aim is to optimize the human activity in the environment through application of knowledge and researches of different scientific directions. The classic concept is defined as adaptability of technical, transport etc., equipment to the human capabilities, effectively and with minimum electric losses. The optimization is based on data for the antropo-metric dimensions of human body, for human's strength and mechanical characteristics, human senses' parameters (vision, hearing, touch etc.) and the reliability of human actions. In this way the entire ergonomic "System-human-machine-milieu", (SHMM) with human as a main factor, is reviewed.

Ergonomics is the science for productive capabilities of the working man and their limits, as well as for the best changing synchronization between the man and its working conditions. This is a science for creation of the best possible labor conditions, through adaptation of objects and labor tools to human's milieu.

2. Problems/Tasks of ergonomic aspect and ways of solving the problem

2.1. Main directions of ergonomics

Ergonomics defines the ways of working process design, working place organization on construction and design, and their adaptation to human capabilities. The ergonomics on working place in transport requires: to describe the factors affecting the working environment using the human-environment model, and the difference between work load and work stress; to study the physical readiness limit and its place in work organization; to illustrate work organization which leads to satisfaction and the one leading to the opposite; to analyze the main principles of work structure; to acknowledge the most important factors affecting capability and readiness for work as characteristics and basic capabilities, knowledge and skills, psychological readiness and motivation; to study the curve of day-night biological rhythm and its reasons; the criteria of appropriate work in the sense of health safety, preservation of abilities and possibility for development. Through systematic approach it is needed to: study the favors of its application in group work; study the differences between obligatory and good aims, valuable and non-valuable aims and

application of the knowledge in projects preparation; description of systematic approach's stages with examples and application of systematic planning during project preparation. To size the load, stress and their consequences by: analysis of the various work and its influence on human; acknowledging the co-relation between load and stress and its application in working systems building; studying the principles and aims of work structuring which should be described and evaluated; to study the influence of shift-working; to acknowledge the connection between tiredness and recovery and to be taken in consideration in organizing of work processes and tasks. The work place organization requires, by anthropometry and labor tools: how to apply anthropometry in work place organization to be explained and to apply the principles into the own practice; the movements made on work place to be described by the view of anthropology; to acknowledge the essential recommendations for arranging and design of manually-controlled tools and other regulation devices; to be based on examples for design of control panels and regulation devices.

In the meaning of the above and in accordance with typical peculiarity of the transport exploitation process, as well as in its organization and management (including the high requirements for safety and reliability), in transport ergonomics, the following tasks can be formulated:

- analysis and valuation of SHMM operator's actions;
- research of human's ergonomic features and defining the reliability of his/her actions;
- organization of the operator's work place during testing his/her ergonomic peculiarities;
- professional selection, preparation and education of operators;
- ergonomic design and valuation of SHMM;
- efficiency definition of ergonomic studies.

The basic principles in transport ergonomics in its organization, management and exploitation can be formulated in the following manner:

- complex system approach for solving the ergonomic tasks;
- Solving the ergonomic problems simultaneously in two directions: from operator's requirements – to technologies, as well as from the technique potential – to the executor;
- Research of human activities in SHMM as an important part from the complex integrated system;
- Perception of the operator as a complex biologically-dynamic system;
- organic connection with many other individual and technical sciences and usage of their achievements for solving the ergonomic tasks.

After extensive researches of the transport exploitation actions' peculiarities, the following main tasks are formed and examined in this publication:

- making of extensive analysis of the condition and tendencies for transport incidents due to failure in the different types of human-machine systems;
- reviewing and analyzing the causes for subjective mistakes in movement organization and management;
- examination and analysis of subjective mistakes' causes;
- development of models for safety and reliability increasing of specific human-machine transport systems.

Ergonomic principles for work design are realization of ergonomic design on each of the three basic components of SHMM. The aim is a work system to be designed, reading the human capabilities, talents, needs. A foremost task is determination of requirements, ensuring efficiency of the work system for safe, healthy and satisfactory labor for the man. The second task is determination of human type, which will work in the system and identifying of operators' specific characteristics. The third task is making of analysis of human-operator's activity including: distribution of functions between operators and the work device; identification of tasks executed by the operator; separation of the tasks on their single components; determination of activity sequence in time that each operator has to execute; analysis of the current operator's actions, for example by stimulating and studying work situations similar to these that are designed.

Ergonomic data are needed for evaluation of a particular project. For example data for design of distributive and sectional stations, location of control panel and management objects. Determination of needed documentation: information about operators, maintenance manuals, work guides etc., Determination of needed education – the results from task analysis are taken into consideration, special requirements for training are formed (usage of simulator in order to prevent critical human mistakes), safety requirements, financial resource etc.

2.2. Ergonomic methods

Considering the operator, machines, subject of activity and environment as one system, the ergonomics solves the problem for optimal distribution and functions coordination between man and machine, designs a process of actions so best conditions to be reached, develops methods for building and exploitation of working systems.

Ergonomics methodology is the idea positions defining the meaning, the way, the destination and the contents of all researches.

To define the model in SHMM, ergonomics uses methods that are applied as theoretical studies and tests of new technologic pattern, which aims an evaluation of their compatibility with human capabilities.

The ergonomics' methods are:

- experimental – milieu influence on the operator;
- psychological – observation, interview, questioning, test or experiment;
- physiological – methods for valuation of operator's functional condition;
- modeling – physical, mathematical, imitational

2.3. Experimental methods

They are developed and used for studying the influence of technical devices and environment on the human-operator. These methods are studied, developed and applied for research of different work processes' activity on physiological functions of the individual for different by content and complexity types of human activity. Quantity accumulation and quality alternation in functional changes in the organism influenced by work environment are studied, as they are difficult for direct observation and analysis. The quality of research activities is determination of European regulations and giving guides for development of innovative tools to the national carriers for design of transport equipment and systems. Nevertheless it is cooperative or single work, usually the studies include the relation between: peculiarities and requests of people using one transport system (i.e. age, experience, activities); the nature of products and usage systems (the comfort and convenience in the vehicles, information devices, the vehicle itself, the control etc.), the seats in the frame of the trip and research of the process (traffic condition, time, lightning); procedures related to the travel (tickets selling, waiting rooms, safety rules, emergency exits in the vehicles etc.).

Methods and elements:

- determination of task (activities) and responsibilities included in the particular job;
- determination of methods for execution of given job;
- determination of place for execution of a given job;

- determination of executors for execution of a given job;
- design of work place – physical environment;
- determination of the social and psychological environment in which the job will be done;
- determination of qualification requirements.

Methods for development of ergonomic indexes:

- on the basis of data for past periods;
- chronomentering;
- method of previously determined time standards;
- extract observation of work time, it is used in designing a work composed of different activities with systematically repeated character.

An observation on the operator is done during defined periods of the working day and it is registered what activity he/she is executing. The aim is to determine the relevant part of each activity in the common work time.

2.4. Psychological methods

With their help, the executor's action (or its separate sides) is analyzed. A valuation of the influence of all types of factors on the operator and the results of it are made in real or laboratorial conditions. The psychological techniques are used for research, study and tests. After that, by monitoring, experiment or discussion, mechanisms of operator's actions are revealed and a psychological analysis is made. With examinations, usually performed by tests, the existing or other psychological qualities and characteristic's levels are determined.

The basic psychological methods are: observation, discussion, questioning, experiment, test.

The natural experiment is performed on the operator's work place in the following forms:

- "additional challenges", that is introduction of changes in the condition of the managed object and the future operator's actions are analyzed;

- alternation of the structure according to examination of the work activities, when the working pose, buttons and tools for operation are changed, which leads to other stress factors and can distract the operator. The natural experiment is used only for analysis of existing SHMM and not every situation can be performed in real time.

2.5. Physiological methods.

They are used for studying operator's functional condition in the work activity process in order to define the causes of alternation in the different organic systems.

- the electromiograph has the following abilities- diagnosis of miogene, neurogene, examination of musculoskeletal system, muscle dysfunction, pathologic movement control, movement stereotype and kinesiological analysis, muscle function, movement control, balance and coordination.
- electroencephalographic examination of the brain cortex ;
- electrocardiography is a graphic register of electric-moving tension, created in the heart before each contraction and conducted to all parts of the body;
- polygraphic method – measuring of breathing, blood pressure, skin conductivity and EEG;
- skin-galvanic reaction registers alternation in the skin potential, which is an extremely sensitive index for emotionally-psychological condition of the man.
- the electrooculography is a record of the potential of eye-ball rotation, which is an important indicator for sight movement towards a given object during work.
- polyeffectorial method is a combination of the examinations above performed simultaneously and giving full picture of the man's functional condition. It gives complex register of psycho-physiological functions and is used for examination of different by content and complexity types of human activities.

2.6. Mathematical methods

The models are: verbal which explain the original by verbal description; graphic which reflect the common traits between the natural object and typical traits of the model; physical, which

represent functional copies of the original in a small scale; mathematical, which represent systems of algebraic or differential equations, describing the functioning (movement) of the object in relevant limited conditions. Modeling is a human activity related with building and reproduction of the entrance-exit results through model experimentation. Building of the model is a formalization of the task in which given non-characteristic traits of pattern functioning are neglected, and only the main, essential relations and interactions of the modeling system are considered. This process includes choice of target function, determination of limiting conditions and creation of relevant equations etc. Experimentation with the model is solving a mathematical task by deterministic or non-deterministic (stochastic) method.

Through modeling is achieved: processes imitation; processes optimization results prognosis; possibility to vary in examination object's parameters in a search of the optimal combination, etc..

Following requests are claimed towards modeling: to reflect the real situation of the system; to have a stable structure; to cover the aims and conditions; to recover the quantitatively-measured characteristics; to be implemented on a computer.

There should be conformity in some degree, between the original and the model. Absolute conformity is not possible due to neglect of some, even non-essential traits of the original. The skill of avoiding the non-essential is a skill of simplifying the task with minimum negligible loss of information, because otherwise the task is getting extremely complex. The difference should be acceptable and not to be a loss of qualitative information or to reproduce the model in a simplified type, in any case.

Building of operational models is the most difficult task related to modeling of real transport-economic objects. This is performed in the following stages:

- setting of the task;
- building of the model;
- determination of the method for reproduction of the final result;
- model verification and valuation of the decisions.

The experimental procedure is a high form of valuation of model functionality. It includes comparison of results, received by natural experiment and results from the modeling. When results are similar enough we consider that the model adequately describes the process.

To the main mathematical methods in the ergonomic studies are assigned theory of mass service, information theory, theory of automatized control, theory of statistical solutions etc. For development of mathematical methods and their application in the ergonomic studies, the following characteristics are learned and examined:

- size – description of the control processes and learning of different co-related variables;
- dynamics – the ability of registering the “time” factor;
- indefiniteness – the ability of registering accidental probabilities constituting operator's activity;
- factor/факторност – the ability of registering the specific peculiarities in executor's behavior;
- descriptiveness – probability for full description of internal psycho-physiological mechanisms in human activities.

2.7. Imitation methods

They take middle position between experimental and mathematical methods. On the basis of data received for operators' activities in SHMM, the imitational methods are close to the mathematical, but according to results character and the way of their obtaining and application, they copy the experimental methods. In case of usage of imitational modeling in ergonomics, the following conditions are required: the sequence in operator's actions can be defined in deterministic or probable way; operator's actions should be analyzed regarding the event probability and the time for their execution; the imitation models mandatory register the psychological qualities of the operator - memory, reaction, ability to interact with other operators, emotional stability etc.

Imitation models have the following structures:

- simulation means and action conditions;
- simulation of its own activities and their analyzing;

- task generating;
- determination and identification of the initial conditions;
- improving of modeling results;
- model control.

If exploitation tasks are solved the imitation methods take operator's actions for examination. In SHMM, imitation methods are divided into two main types:

- operator decision on separate, specific tasks;
- operator functioning in conditions of task flow (service models).

In the first type on the basis of multiple modeling, main characteristics and tasks have originated: average time of solution (execution of operations), quadratic-average deviation from time and probability of task execution on time.

In other models type, operator's solutions for specific tasks are considered as known magnitudes and appear as outgoing data:

- series of tasks, solved and executed by the operator;
- types of operators' mistakes;
- individual psycho-physical characteristics of operator regarding his work;
- peculiarities during control process (terms, особенности при протичане на процеса на управление (срокове, compulsory waiting, waiting for service, release limits)

In a result of the modeling the operator activity's characteristics are calculated: load rate, busy period, on-time solution with challenges etc.

The essence of modeling method is, the real operator activity to be examined and on the basis of the study psychological, mathematical and statistical models to be build.

- psychological modeling;
- mathematical modeling;
- statistical modeling;
- theory of information.

In theory of information “channels with memory and no memory” are differentiated. Accordingly, considering the operator as a channel for information transformation, analogically we can talk about channels without memory, with short or long term memory

In the first case the man is functioning as a channel for information transition, the sequent signals are not mutually dependent, the previous signal does not affect the coming of the next one (its receiving, understanding, memorizing)

The theory of information is used in ergonomics for solving of the following tasks:

- determination of operator's work complexity, which allows a comparison between different types of operational activities to be made, on the basis of processed information volume;
- valuation of time needed for perception of this information;
- determination of information processing speed and comparison with psycho-physiological abilities of the operator.

The main disadvantage in the information theory is that it does not register:

- mind information, its value and significance, which is very important for operator's actions;
- temporary ambiguity of the signals when entering.

2.8. Automatized control theory

It is used for building of mathematical models when operator's actions are in a system of constant type (in transport this is locomotive, automobile driving, conduction of trains in railway section, dissolution over the hump, load-unload processes, freight transport on pipe ways etc.)

From the position of automatized control theory, the human operator is considered as an element of the control system, which is SHMM. System analysis process with this theory is on three stages:

- establishment of behavior criterion in closed system and determination of its transfer functions, which characterizes the dynamic relation between the elements and the human operator;
- activation of operator's actions which allows finding the needed values of the whole transport system;
- making of numerous events (selection, operator's training, modernization of the technical equipment of SHMM), ensuring operator's needed functions.

The main disadvantage of the automatized control theory is the linear representation of operator's actions, while the human is a non-linear part in the control system.

2.9. Theory of mass service

This theory is used in ergonomics for building a model of operator's actions and solutions of the following tasks:

- determination of the SHMM's operative memory volume when the operator considers the system as system for mass service with limited duration of expectation and limited time for service;
- distribution of the work between operators, when SHMM is considered as multi-channel and multi-phase system for mass service;
- determination of the operator's mistakes probability, as this should be considered as failure of the service equipment and the time for its recover;
- determination of operators number in accordance with the order flow;
- limitation of order flow in the system.

3. Conclusion

Solution of appeared problems or current task by responsible subjects (managers, dispatchers, movement director, vehicles' drivers, operators, etc.) only based on experience and the known to the moment ways, leads to not making the best decisions. The first approach of decision making is apparent – the easier and most common – the method of test and error. The basic aim in studying the quantitative methods in transport management or examination of operations is usage of the received results from their application for making the best and most accurate decisions, or this is application of the second approach – the scientific one, based on scientific analysis. It assumes application of operational method for reproduction of the final result in a function of the main input disturbing and managing factors.

4. Literature

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