

JURIJ KOLENC, D.Sc.  
Fakultet za pomorstvo in promet  
Pot pomorščakov 4, Portorož

Science in Traffic  
Review  
U. D. C. 656.05:331.101.1  
Accepted: Nov. 26, 1998  
Approved: Jun. 1, 1999

## RESEARCH PROBLEMS AND APPROACHES IN TRANSPORTATION ERGONOMICS

### ABSTRACT

*The paper analyses the actual problems and procedures in studying ergonomics in transportation. Special emphasis is put on the specific features of the problem and the research development in accordance with the characteristics of the single sub-systems and elements of the transportation system and research approaches.*

*According to the structure of the development and actual problems of the research, the following approaches have been analysed: psycho-physiological, systemic and technical, cybernetic, exploitation, and pedagogic, within which also the basic tasks of studying ergonomics in transportation have been indicated.*

### KEY WORDS

*ergonomics, traffic, cybernetics, exploitation*

### 1. INTRODUCTION

Continuous and intensive development of transportation system elements has been constantly imposing new problems and requirements for finding solutions particularly in the area of human users adaptation.

World-wide methodology research of defining the transportation system ergonomic problem has been carried out.

In this paper actual ergonomics problems in transportation research and research approaches are being discussed. The overall objective is aimed towards achieving higher level of transportation system performance.

### 2. ERGONOMICS RESEARCH PROBLEMS IN TRANSPORTATION

Advanced transportation techniques assume large energy capacities, high speeds, complexity of physical processes, and huge amounts of information. The role of transportation to enable movement of people and

goods is of great importance. The character of transportation requires the users to have high sensor, intellectual, psycho-physiological and other abilities. The users very often have to act on the edge of their own psychological and physiological capabilities, either under stress, or in limited time and lacking information. The pilot, for instance, is subjected to big stress and strain during the flight.

Human capabilities, i.e. the "brain level capacity" are limited in receiving and processing information. If the speed of transmitting information exceeds human processing capabilities, a system failure becomes inevitable.

Considering human capabilities and limitations, the problems impose new requirements on the transportation system designers as well as on the transit operators. Human and techniques problems in transportation have been highly ranked by the transportation science today. Unfortunately, the problems are still treated in a non-systemic way, by applying different methodologies and approaches.

It was in the past that, with no exception, the human user had to adapt to the technology, operation, and complex environment in a fairly developed transportation system.

At the beginning of the next century the transportation system characteristics inevitably are to impose the task of a whole system and subsystems adaptation to the human abilities and limitations. This does not necessarily mean less human adaptation.

These are the main reasons for introducing ergonomics-based knowledge in transportation. In order to achieve high level of safety, reliability, efficiency, comfort, and performance, the human role and functions are to be investigated.

Generally speaking, ergonomics relies on general psychology, physiology, psychology at work and pedagogy, and on the other hand on technical sciences, systems sciences, cybernetics, the theory of probability, the information theory, modelling theory, the theory of chains, etc.

Transportation ergonomics is a very oriented discipline. That is why the same ergonomic cognition could not literally be applied to each transportation discipline such as road, rail, air, or maritime transportation. Ergonomic research development is shown in Fig. 1.

The following are the actual problems that transportation ergonomics methodology is facing:

- definition of the human role in design, construction and operation of transportation devices, transportation infrastructure, and the complex environment conditions;
- definition of the ergonomics structure and principles in transportation;
- "man-machine" related structure definition in transportation;
- choice of experimental investigation methods and tools requirements;
- scientific and research tools and methods adaptation for a specific research;
- knowledge- and skill-based methods, primarily in users behaviour adaptation in transportation;
- defining of the methods compatibility in parameters and research results for separate parts or for a transportation system as a whole.

### 3. ERGONOMICS RESEARCH APPROACHES IN TRANSPORTATION

Following the ergonomics structure development, several research approaches such as psycho-physiological, technical, cybernetic, operational, and pedagogical can be accepted.

#### 3.1. Psycho-Physiological Approach

Psycho-physiological human analysis deals with problems in receiving, processing and storing information as well as the motoric, spatial and technical abilities to perceive and think in an operational way. The assessment of human ability to participate in transportation has been an issue of concern.

For most of the transportation users characteristics the quantitative values are well known. Unfortunately it appears very often that for specific psycho-physiological processes the distribution and data accuracy are not known.

It is of major ergonomics importance to perform an integral characteristic assessment of humans. It applies to work safety, reaction speed, work accuracy, reliability, etc. So far, these problems have not been sufficiently investigated yet, particularly in the area of

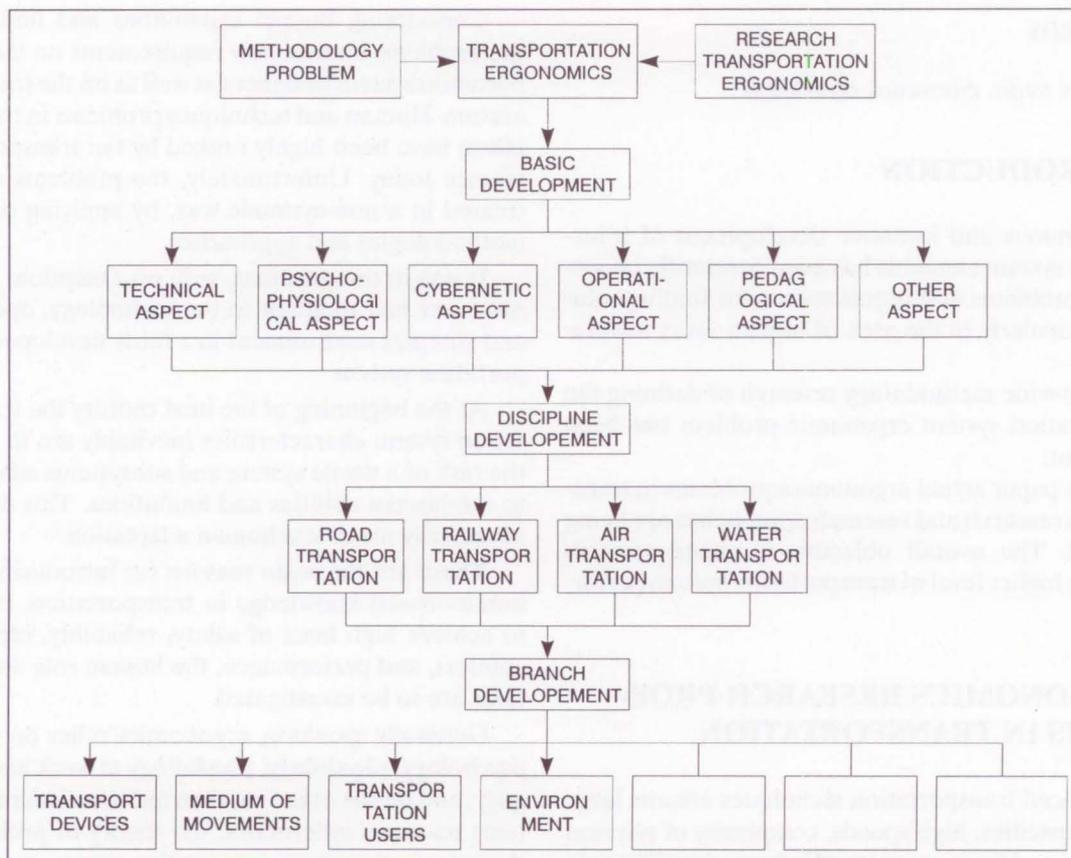


Figure 1 - Structural pattern of ergonomics research development

human reliability in transportation. Human reliability is a non-linear function of its professional eligibility, training, qualifications, stress stability, and individual moral and psychological characteristics.

From the psycho-physiological point of view, most of the authors suggest man reliability criteria for the "man-machine" system in transportation such as:

- probability of free from error work in a defined time interval;
- frequency of failures;
- work readiness and stand-by;
- time and other criteria.

Particular emphasis has been laid on the sc. function-algorithms analysis of transportation users operation. It concerns operational analysis, elementary operation and logical conditions decomposition in order to make the entire whole again, as well as the formal operation description. A set of empirical and time related characteristics, stereotype indicators, logical units have been suggested.

The function-algorithmic analysis is significant for operation design and users human working conditions in transportation. In can be done by pointing out the "weaknesses" under specific conditions, or by information flows redistribution and improvement of the methods of work etc.

From the ergonomic aspect, the psycho-physiological solution of the problem is to be expected after specific methods of objective recording have been applied and psycho-physiological tolerance criteria limitations set up.

### 3.2. Systemic - Technical Approach

The systemic - technical approach within its theoretic and practical tasks determines a broad spectrum of problems such as:

- engineering-psychological design and building of a transportation system, its subsystems and elements;
- optimisation methods and criteria setup to adapt human abilities to the transportation system technical and existing characteristics;
- methods and criteria setup to determine human function automation purposes and possibilities;
- information flow and structure optimisation methods and criteria setup in transportation system and subsystems;
- optimisation methodology equipment setup at the points of transportation devices management;
- design methods setup to present the transportation information;
- control devices producing methods in transportation management;
- "Man-Machine" system analysis and performance evaluation criteria.

It is quite obvious that the main objectives are focused on the engineering-psychological design, building, maintenance and transportation devices operation. As a particular objective, the building of complex dynamic systems is setup. The building and improvement of such systems appear to be very complex creativity processes assuming interdisciplinary professional involvement.

According to transportation experts, the system-technical research approach assumes several phases such as the preparation, organisation, preliminary design, principal design, modelling, solutions examination and final decision-making. In each phase a particular engineering-psychological task has to be resolved.

In the above mentioned research approach the man-user relation in transportation is considered as a matter of particular concern. It entails:

- human role in transportation in different phases and at different levels;
- transportation users functional obligations;
- structure operation analysis;
- human psycho-physiological requirements in terms of motor, psychological and functional characteristics;
- transportation users model of behaviour adaptation and limitations;
- optimal man-transportation user feedback and its technical, existing and organisational system requirements.

The next problem lies in the optimisation methods and criteria setup for the human abilities to be adjusted to the technical and existing transportation system characteristics. According to the state-of-the-art knowledge, the following principles could be applied:

- to adjust human priorities and technical possibilities to the optimal system where man and machine functions are distributed according to their priorities;
- to acknowledge the equivalent human and technical devices input-output elements in transportation;
- to maximise the "man-machine" system parameters in transportation such as of the reaction speed, accuracy, work efficiency and reliability;
- to excerpt importance of function distribution between the human and the technical devices in transportation;
- to excerpt human psychological structure particularities when acting as transportation users.

The next objective due to the transport system complexity is the requirement for optimising the information flow. From the ergonomic point of view, it is very important to select the information at each level.

Due to this approach, numerous high quality solutions already exist. Particularly successful are those when the information model overlaps with the imagi-

nary transportation system operational image. A thorough ergonomic research has been done related to the transportation management issues at different transportation stages. When building up a system, very often the principle of operations savings is applied. It is assumed that any of the transportation operations initiative requires minimum energy input in order to obtain maximum results. However, this has not always been the case.

Updated research has indicated that errors committed by direct transportation system operators were not due to the large energy and strength input into the process of operation. It was that improper system and technical solutions were adopted thus making the operations conditions inapt to the human needs and abilities.

### 3.3. Cybernetic Approach

In transportation ergonomics, considerable role has been given to modelling the transportation users operations either by mechanical or physical models applied. This is conditionally called cybernetic approach. Its main objectives are:

- to model chains of the "man-machine" system as for the performance and optimisation could be programmed;
- to apply cybernetic methods in order to investigate human functions in transportation;
- to model psycho-physiological human functions like perception, sensomotoric, energy and others in order to design transportation technical devices.

Psychology as a science, has accumulated a great amount of material to describe the sc. perceptual or conceptual substantial models.

There are numerous pre-programmed and stochastic models for self-training purposes. Very often these models do not correspond to the substantial psychological models because of their algorithmic structure or inactivity. Thus, the universal approach to information derivation, i.e. the recognising objects character is not possible.

It appears that the theoretical and practical investigation of the "psychological" man-machine related issue has to be more acceptable. Thus the machine "language" becomes much more closely related to the human "language".

### 3.4. Operational Approach

The scope of the operational approach is:

- to investigate the transportation system and its sub-systems reliability criteria regarding transport users impact;

- to analyse the transport users behaviour, working abilities for different operations and particularly under severe conditions;
- to psychologically insure the system "stand-by" state because of the transportation stochastic character;
- to study methods, criteria, and control tools for transportation users psycho-physiological investigation;
- to consider the psycho-physiological parameters in transportation operations making decisions;
- to resolve the common psychological problems by exploring the societal-psychological character of transportation users, their physiological and psychological compatibility, the possibilities to co-operate as well as to assess the transportation devices reliability.

The operational approach is faced with great difficulties in the areas of operations structure, working abilities, transportation reliability for the users, particularly under severe stress like at the risk of life, when the failure in the system "man-machine" may be expected.

Another problem is the behaviour and transport users working capacity under severe conditions.

In "stand-by" state, there is a problem of operation activation. Monotonous observation over the time of "expectancy" may result in a sequence of loss of "alertness" and possible errors might occur.

From the operational point of view it is very important that the area of "common psychology issues" should be considered and expressed, i.e.:

- relations of creating transportation services and detecting prominent individuals, i.e. leaders;
- psychological compatibility;
- overall transport users activities and their mutual co-operation as described in the driver-pedestrian, driver-passenger, pilot-copilot relations;
- transportation service reliability assessment.

Living and working conditions issues are very closely related to the transportation ergonomics. Its main objective is to investigate the environmental impact on the quality of life as well as on the transportation users working capabilities.

### 3.5. Pedagogical Approach

The transportation users performance preparation implies appropriate training and education whereas well studied methods for practice training should be applied.

The main objectives are:

- to consider psychologically related principles and methods in transportation users training;
- to analyse algorithmic basics in creating transportation knowledge and skills;

- to investigate relations in creating transportation skills and knowledge;
- to study methods and criteria in transportation users training;
- to investigate psychological basics for programmable training;
- to investigate the principles in using simulators and other technical devices for transportation users training;
- to investigate the psychological basics of specific methods in training for different users;
- to identify training problems within the general technical and transportation education;
- to investigate the principles in developing curricula in transportation users training and education;
- to produce transportation professionals for different fields of study.

Generally speaking, the training objectives are very closely related to the societal education. To be a transportation user, not only technical knowledge, skills and attitudes are required, but certain organisational, psycho-physical and methodical features and habits, as well.

Related to a different transportation area, the technical way of thinking and perception as well as significant psychological features have to be applied.

Unlike other approaches, the pedagogical approach emphasises the need for all the transportation users to "adapt" to the system, by acquiring proper training. Thus, if for any reason, in a particular transportation domain, the adaptation had not been carried out properly, the users would have a chance to improve themselves.

#### 4. CONCLUSION

Beyond any doubt, the character of transportation system produces numerous ergonomic problems, especially in the domain of the fundamental "man-machine" interaction. Studying the problems by applying finite approaches, offers very limited results.

To solve an ergonomic transportation problem in compliance with its character, a system approach has to be imposed. Thus, any of the research approaches to transportation ergonomics will be highly regarded.

The psycho-physiological approach aims at studying the transportation users' psycho-physiological characteristics. It is related to other system elements characteristics.

The system-technical approach starts from construction and technical-engineering issues which influence the transportation system function in compliance with the transportation users' abilities and requirements.

In the cybernetic approach, transportation operations modelling has been given significant emphasis and mechanical and physical models are used.

The operational approach is aimed at investigating different transportation users' operation structures, i.e. operation of transportation devices in compliance with psycho-physiological and other attributes.

The pedagogical research approach stresses the problem of transportation users' knowledge, skills, and behaviour acquisition in relation with transportation system character, i.e. the need to their adaptation when no mutual compliance is achieved.

#### SAŽETAK

#### PROBLEMI I PRISTUPI ISTRAŽIVANJU ERGONOMIJE U PROMETU

*U članku su obrađeni aktualni problemi i postupci istraživanja ergonomije u prometu. Pritom je posebno ukazano na specifičnosti problema i pravce razvoja istraživanja sukladno značajkama pojedinih podsistema i elemenata prometnog sustava i pristupa istraživanju.*

*Sukladno strukturi pravaca razvoja i aktualnih problema istraživanja obrađeni su sljedeći pristupi: psihofiziološki, sustavno-tehnički, kibernetički, eksploatacijski i pedagoški, u okviru kojih su naznačeni i osnovni zadaci istraživanja*

#### REFERENCE

- [1] Kolenc, J.: *Doprinos teoriji opasnosti u cestovnom prometu*. In *Suvremeni promet*, Zagreb, 1997, Vol. 17, 1-2.
- [2] Kolenc, J., and Džanić, R.: *Doprinos metodologiji znanstvenog istraživanja ergonomije u prometu*. In *Via Vita*, Zagreb, 1992, Vol. 38, 3-4.
- [3] Kolenc, J.: *Organizacija rada u saobraćaju i transportu*. VVTS, Zagreb, 1989.
- [4] Drayfuss, H.: *The measure of man-human factors in designing*. New York, 1967.
- [5] "Nationell trafikakerhets program 1995-2000". Stockholm, 1994.
- [6] Hill, P.: *Nauka i iskustvo projektiranja*. Nauka, Moscow, 1973.
- [7] Gledec, M.: *Sigurnost prometa*. MUP, Zagreb, 1996.
- [8] Kolenc, J.: *Some aspects of ergonomic road adaptation*. In *Via Vita*, Zagreb, 1995.
- [9] Kolenc, J.: *Funkcionalna zanesljivost sistema*. DVRE, Bled, 1998.