NEEDS AND OPPORTUNITIES TO USE THE MODEL OF THE SELECTED FEATURES OF SYSTEM: MAN – TECHNICAL MEAN – ENVIRONMENT IN USING AND MAINTENANCE MANAGEMENT IN ENTERPRISE

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Summary: This paper outlines the concept of the model of the selected features of the system: man - technical means - environment which would be used in using and maintenance management of technical means. The areas of application of the proposed model, including the needs and possibilities of its use were also identified.

Keywords: maintenance management, production engineering, human engineering, reliability, ergonomics, psychology, computer support, artificial intelligence, virtual reality, modeling, GIS, CMMS.

1. Introduction

The execution of production tasks is determined by the proper functioning of the system: man - the technical mean - environment not only when carrying out production activities, but also in ancillary activities, whose example is the using and maintenance technical means. The objectives of the organization will be achieved if, as a result of its business the needs, associated with achieving the desired effectiveness and efficiency of using and maintenance processes and systems will be met, but also if sufficiently attention of policy makers focus on a human - user or maintainer of the technical mean, exploited in the organization.

It is therefore proposed to the original human centred philosophy, which assumes that the using and maintenance of technical means should be based on protecting "the interests" of each of the participants in the system: man – technical mean – environment. According to its assumptions it is necessary to be sought compromise involving the agreement of interests of the organization (expressing by adequate effectiveness, efficiency, reliability of technical means, etc.). According to its assumptions it is necessary to be sought compromise agreement of involving the interests of the organization (expressing by achieving adequate efficiency, performance, reliability of technical means, etc. in the area of the organization) with the needs, possibilities and limitations of human carrying out maintenance work, restoration of ability to use (repair, overhaul) and the use of components of the technical system in the workplace. An additional element of the proposed philosophy is to take into account also the risks of human - technical mean relationship at the stage of realization of management actions (i.e., resulting from the operation of technical mean, but also from human activities involving the use or maintenance of these means).

The need to meet the needs of the individual "participants" of the system: man – technical mean – environment, what is a prerequisite for their proper functioning in this system led the author of the article to scratch the concept of the model of the selected features of the system: man - technical mean - environment, which would be used in the

using and maintenance management of technical means. Moreover the areas of application of the proposed model, including the needs and possibilities of its use were also indicated.

2. Characteristics of the model of the selected features of the system: human - technical mean - environment

Defending sufficiently "interests" of each participant of the system: man - technical mean - environment, in accordance with the assumptions of human centered philosophy, is possible only by recognition of knowledge about the organization, particularly those related to the activities in the area of using and maintenance of technical means but also the knowledge of man, leading basic activities (production) or an ancillary activity by such means. Therefore, the creation of a rational basis of the philosophy in question requires a critical look at the paradigms, which are a component of the knowledge about exploitation of technical means, but also to those produced in other fields of knowledge derived from the technical sciences and management ones. Ensuring the "fit" of human to exploited technical mean, under the assumptions also requires a review of the state of knowledge, derived from the sciences on human and also demands critical look at engineering knowledge from the perspective of this knowledge; in recent years a significant element in the development of research on the man's role - user or maintainer of technical mean has become the use of models of human engineering type, allowing to show human participation, as a structural component of the tasks performed in the system. Assessing the degree of fit human into the system: technical mean - environment should be accompanied among other by an insight into areas of knowledge such as anthropology, ergonomics (including human engineering), psychology (including engineering, cognitive, developmental, emotion, motivation, cultural), industrial gerontology and other. The result of research should be the most advanced knowledge, obtained, derived from the theories of those disciplines. On their basis, as well as current knowledge from management sciences it is possible to develop the original complex model of the selected features of the system: man – technical mean – environment, which will be support decision making at the stages: planning and execution of using and maintenance tasks of technical means and will take into account also needs, opportunities and risks for humans in addition to the needs of only a technical mean. Thanks to acquisition of mentioned knowledge and on its basis by the development of the original model of the selected features of the system: man - technical mean - environment, and its application in the planning and execution of using and maintenance tasks of technical means there will be possible more effective identification of needs, possibilities and limitations of a particular human having specific psychophysical condition and the definition of threads in relationship: human - technical mean will be more precise. Among the maintenance tasks for technical means that you can indicate to the execution of on the stage of planning of maintenance tasks based on: data, information and knowledge provided through the use of the model it is possible to distinguish:

- proactive tasks (restoring technical mean prior to the boundary conditions (scheduled restoration tasks), disposing of specific elements prior to the boundary conditions for it, planned scrapping of the element, irrespective of its use (scheduled discards tasks), actions carried out as a result of evaluation of technical elements),
- alternative actions (searching for hidden damage, component redesign etc., deliberate decision on the admission of failure).

This model is complementary to the conventional model solutions, dominated mainly by the features - the characteristics of the technical mean) of human characteristics. It should use the elements of the basic management model, shown in fig. 2. This model in the general form is shown in fig. 1.

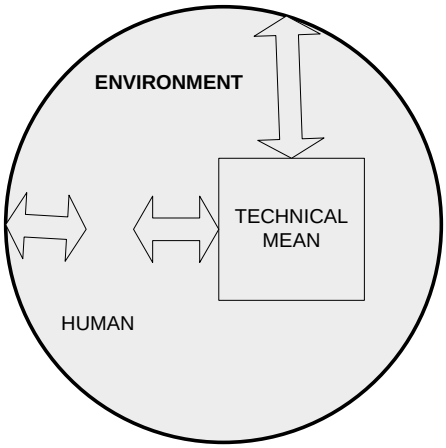

Fig. 1. Model of the system: human – technical mean – environment

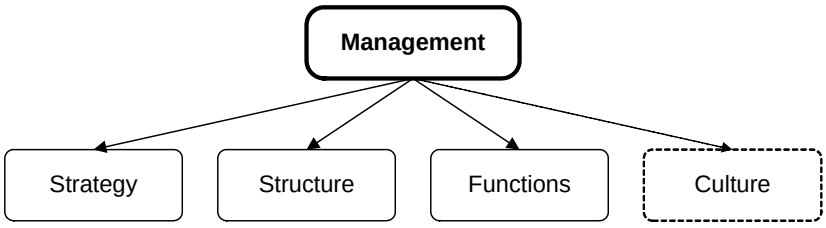

Fig. 2. General model of management [1]

If the exploitation is under consideration, the term "maintenance strategy" should be understood means any generalized strategy (breakdown maintenance, preventive maintenance, predictive maintenance; all these strategies were described in [2]) or any maintenance philosophy. The proposed human centred philosophy should include the elements, which are also contained in the other well-known and widely used philosophies:

- maintenance philosophies – it is proposed that human centred philosophy first of all includes the elements of RCM (Reliability Centred Maintenance) philosophy, described in [3, 5, 6, 7, 9],
- other – like human resource management.

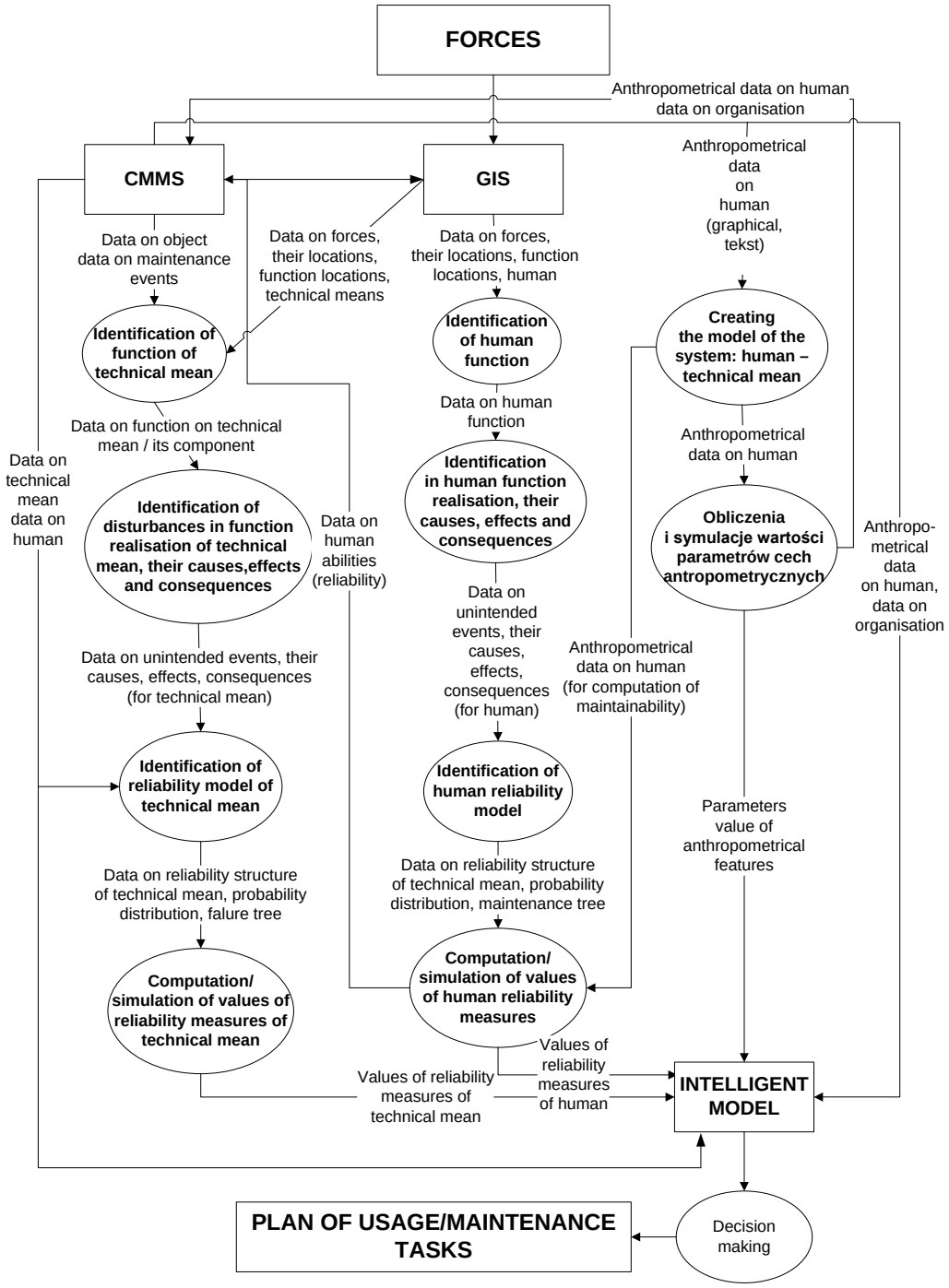

Fig. 3. DFD (ang. Data Flow Diagram) model of the feature of the system: human – technical mean – environment

The proposed model of the selected features of the system: man - technical mean - environment, presented as a DFD diagram (Fig. 3) includes a collection of data and information, as well as a sequence of processing steps. It is possible to distinguish the following steps:

- **identification of environment of the system: human — technical mean** — in accordance with the proposed modeling conception, this task will consist of indication of influences (forces) on technical mean / its components and influences on the human. Forces will result from appearing selected maintenance conditions in technical mean environment. These conditions can be a result of human (user and maintainer) activity or human environment. Influences are assigned to geographical locations in which they are appearing and are connected with exploited technical means and with users and maintainers on which the forces has an influence. Modeling these forces, which are appearing around technical means and people can take place based on map models, implemented in GIS (Geographic Information System) system. Every layer of GIS model as a component of model supporting the planning and execution of exploitation tasks, in accordance with human centred philosophy includes an information recorded by the use of the following models: spot (examples: bus stops/parkings, trees, traffic signs), linear (examples: installations of different type, roads etc.) and field (examples: mining damages, temperature, humidity of air, solar radiation, wind, fog, storm, rain / snow/ hailstorm, flood, an earthquake, the drought). In case of applying the GIS model, for purposes of description of mobile technical means, the examples of objects contributing to appearing forces on object can be: traffic signs (speed limit, values announcing threats, on which driver of vehicle on road is deciding on change of parameters dynamic vehicles), buildings, green (their localization influences meteorological parameters wind), bus stops/parkings (their appearing is contributing change of values parameters describing conditions transport- stop of the vehicle). In accordance of the proposed model conception, to the particular forces special attributes will be assigned - they will be values or sets of values of sizes, being characteristic rank, in which the force affects environment. Details about forces exerting influence on technical mean / its components and influences on human will let for outlining areas in frames of one special layer, in which technical mean / human is carrying peculiar functions out (according to RCM methodology in description of function details about forces will constitute operating context as the element of description of functions of technical mean / human functions). The GIS model with separated layers was introduced on Fig. 4,

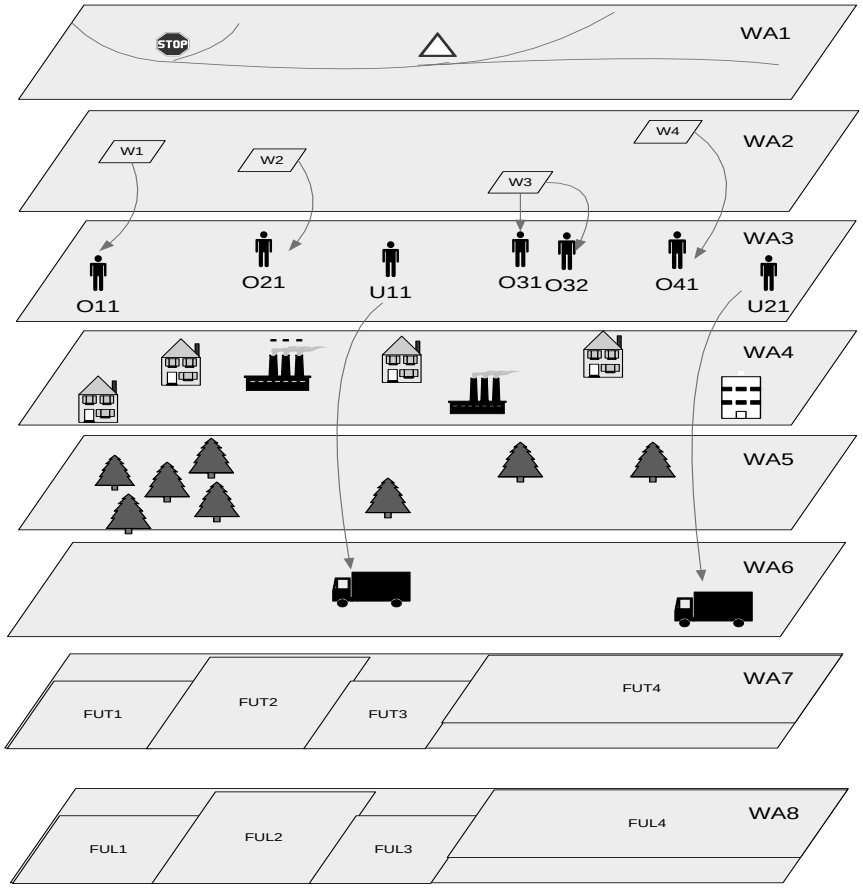

Fig. 4. Layers of proposed GIS model:

WA1 – layer „Roads", WA2 – layer „Workshops" (where: W1…W4 – elementary workshops), WA3 – layer „Workers" (where: U11…UNM – users (1…M) assigned to 1…N workshops and O11…UNM – maintainers (1…M) assigned do 1…N workshops, WA4, WA5 – layers „Forces", WA6 – layer „Technical means", WA7 – layer „Function of human" (where: FUT1…FUT4 – functions realized by human), WA8 – layer "Function of technical means" (where: FUL1…FUL4 – functions realized by technical means).

– **identification of technical mean** — this task will consist in indicating technical mean / its component based on its individual and group model. Specific properties are assigned to particular components of models. The examples of such models were shown on figures: 5 and 6.

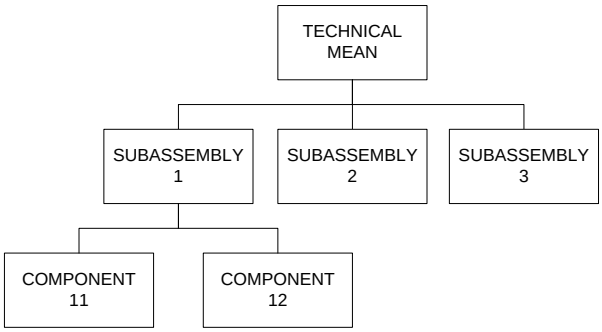

Fig. 5. Individual model of technical mean

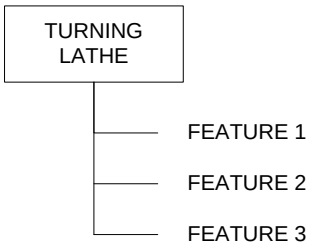

Fig. 6. Group model for technical means of the selected class

– **human identification** — a conception of 'virtual human', proposed a component of model of the features: human – technical mean – environment, whose behaviour (ways of thinking and acting) will be the object of analyses, proposed with the use of this model and aiming at developing scenarios of the plan of the using and maintenance tasks requires identification of the human — participants in the plans of tasks. Thus, elaborating of a list of 'candidates' to perform the task (using models of individual person) is necessary. Further elaborating of a list of working teams (teams indicated by organizational solutions — mechanics, electrics etc., indicated by specific features of the workers) by using group models is needed. It is also necessary to assign specific attributes to them – data, information and knowledge about their characteristics: anthropometric, sensory, physiological and psychological. Model of individual human is shown in Figure 7, while a model of human group is shown by Figure 8,

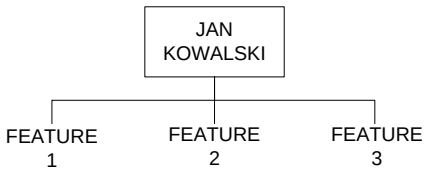

Fig. 7. Model of individual human

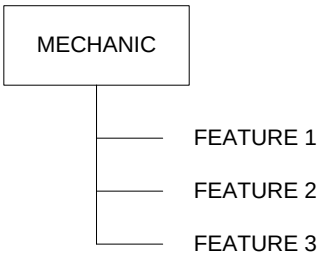

Fig. 8. Model of human group.

- **identification of functions of the system: human — technical mean** – at this stage on the basis of data on forces, existing in the environment of the system: human — technical mean, using elaborated model it is possible to indicate functions performed by a human and technical mean/its component. The term used to describe every function should comprise: object, verb and standard of performance (expressed as amount a where possible) [7]. Standard of performance included in the name of the function should describe the level of demands for the owner/operator of technical mean in a given operational context. Operational context is a description of conditions in that a specific technical mean is operated. An example of the function of mobile technical objects is shown in the Table 1.

Tab. 1. An example of the function of mobile technical means

The function of mobile technical mean
Transporting a large number of passengers in a heavy traffic on slippery road in winter

Indicating every function in accordance with the proposed conception of model of the features of the system: human – technical mean – environment will be performed using expert system models. Connection between functions and objects/their components (data of them should be recorded in CMMS class system) and maps (being components of GIS system) is shown in Figure 9,

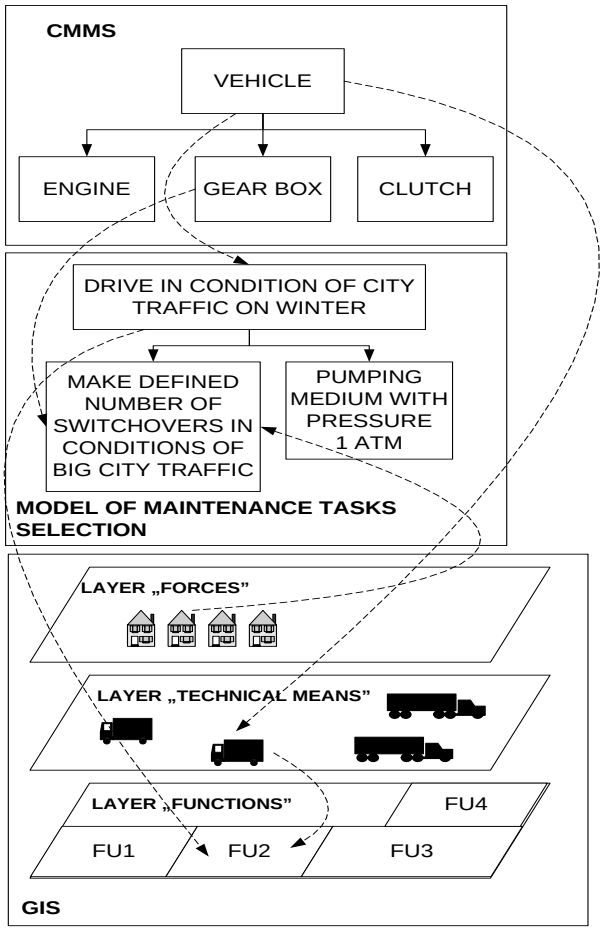

Fig. 9. Connection between functions with object/their components (CMMS) and layers of maps (GIS)

– **identification of exploitation events, resulting from functions performed by technical mean and functions assigned to a human** — at this stage disturbances in function performance (functional errors) and their causes, results and consequences should be indicated. All causes of damages comprise three basic groups [3]:

- causes resulting from falling the capacities of technical object below optimal performance (aging, damages resulting from inaccurate or lack of lubrication, dirt, decomposition, human errors influencing on capacity limitation),
- causes resulting from reaching optimal performance on the level outreaching primary capacities (deliberative overloads, non-deliberative overloads, sudden not planned overloads, processed materials or packaging materials)
- causes resulting from lack of possibility of technical mean performance which is demanded from the start.

Among causes of disturbances there are some, that are a result of decisions and actions of human (user and operator). Four groups of factors influencing human errors can be identified [3]:

- anthropometric factors,
- sensoric factors,
- physiological factors,
- psychological factors.

Consequences of damages are [3]:

- consequences connected with safety and environment protection,
- operational consequences (influencing on effectiveness, quality of the product, customer service, costs of operation. costs of repair),
- non-operational consequences (eg, hidden damages).

– **identification of model of technical mean reliability and human reliability model, and calculations and simulations of reliability measures**— at this stage the activities should rely on a creation of a complex model (analytic or simulation one), which allows estimation of the reliability values for both the technical means and human. The model will consist of: reliability block diagrams, being a practical representation of reliability structures of technical means and failures trees, being as well models of events occurring while functioning of the technical means as models resulted from human contact with the technical mean. The component of model should also be models and methods for assessing human capabilities, functioning in the system: man - technical mean. It is also possible to distinguish [4, 8]:

- Rasmussen models,
- S – R (ang. Stimulus – Response) models,
- THERP (ang. Technique for Human Error Rate Prediction) method,
- HRC (ang. Human Cognitive Reliability) method.

– **elaborating of human anthropometric features model** – this model (being a component of a complex system: human – technical mean – environment) will be a result of the need of taking into account the presence (in the process of technical means exploitation) of:

- users of technical means — exploited technical means performs functions that are result of real needs of the user (including conditions of human/technical mean cooperation). It can be a cause of high repair costs. That's why optimization including criteria such as costs — measures of adjusting human to work conditions is necessary,
- operators of technical means — at the stage of indicating maintenance tasks to be performed prior to it a thorough analyses of needs, limitations, capabilities, dangers etc. of the operator is needed. It should be performed by calculating time of services / repairs on the basis of the maintainer’s behavior in his/her work conditions.

Consequently described model (comprising human anthropometric feature model) should facilitate following actions:

- selection of maintenance tasks on the basis of functions performed by technical mean, elaborated after considering user’s needs, which are reflected by his/her adjusting to the workplace (positions in an operating system),

- choice of maintenance tasks — repair tasks on the basis of maintainer's needs — a methodological solution that is discussed should contribute in minimalizing of maintenance time of technical mean on the one hand and to shaping human — technical mean relationship on the other.

Among upper mentioned relationships it can be specify ones, which can have character of somatic relation and ones, that can have character of sensory relationship. Somatic relations are realized by system of organ of human motion. The examples of somatic relations are: limbs ranges, forces exerted by limbs, load of motion organ. For avoidance of failure occurrence, that is result of mismatching of position of human (maintainers) motion organs to workstation space, established by technical mean and elements of maintenance infrastructure, that are situated one to another, result of lack of possibility of access to used / maintained elements or lack of possibilities of their movement or movement of tools in workspace (all these lacks are consequence of an inadequate shape and location of elements subjected to maintenance) it is necessary- to perform analysis of influencing of incorrectly shaped somatic relationship to usage / maintenance process. For example non — ergonomical shape and location of elements of maintained technical means can cause performance of maintenance tasks in forced body position, being loading for worker and therefore it may increase a risk of making fault or achievement of inadequate quality – of performed activity. Performing above-mentioned analysis is also purposeful because of existing need of assessment of maintenance time and also cost of maintenance performance. Therefore, in accordance with the accepted original conception of the model, graphical data representing a model of human anthropometric characteristics will be passed for the purpose of calculating of technical means maintainability with the use of reliability models. Sensory relationship are realized by the use of system of sensory organs and concerns human reaction to stimuli from technical object. An example can be field of view, noise, vibration etc. In this context it is purposeful to perform reliability analyses. These analyses can be performed from the point of view of an ability of human identification of signals, generated by technical mean and from the point of view of existing need of shaping correctness of relationship: man — machine. These relations should be shaped in early step of designing (on the stage of creating conception) and they can be used on the step of maintenance of technical mean. An example may be shaping man — machine relationship, where human realizes identification of technical state with the use of organoleptic method in conditions of the realization of predictive maintenance strategy. In every case it becomes reasonable to perform simulation of tasks, done by human. The necessity of the realization of above — mentioned assumption of ergonomical designing of shape and location of elements of technical systems justifies a use of CAD environment. A use of selected tools of CAD class system should enable to perform simulation analyses in virtual work environment. These analyses by the use of computer models will reflect relationship in human engineering model. CAD will also enables to perform ergonomical analyses and let to optimally adapt maintenance conditions for technical mean (resulted from the accepted maintenance technology, maintenance infrastructure etc.) to predisposition of worker having specified anthropometrical features.

- **model for decision making on the selection of usage and maintenance tasks** — this model will be used for the indication of the most optimal plan of proactive and alternative tasks. This indication will be made on the basis of sizes, such as time and cost of performing the tasks, availability and other indicators of the measurement of as well technical mean and human as their environment (the

organization). The base are calculations and simulations conducted on the basis of the following data:

- data on the interactions on technical means and people (users and maintainers),
- data on the technical means / their components under operation and maintenance (code, name of the technical mean/ its component, technical specifications etc.).
- data on people – users and maintainers (code, name and surname of the person, master data, data on characteristics: anthropometric, sensory, physiological and psychological,
- data on the functions of technical means,
- data on maintenance events – unintended (type of event, cause, effect and consequence of event) and intended (type of event: repair, overhaul, inspection etc.),
- data on the reliability of technical means (including measures: characteristics: reliability, maintainability, mean time between the failures, time of waiting for the maintenance, time of maintenance, availability, unit costs of materials, tools, workers, other etc.).

At the stage of planning usage and maintenance tasks it is expected to be used the following methods from the RCM analysis:

- Questions Yes/No,
- Criticality Factors,
- Failure Effect Categorization,
- Maintenance Task Selection,
- Failure Mode and Effect Analysis — FMEA.

FMEA method will be used for answering the following questions of RCM analysis: what causes an occurrence of every failure and what is going on when the failure will occur ? FMEA performance enables to identify causes and effects of failures that can influence incorrectness in functioning of technical mean. This method will use RPN priority number and criticality analysis.

3. Specification of the possibilities and needs to use the described model

The objectives of the organization, achieved by ensuring its effectiveness and efficiency of its processes and systems efficiency will be conditioned by the effectiveness of the organisation responsiveness to the needs, possibilities and limitations of human, as well as threats in man - technical mean relationship. Examples of situations that constitute this issue and are present currently or in the near future, or may occur can be distinguished:

- need to exploit machines, devices and systems on-the-job by more and more old persons: it is a result of increasing the retirement age among others (both in Poland, as well as other countries of Europe),
- need to keep required durability and reliability of technical means (on consequence reduction of costs of their use), which are exposed to acts of vandalism, commited by people of different age, personality, culture etc. (for example destruction of the toys by the children, demolition of components of city-buses by passengers or of accessories of football stadiums by football hooligans etc.),
- permanent need of the improvement the standard of living of the disabled persons, requiring adaptation of environment in which they live to their psychophysical features.

Application of the described model of the features of the system: man - technical mean - environment in maintenance management of technical means will also be possible in the following areas of human activity:

- planning and realisation of maintenance and repairs — the developed model of the selected features of the system: human – technical mean – environment will enable to indicate maintenance tasks to realisation, as effect of three general maintenance strategies: breakdown (emergency, critical) maintenance, preventive maintenance and predictive maintenance on the grounds of the optimization of the system: human –technical mean – environment, optimization of maintenance structures, control of maintenance organisation (on the grounds of measures of organisation and human assessment), improvement of effectiveness and efficiency in maintenance organisation, selection of methods and techniques of technical diagnostics for selected locations (for the sake of a need of realisation of predictive maintenance strategy),
- matching of human body to perform maintenance tasks taking into considerations his features: anthropometrical, sensors, physiological and psychological,
- matching of selected elements of workshop equipment (tools, machines and devices used for repairs and maintenance, roads for transport) to human body,
- analysis of crisis situations (existence of accidents, failures, catastrophes),
- assurance of human and technical systems safety (including an influencing reliability and durability of technical means with taking into consideration cultural features of users and maintainters,
- maintenance inventory and tools management,
- an improvement of technical means maintainability.

4. Conclusions

The proposed original human centred philosophy responds to the need to "defend the interests" of individual participants in the system: human – technical mean – environment, including the need to take account needs, possibilities and limitations of human, as well as risks inhuman - technical mean relationship in the planning and execution of tasks. The continuous acquisition of new knowledge both about the technical mean and of human shall arrange to obtain properties of the model of the system: human – technical mean – environment setting a level of detail sufficient to rationally plan the job in manufacturing or ancillary in the organization, while properly treating the of human participation in the system under consideration. It will contribute simultaneously to make a significant step towards the humanization of work, carried out in the company. Due to knowledge about organization and taking into account the presence of 'virtual human' attributed with anthropometric, sensory, physiological and psychological characteristics, assessing the relevance of human with varying degrees of ability, age, nationality, culture, personality etc. to assigned maintenance task will be possible. Such a broad possibilities of the proposed model will ensure that it is possible to use them in an extremely wide range. It is also assumed that the development and verification of this model for using and maintenance management of technical means will be an inspiration for authors of similar solutions, supporting activities in other (non – maintenance) areas of the human activity.

Innovativeness of the proposed model results from the use of resources of knowledge from different fields of knowledge on human. It is a consequence of the association of a variety of commonly used or new supporting methods and techniques. An example in this

regard may be an association of probabilistic methods for assessing the reliability with methods of virtual reality, made because of the need to assess the maintainability of technical means functioning in the ergonomic (human engineering) system.

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