Automation and Robotics in Construction XII
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PROCESS AUTOMATION VERSUS MACHINE DEPENDABILITY

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Abstract

This paper discusses the dependability of machines with particular reference to construction equipment in relation to increasing levels of automation. Various strategies are presented and their impact on utilization systems. Finally, reducing health hazards and environmental protection are addressed in dependability assessments.

1. INTRODUCTION

Every technical activity results from general requirements for quality and as a consequence from the economical and social conditions (Fig.1).

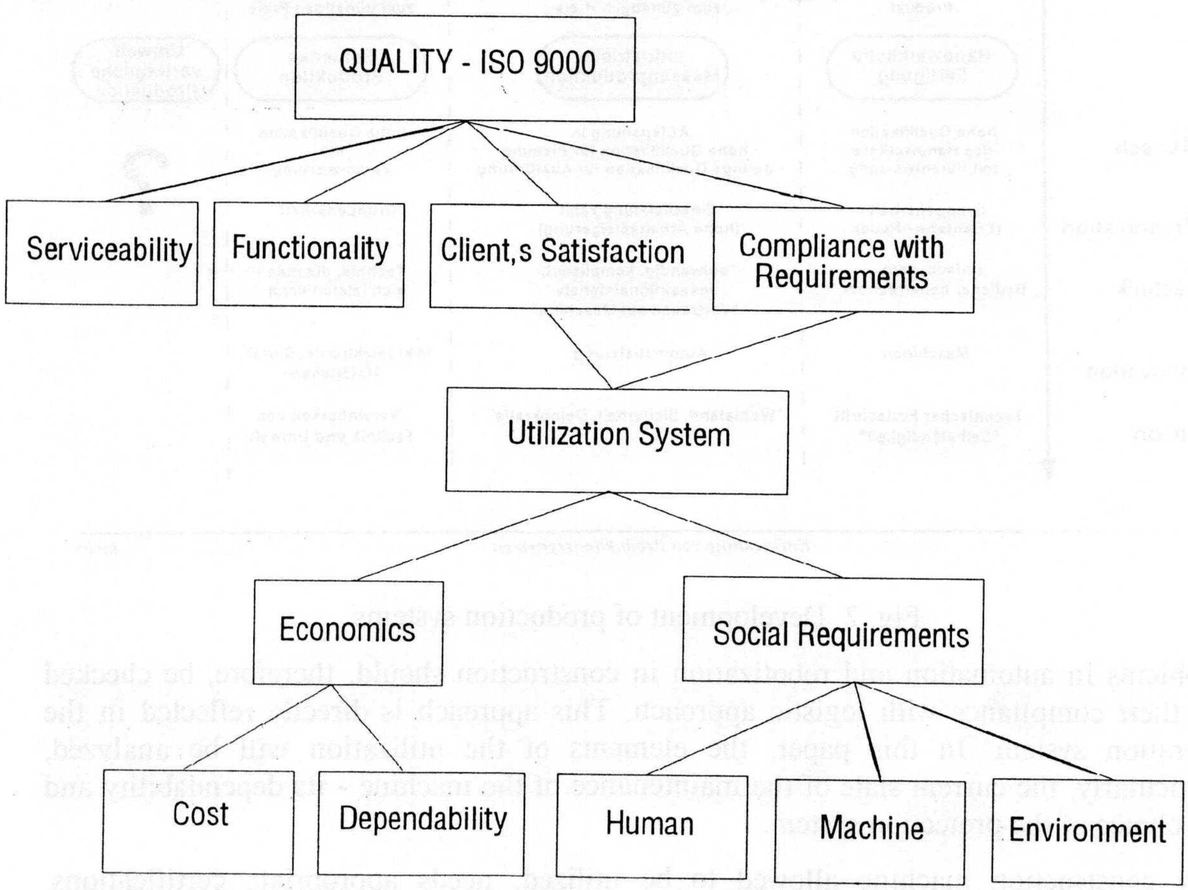


Fig. 1. Quality requirements

Automation of construction processes is similar in essence and therefore must result from the same conditions. In the case of my research into quality assessment of the machine, the above initial conditions also apply. If the machine was chosen in compliance with its intended use and functionality, then two out of four requirements set in ISO 9000 under the heading of 'quality', are fulfilled.

These two elements can be violated by the incorrect choice of operation system and as a result, lead to product disqualification.

The choice of the operation system results from logistic equations, based on the technique, economics and informatics. In the above fields, the science which needs special and explicit attention is 'innovation' or in other words 'automation', this need was especially stressed at the last conference - 'The 12th Dormunder Gesprache fur Logistik - Dortmund, October 1994'. Other branches of science also mentioned, covered micro-electronics, bionics, advanced materials, vision and co-existence between the new techniques and environment in safety and reduction of health hazards (Fig.2).

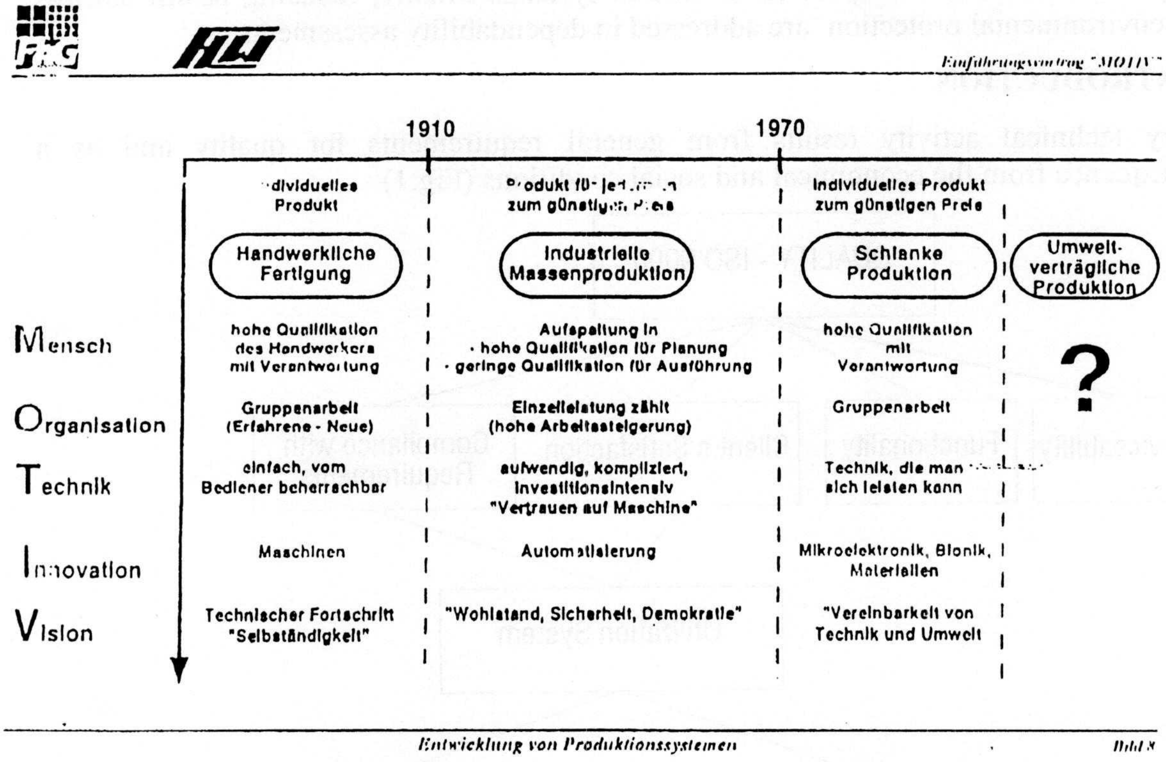


Fig. 2. Development of production systems

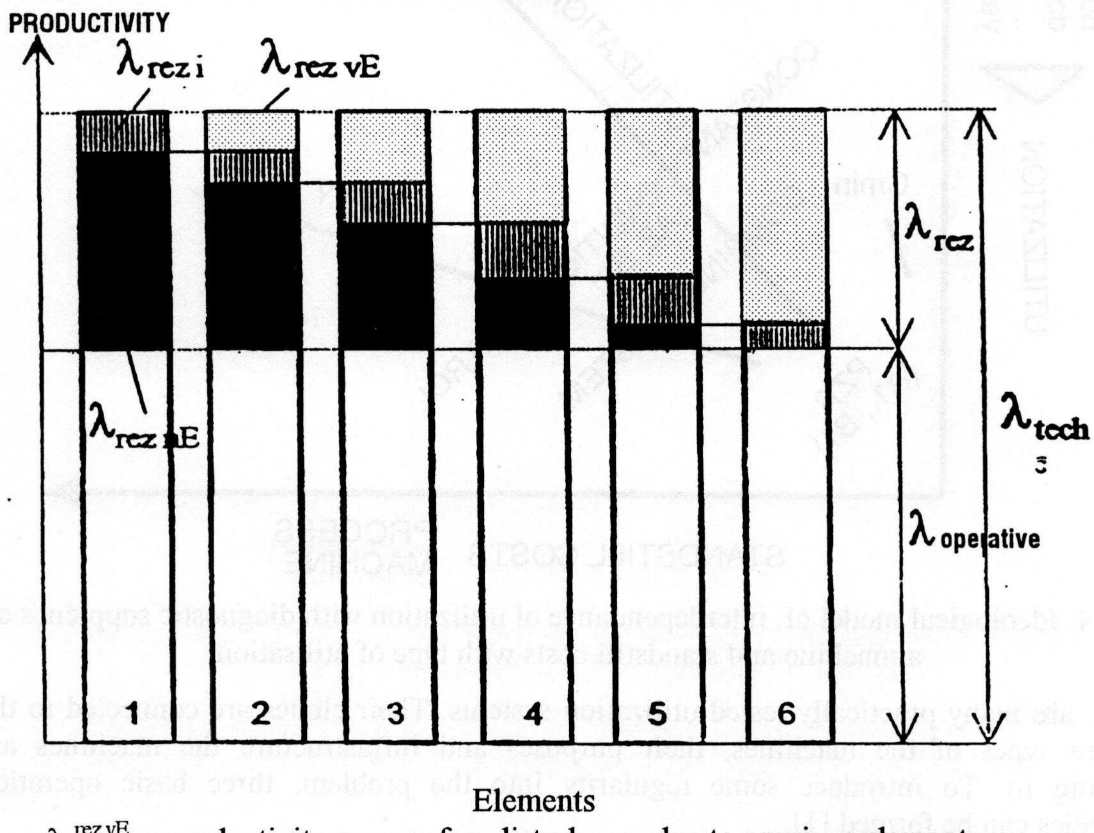
Problems in automation and robotization in construction should, therefore, be checked for their compliance with logistic approach. This approach is directly reflected in the operation system. In this paper, the elements of the utilization will be analyzed, particularly, the current state of the maintenance of the machine - its dependability and the choice of the protection system.

Any construction machine allowed to be utilized, needs appropriate certifications. Certification should be carried out every year, throughout the whole working life of the machine, due to its wear and tear. Consequently, all the requirements for regeneration, modernization and even reconstruction will be based on the results of the logistic analysis. The machine dependability and its protection systems rely largely on the ability to carry out consecutive reconstructions and the ability to do so again and again, as this reflects the level of degradation.

2. DEPENDABILITY

Although dependability was placed as part of economics, as shown in Fig.1, it closely related to costs. Financial losses are the direct consequence of the lack of dependability and may affect such distant production aspects as job losses in various departments due to not meeting the plant's obligations, loss of clients, loss of credibility, etc,.

Dependability describes the state of readiness of the machine to carry out its tasks maintaining the prescribed productivity, while the condition of the machine, its state of maintenance, housing conditions, types and amount of repairs are taken into account. The definitions, further descriptions and methods of calculating the dependability are discussed in VDI 3649 and the specific approach to machines is given in [1].



$\lambda^{rez\,vE}$ - productivity reserve for disturbance due to previous elements

λ^{rez} - productivity reserve for sale disturbance

$\lambda^{rez\,ni}$ - productivity reserve for disturbance due tothe following elements

Fig.3. Relationship between element and system productivity according to VDI 3649

The productivity of a typical machine or a six element system is shown in Fig.3, using the deterministic - theoretical approach. Our exploitation system should guarantee achieving this productivity with required probability and in an assumed time limit. The warning system, which will maintain or correct the probability level, is the automatic diagnostic system, monitoring the operating and technical condition of the machine. This system, in-built into the machine or operating from outside (operator, maintenance level, service, etc.) should guarantee the completion of the planned productivity and achievements with the calculated risk level. Differentiation into safe system and safety level in the machine and definitions of their functions are explained in [2]. An ideological scheme indicating the relationship between the operation model and diagnostic suppleness of the machine against the losses due to standstill and loss of value due to usage, is shown in Fig.4. It proves that many elements of utilization systems affect the dependability. Therefore, while solving technical problems of the structural elements of the machine, their logistic interaction should not be neglected.

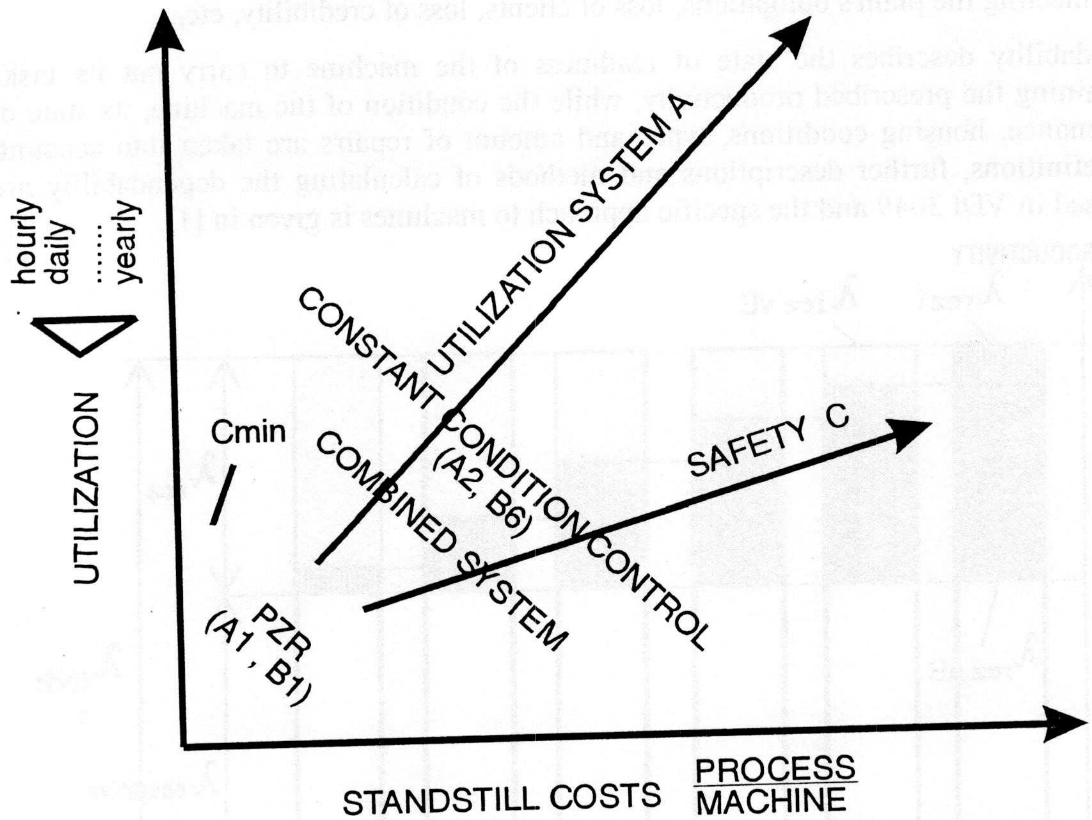


Fig. 4. Ideological model of interdependance of utilization with diagnostic supplenes of a machine and standstill costs with type of utilisation

There are many practically tested utilization systems. Their clones are connected to the various types of the machines, their purposes and infrastructure the machines are working in. To introduce some regularity into the problem, three basic operation strategies can be formed [1]:

(i) strategy of the pre-planned resources at the project level and expressed by the range of the preventative repairs (PZR) based on the technical blueprints of the mobility (DTR). The repair should take place before the actual fault occurs;

(ii) strategy of the full reliability based on statistical data of the time periods between damages and assuming a certain level of probability, the machine will be operational during this time. The machine is used until it is out of order, the fault should be immediately discovered and be of a minor importance;

(iii) strategy of the constant control of the technical and operational performance of the machine. This approach guarantees that each fault is detected and repaired before occurring.

Utilization strategies are imposed by the quality level of all elements.

Further analysis can be carried out and three graphs for a density of probability that a machine is going to perform for a certain period of time, without stoppages, can be plotted (Fig.5). The conclusions drawn from studying the graphs, determine the utilization strategy.

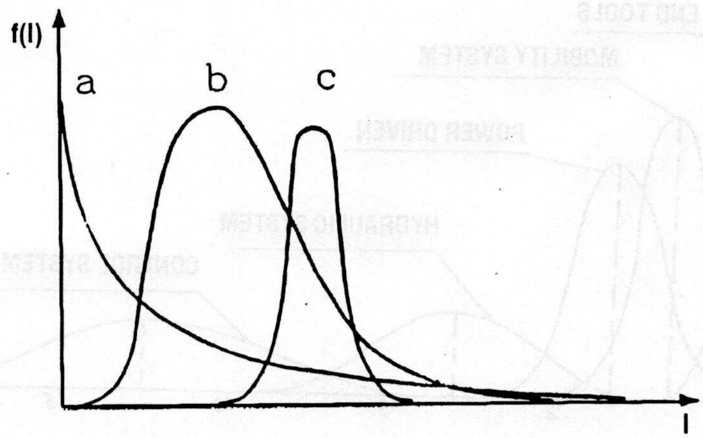


Fig.5. Function ofe density of probability that a machine is going to perform for a certain period of time; a - according to strategy of full reliability - NZ, b - according to strategy of condition - SS, c - according to strategy of resources SZ

Graph (a) is typical for electronic systems, together with the full reliability strategy.

Graph (c) characterizes the systems which come already with the data about the durability and reliability of their elements (for example of the prototype). In this case, the cheapest solution will be design and utilization using DTR and avoiding faults using PZR.

Graphs (c) and (b) differ through fluctuation density distribution of the probability function.

Graph (c) will be achieved using the element of a small deviation of the real material and technological characteristics with precisely fixed working conditions. Requirements of this type boost up production costs and narrow down the range of equipment used to ones with a specification exactly matching the type of production activity.

The equipment of high production cost, due to narrowed range of control parameters in design and manufacturing, correctly chosen according to use and function, exploited using DTR in the system PZR, will guarantee the user high dependability and low working costs.

The above requirements, however, become uneconomic when it comes to construction machines, which are multi-functional, produced in small sets and application versatile. In practice median of the values t for the function of the density of the probability of the machine working without a fault, even if it possesses small fluctuation, is located at a different value level of t (Fig.6). Therefore, allocating the proper cycle for the whole machine becomes very difficult. Few percent of the parts force the setting up of time t very early, when the working potential of most of the parts was only partially exhausted. Hence current research in this field searches for the variety within the utilization systems [1] and concentrating particulary on 'grouping system', where the PZR cycle does not affect the whole system. The PZR cycle is broken into several sub-groups, for which more precise durability distribution is devised. Modules have become these areas and if they are aided with monitoring of symptoms, then we have obtained a classical mixed system - of the task reliability strategy.

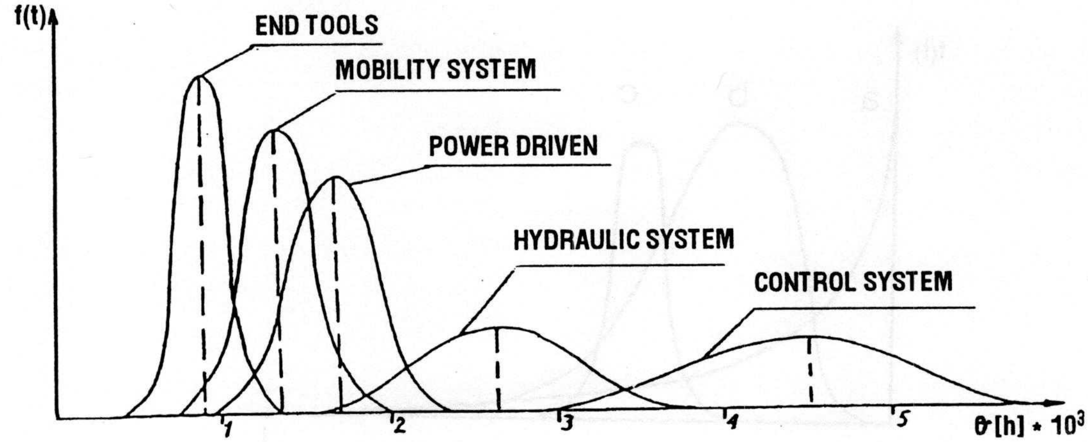


Fig. 6. Density of probability of the working duration for systems

Moving from the monitoring of symptoms to monitoring on the constant basis and internal diagnosis, and when related to the control of the whole technical and operational state of the whole machine, gives the equipment with the automatic control [4] (Fig.7). These days, systems of this type are utilized in aviation, however due to high working costs and high service requirements, they will not be used in Poland for construction for quite some time yet. Even in aviation, there was strong objection against utilization assessment according to state of groups.

3. CHOICE OF PROTECTION SYSTEM FOR THE MACHINE

According to Fig.1, there is an area within quality assessment for the machine, which needs to be addressed on social grounds. The low costs are not a primary objective and we have to take into account possible hazards to humans and the environment, caused by the machine.

The importance of this aspect is growing and the EN requirements are higher and higher. It is no longer enough to just state the load capacity of a crane arm. New requirements cover restriction in the range of movements, capacity reduction and even automatic engagement of mechanisms preventing the crane from tilting, regardless to the operator's reaction.

It becomes necessary, during the design stage for the machine sub-groups catering for its safety, actually isolating the safety states, level of hazard and loss of safety [2].

For such systems, the following assumptions need to be established:

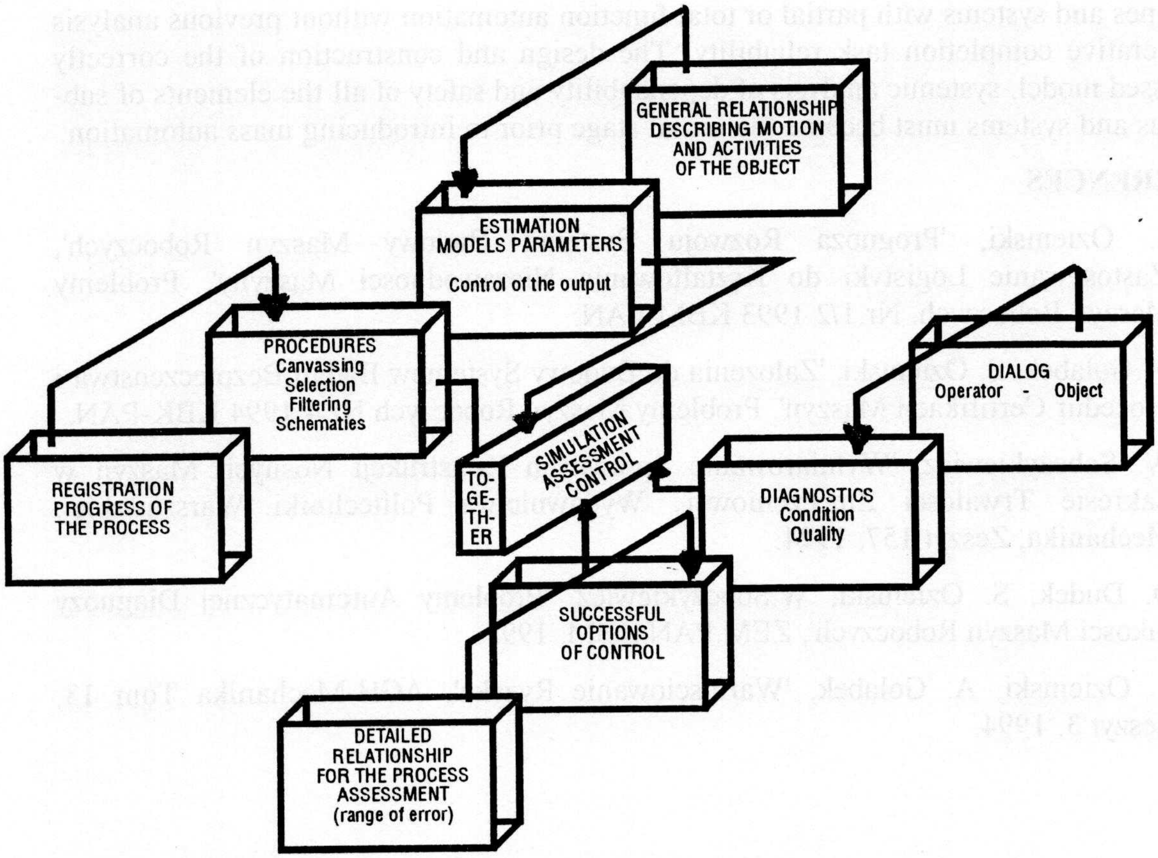


Fig. 7. Algorithm of automatic estimation of parameters of working object utility, diagnosis of its condition and quality and an adaptative aided control

(i) level of severity of hazard,

(ii) research focusing area,

(iii) separated range,

(iv) iterative model and

(v) expected quality level of solution.

This type of system, automatically achieving its goal - accepted level of hazard, will become the basic criterion for the certification of the construction machine.

In Polish reality, all machines should be equipped in the automatically controlled safety system providing compliance with the socially accepted risk level for the operators as well as for the environment.

4. CONCLUSIONS

Automation requires the development of diagnostic systems providing assessment of the technical and operational conditions and related control system (Fig.7). This mainly refers to the electric and hydraulic systems.

Latest statistics show that in Poland these two systems are the main cause (98.5%) of failure of derricks (limited series production) and (43%) of failure in cars (mass production). That proves that only a partial level of dependability can be achieved in machines and systems with partial or total function automation without previous analysis and iterative completion task reliability. The design and construction of the correctly addressed model, systemic analysis of dependability and safety of all the elements of subsystems and systems must become the initial stage prior to introducing mass automation.

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