Journal of Polish CIMAC
Gdansk University of Technology
The Faculty of Ocean Engineering and Ship Technology

# A NEW APPROACH TO RELIABILITY IMPORTANCE ANALYSIS OF COMPLEX TECHNICAL SYSTEMS

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**Abstract**

*The paper presents new approach to the reliability importance analysis which is main topic of the author's last research. The concept of comprehensive qualitative-quantitative method for the importance analysis for complex technical systems components has been shown. Extension of importance criteria of components to: safety, maintainability, spare parts waiting time and other factors has been proposed. Research conception, plan and final conclusions have been shown. The application of expert knowledge and reliability databases in case of limited knowledge about the system have been proposed.*

***Keywords:*** *importance analysis, subjective probability, qualitative-quantitative method, expert knowledge, system structure*

## 1. Introduction

Due to problems with application of known reliability importance measures for complex technical systems (CTS) [5,7,10,15], the research work to create the new qualitative-quantitative methodology of importance analysis have been introduced. New methodology is supplied with expert knowledge, different importance criteria and application of reliability databases. Comprehensive methodology can be applied to CTS with different range of knowledge lack (unknown reliability structure, partly known components reliabilities etc.). The main aim of the paper is to show of the concept of developing of the current state-of-the-art of reliability theory mainly reliability importance analysis. It will be carried out by developing theoretical expressions and methods which enable quantitative and qualitative assessment of CTS reliability importance of components and group of components. As part of the work new tools will be developed and popularized (algorithms and the dedicated software) for the evaluation of the importance of the components in CTS. New developed tools will be used in the evaluation of the components importance of vessel propulsion plant as the appliqué example.

## 2. Significance of the new approach to importance analysis

High reliability of CTS is a basic condition of the safe and effective operation of the system. During operation the requirement of increasing of the system reliability by the alteration of the system structure or increasing the reliability of chosen components often occurs. During analysis of the reliability of the technical system the analyst usually cares about finding the most sensitive

components (*importance measures of components*). Reliability of these components should be increased to optimal raise the reliability of the entire system [1,2,3,12,13,14]. Similarly an importance of the minimal cut sets of the system is being considered (*local measures of the importance*). These issues are connected with seeking so-called *weak links in the system*, which are of the most unreliable components and groups of components in the system (*importance analysis*).

CTS are objects about which we never have complete information on components reliabilities and on the system reliability structure. This problem makes known measures limited in use in the utilitarian aspect.

Criteria of the importance for known importance measures concern basically the reliability, availability or time to failure function, however in many cases in the analysis of the importance an assessment of the impact of the given component failure for the operation of the entire system in the aspects of maintainability, life cycle costs, availabilities of the spare parts and operational safety is supposed to be taken under consideration.

In relation to the limited applicability or the lack of applying many known importance measures [5,10,13,15], a requirement of draw up the modern qualitative-quantitative methodology giving the importance of components and groups of components for determining importance rankings in CTS for given criteria of the importance including the aspects: cost-effectivenesses, availabilities of the spare parts, maintainabilities and operational safeties appeared, what should be developed.

New methodology will develop the technical sciences as well as find application in many branches of industry. It will affect the development of the civilization and the society using complex objects of the exploitation in many aspects of the daily living.

## 3. Conception and research plan

Literature analysis made by the author shows, that publications devoted to the utilitarian application of importance measures of CTS components occasionally appeared in relation to presented problems with application.

According to the author, one of the ways of acquiring the knowledge about the system using expert methods and application of the subjective probability [4]. Current research papers describing scientific works on the importance evaluation as the object of analysis use simple theoretical systems with statistically independent components failures and implemented basic interactions with surroundings.

Creating comprehensive quantitative-qualitative methodology will allow to much more effective analysis compares to known methods.

New importance measures should use of the number of criteria of the importance which were not taken into account in so far known in theory reliability measures of the importance e.g. Birnbaum, Vesely-Fussell, Barlow-Proschan, Natvig etc.

The initial importance of components based on the unreliability of the given component $F_i(t)$ taken from operational research and number of path sets $x_i$, in which the $i$-th component is participating out of $x$ of all path sets of the system will be determined:

$$I(t) = f[F_i(t), x_i, x] \tag{1}$$

The author proposes introducing measures describing the importance of the component including appropriate criteria. It will be determined by implementing appropriate rates of weight coefficients for various criteria, so as the criterion of the time required for maintenance, of circulation of the participation of the staff, maintainability, time required for spare parts delivery, the economics of the service and the operational safety. It is possible then to describe the importance of the component:

$$I^{KRYT}(t) = f[F_i(t), x_i, x, c_t(t), c_p(t), c_m(t), c_s(t), c_e(t), c_b(t)], \quad (2)$$

where:

$F_i(t)$ – unreliability of the $i$-th component of the system,
$c_t(t)$ – weight coefficient of circulation of the working time for performing the restoration of the component,
$c_p(t)$ – weight coefficient of participation of the staff for performing the restoration of the component,
$c_o(t)$ – weight coefficient of maintainability (service susceptibility) of the component as part of the restoration;
$c_s(t)$ – weight coefficient of waiting time to the spare parts for performing the restoration (repairs) of the component,
$c_e(t)$ – weight coefficient of costs of the maintenance of the component; $c_b(t)$ – operational safety change due to component failure.

Finding suitable functional forms new measures will be one of the tasks carried out as part of the work. Lack of complete information on system reliability structure and reliabilities of the system components will be solved with using of qualitative models (comprehensive – qualitative-quantitative) and with application of the experts knowledge described using rules of concluding and the subjective probability [4].

Results of the author's preliminary research [5,10] show the rightness of adopted assumptions and lack of possibility of the evaluation of the importance of components and groups of components of CTS using the known methodology.

## 4. Research methodology

Measures drawn up will be applied for model CTS which the vessel propulsion plant installed onboard the transport maritime vessel. Conception of comprehensive attempt at the evaluation of the importance of components and groups of components in CTS with the application experts knowledge is shown in the Fig 1.

The author put forward the theses, that: "full evaluation of the importance of components in the CTS reliability structure is possible only with the use of the comprehensive attempt by applying qualitative-quantitative methods" and that "for the global assessment of the importance of system components one should widen evaluation criteria introducing measures describing consequences of corrective (maintenance) action after fail of given system component".

Analysis results will be assessed by comparing gained importance rankings of components for different initial information about the examined system, in particular:

- coarse information about functional components and relations in the system;
- reliability structure well-known and system components reliabilities unknown;
- system components reliabilities and system reliability structure generally known;
- system reliability structure well-known and selected system components reliability known.

Research methodology has been schematically presented in Fig. 2. So far the author carried out preliminary, essential tasks (**already finished**) for the purposes of the new methodology implementation, such as:

- the identification of factors justifying the need of modifying evaluation tools for the reliability importance analysis of components and groups of components in CTS;

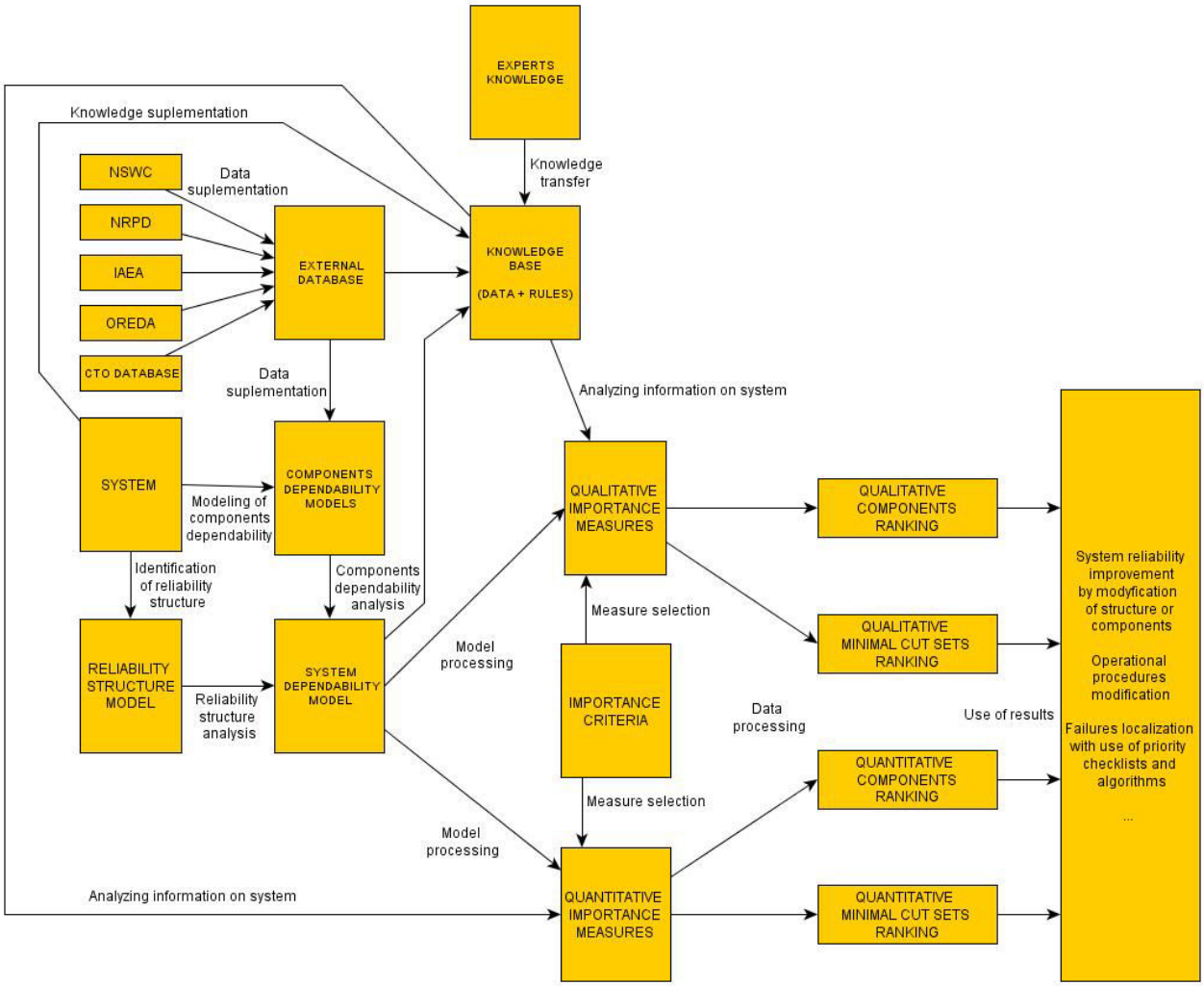


*Fig. 1. Proposed comprehensive qualitative-quantitative importance analysis*

- the review of known measures of the importance and models of the structure for CTS and the literature critical analysis of achievements of other researchers of the subject matter of the evaluation of the importance of components in CTS;
- tidy the terminology up in the analysis of the importance of components as well as the description of the system reliability structure;
- collecting statistical data about failures of components of systems of vessel propulsion plants installed onboard many transport vessels.

The main goal of the future work will be fulfilled by performing individual detailed tasks (**to be done**), which are:

- developing new measures of the importance of system components for various criteria of the importance (maintainability and maintenance costs, operational safety etc.) which will be the alternative to measures presently applied;
- developing new models (of way of the description) of reliability structure and redundancy (reserving in CTS), e.g. proposed by the author the application of the complex numbers plane [6], proposed by the author applying the external events vector [8,9] and applying of the modified measure of reservation by Jaźwiński and Smalko [11];
- developing the comprehensive attempt at the evaluation of the importance of system components by using quantitative-quality models;

- evaluation of the importance of components with proposed methods for chosen technical systems (exemplification based on vessel propulsion plant);
- assessment of the impact of applied methodology and the assortment of measures of the importance to gained rankings of the importance of components and groups of components by mutual comparing of rankings taking under consideration measures definitions;
- discussion on usefulness of known and newly developed importance measures with exemplificative examples;

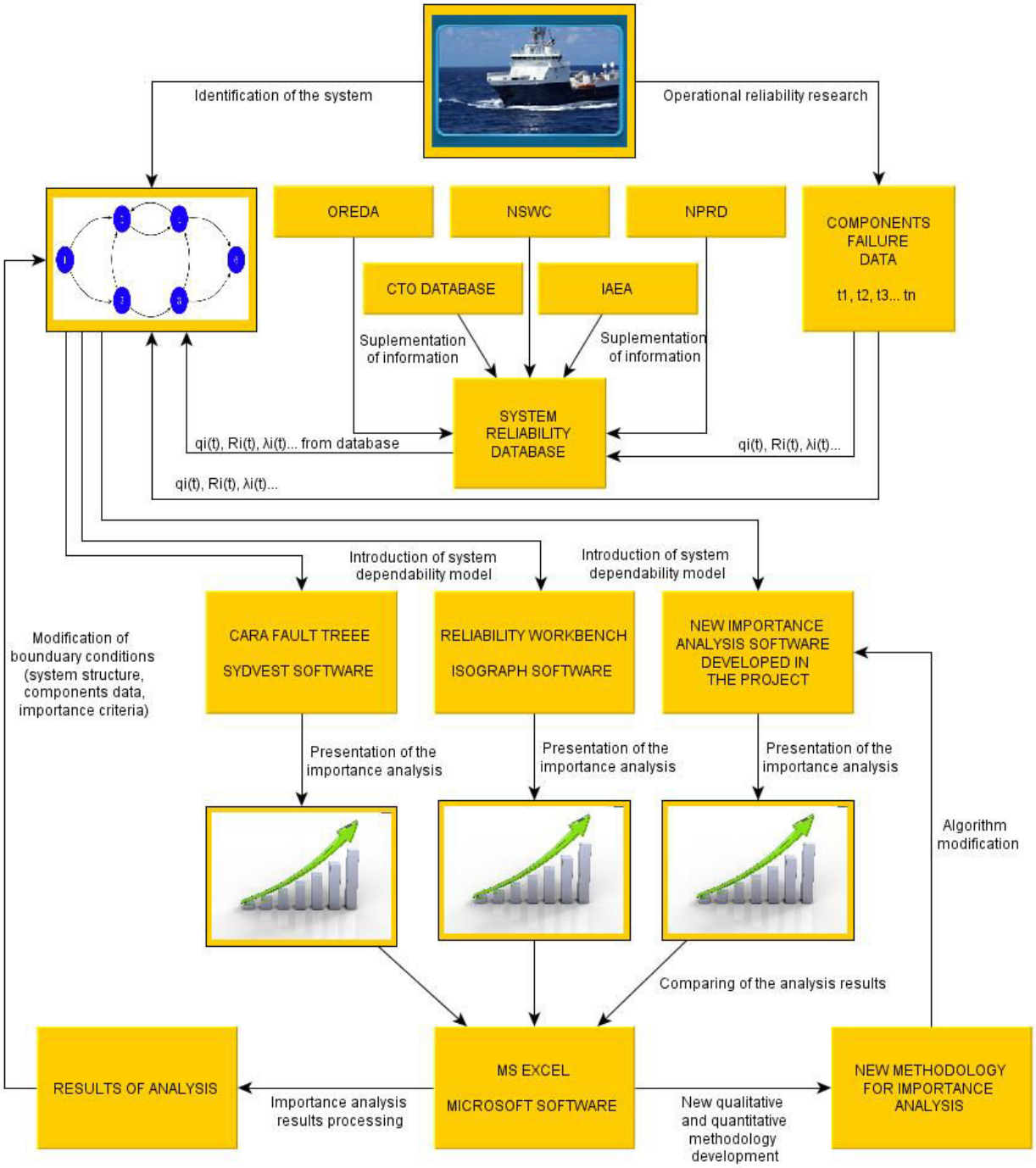


*Fig. 2. Basic steps of research methodology for drawing up the modern comprehensive methodology of the evaluation of components importance and groups of components importance in CTS*

- developing the general algorithm of the evaluation of the importance of components, in it of assortment of methodology and measures for the evaluation of the reliability importance depending on available information on the system;
- publication of new methodology results in scientific papers.

As part of examinations a vessel propulsion plant of a cargo ship will be an object of analysis as the example CTS. Literature analysis of the subject matter was the first research stage, next action will consist in drawing up new measures of importance and algorithms of acting in the evaluation importance of components and groups of components into CTS. It will be done by synthesis of current importance measures and quantitative and qualitative characteristics of the reliability of the analyzed system. Obtained measures will be used for estimating the value of the importance and creating rankings of the components importance. The lack of complete information about the system will be compensated by supplementing this information using the knowledge base (information gathered systematically from the system and the knowledge of experts). The knowledge of experts will be entered into analysis with using of subjective probability. As comparative results analogous rankings will be made based on different measures.

In the analysis comparing rankings gained from individual analyses of the importance for different initial details about the given CTS will be done. Rankings will allow to quantify through statistical processing of results get based on individual measures of the importance.

Calculations can be performed with use of professional software by known worldwide companies: Isograph Software (Reliability Workbench, Isolib libraries) and Sydvest Software (Fault Tree Analysis Academic Version). Comparative analyses will be carried out in the Microsoft Excel spreadsheet.

As part of the new methodology implementation a modern software will be drawn up being used for analysis of CTS components importance (in which a proposed comprehensive methodology for the evaluation of the reliability importance will be implemented).

## 5. Final conclusions

The new approach to the importance analysis will contribute to draw up modern methods, models and measures which allow to the evaluation of the system component importance in the reliability CTS structure. Additionally, implementation of new measures will contribute to: criticism of the current importance analysis methods; comparing both the evaluation of the usefulness of different importance analysis methods and measures; developing the algorithm of the rational evaluation of the importance of components and groups of components in CTS depending on information about the system; and of unification of the terminology in the area of importance analysis.

As a result of the proposed methodology implementation a series of statistical results will be obtained, which will be useful in further research, so as: details about importance of analyzed CTS components, estimating the reliability and availability of analyzed CTS, rankings of the importance of components in analyzed CTS and comparing the evaluation results from calculations made with various methods and for various criteria of the importance.

Due to interdisciplinary natures of issues being a subject of the plan, execution of particular tasks will affect the development of the civilization and the society using complex objects of the operation in many aspects of the daily living. Results can be applied in designing new systems and in operation of existing systems (the evaluation of the technical condition of the system, developing exploitation procedures and the alteration of the system in the destination of increasing the reliability).

With reference to CTS (e.g. vessel propulsion plants) the new methodology implementation will give utilitarian results, due to useful methodology drawn up for:

- aiding the CTS managing staff as the tool for assessment and developing maintenance schedules and programs;
- aiding CTS operators by means of diagrams, graphs, priority checklists of inspections and exploitation procedures created with use of the importance analysis.

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