III-rd Section:

SCIENCE OF COMPLEXITY

THE PROCESS ORIENTED FAULT-TOLERANCE OF THE COMPLEX ECONOMIC SYSTEMS

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Abstract. *The complex economic systems represents the main context that form an important part of the human society, and that determine the other dimensions regarding the society, these determinations being more acutely observed in the perspective of globalization. In this context becomes critical to consider the economical systems through their complexity, but also, as artificial systems that can be designed and controlled based on the objective laws that governs them, such that their functions to the society and individuals is optimal and positive. In this context the safety problem should be considered, and its corresponding solution of fault-tolerance must be integrated and developed in the complex economic systems. From this point of view, this paper proposes a specific safety analysis of the complex economic systems and the application of the process oriented approach for the fault-tolerance of the complex economic systems, such that a desired positive evolution of the complex economic systems in the present framework of globalisation will be obtained.*

Keywords: *complex economic systems, fault-tolerance, synergy, safety, economic systems design.*

1. Introduction

The complexity of the economic systems becomes a new dimension of our world development and future, that has important influences in the global evolution of the human society. In this context, considering the system theory and models in the representation and analysis of the economic reality, the design and development of the artificial systems with various objectives and functionalities becomes an important problem, considering that hey are building a new reality of actions, relations, evolution, and even of social existence.

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From this point of view, the aspects regarding safety as the expression of trust in these systems and their performed functions is a critical problem that must consider both the complexity of the context and the fault-tolerance capabilities as the expression of working in the presence of faults / errors.

2. The complexity problem

The attribute of complexity has many interpretations, according to the context considered. From the systemic point of view and taking into account the safety problem, the following dimensions of complexity are proposed:

1. The functional complexity that implies at least one feedback and the control and decision capabilities at the system level.

2. The structural complexity is determined by a large number of components and interconnections. It should be noticed that structural complexity does not necessarily imply functional complexity.

3. Heterogeneity represents the presence in the construction of a system of different types of functions and accordingly, of components that appertain to different disciplinary domains.

4. Synergy determines the creation of a new level of the economic systems construction through collaboration, communication, cooperation, (self) organization, and (self) structuration.

5. Evolution or dynamics represent the capabilities to develop different properties, structures, or even functions, such that the initial construction of the economic system is modified by the system itself.

6. The transdisciplinarity level represents the number of reality levels integrated in the context, a reality level being defined as a set of systems that are invariant to the actions of some general laws (e.g. technical, social, cultural, economical, ethical, educational etc.).

According to the above determined dimensions, results that the complex economic systems integrate all the identified characteristics (Fig. 1).

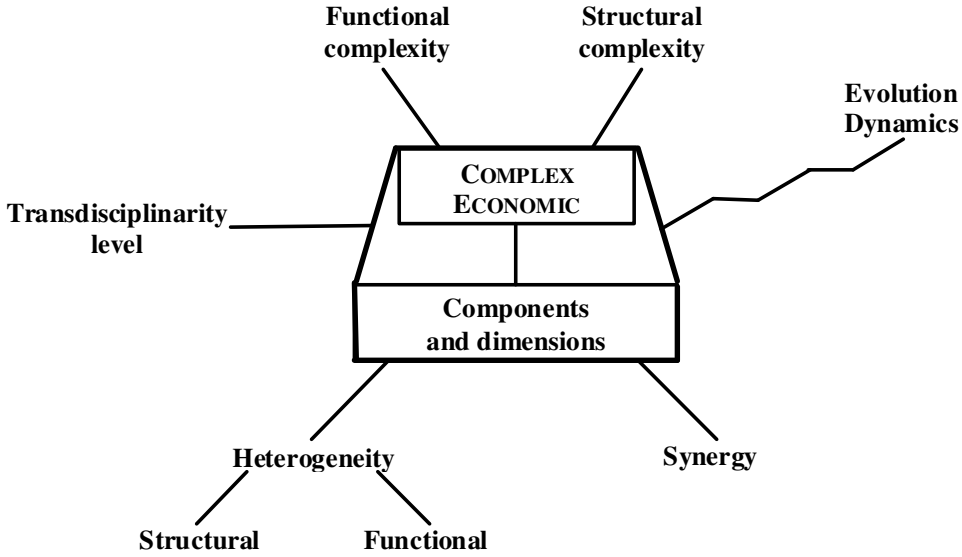

Figure 1. The complexity dimensions of the economic systems.

3. The safety of the complex economic systems

As any developed system, the economic ones may be considered through their specific states that can be classified in three main categories:

a) the correct states regarding functions and/or dynamics that are performed according to the accepted specifications of the system;

b) the faulty or erroneous states for which the behavior of the system does not correspond to the accepted functions and/or dynamics;

c) the maintenance states that are oriented to 'repair' the errors or faults of the system and to preserve the trajectory of the desired evolution.

All the states of a complex economic system at different moments and in different time intervals correspond to these categories, such that their succession in time through transitions in the state space determines the real trajectory of the system.

In this context, it should be considered that any complex economic system integrates humans, being based on specific relations between individuals and organizations, and also represent a 'product' that offers specific services to the human society and to the every individual (Fig. 2).

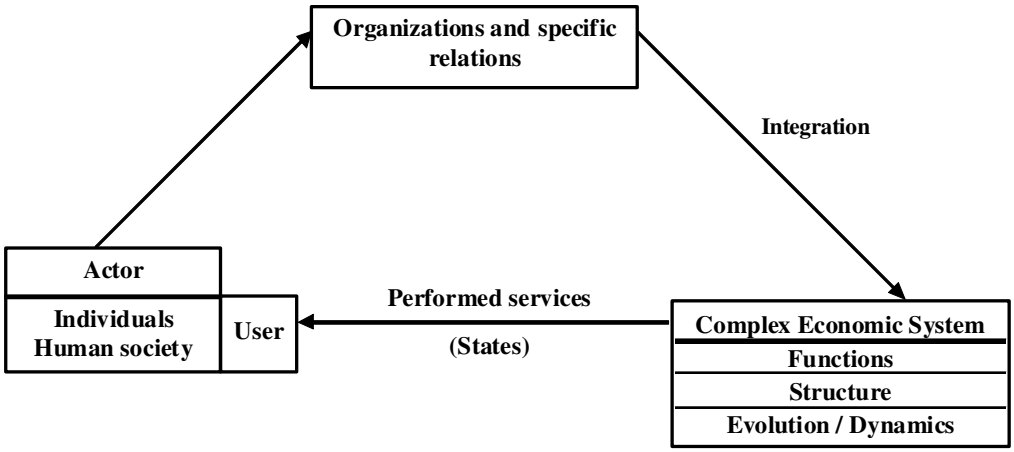

Figure 2. The human factor – complex economic system relation.

From figure 2 results that any state transition of the complex economic systems determines responses at the human society level, fact that imposes to consider the trust in the functions and dynamics / evolution of the complex economic systems. At the system level, the users' trust in complex economic systems is integrated in the **safety** concept defined as following:

Definition 1. The safety of a complex economic system represents its properties that permit the user to consider it in all its dimensions with a justified trust.

Definition 2. The safety of a complex economic system represents its capability to perform correctly its functions at a given moment and in a given time period, if it is used in the specified conditions, to perform selftesting, and selfdiagnosis of the present faults or errors, with selfreparation, reconfiguration or by blocking its erroneous functions (error oriented fail safe).

According to the above definitions, the safety dimensions can be determined from two points of view: the user, and respectively, the complex economic system.

For the **user** the safety of the complex economic systems is perceived through the performed services, and the corresponding dimensions are identified as following:

U1. *The reliability* – the service is uninterrupted.

U2. *The availability* – the service can be performed at a given moment.

U3. *The security* – the losses associated to the faults or errors of the service.

U4. *The informational security* – the integrity and confidentiality of the information corresponding to the performed service.

U5. *The credibility* – the complex economic system does not perform undetected erroneous services.

U6. *The diagnosability* – the possibility to identify the process of the service that is not performed according to the specifications and to the corresponding users' requests.

U7. *The independence of the service regarding some faults or errors* – the service is performed even if some processes are defective, being possible that some performance parameters to be degraded.

U8. *The conformity degree* – the performance characteristics of the service, at a given moment, correspond to the specifications and their accepted tolerances.

For the internal context of the **complex economic systems** the safety is considered through the following dimensions:

E1. *The reliability* – the functioning of the system is continuous.

E2. *The availability* – the functioning is correct at a given moment.

E3. *The security* – the losses associated to the faults or errors of the complex economic system.

E4. *The informational security* – the integrity and confidentiality of the information corresponding to the functions performed by the complex economic system.

E5. *The detection capability* – there a not faults or errors in the complex economic system that are not identified.

E6. *The diagnosability* – the possibility to identify the causes and the defective components that determined the fault or error of the complex economic system.

E7. *The capability to cover the errors / faults* – the complex economic system functions correspondingly to the specifications in the presence of some known, detectable, and reparable defects.

E8. *The reconfiguration capability* – the inner structure and interconnections of the complex economic system can be modified, such that, in the presence of some faults, the system is functioning correspondingly to the specifications, or in an accepted degraded manner.

E9. *The selftestability* – the capability of the complex economic system to identify its states or the states of its components.

E10. *The predictability* – the capabilities of the complex economic system to determine its future states based on the information regarding the dynamics of its inner and external parameters until a given moment.

E11. *The conformity degree* – the performance characteristics of the complex economic system, at a given moment, correspond to the specifications and their accepted tolerances.

Between the above two perspectives U1 ÷ U8, and E1 ÷ E11 can be established the correspondence relationships, as in figure 3, based on which the safety requests from the user's point of view can be translated at the level of the complex economic system, and reciprocal, the specifications of the complex economic system can be expressed in terms of safety of the services offered to the user.

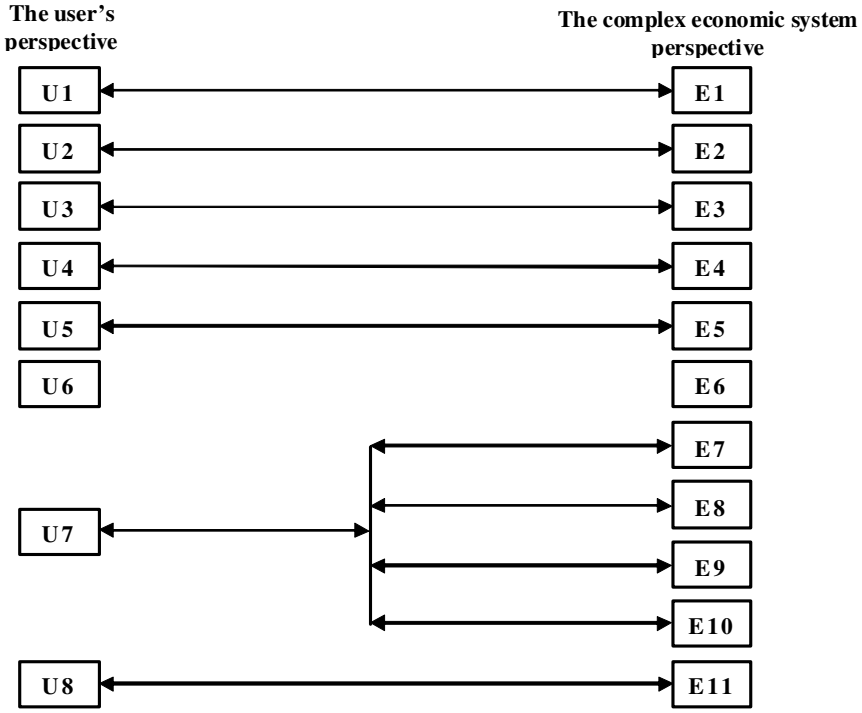

Figure 3. The relations between the user's perspectives (U1 ÷ U8), and the complex economic system perspective (E1 ÷ E11) of the safety concept.

Thus, the following safety solutions for complex economic systems are identified:

a) the solutions user / service oriented, that considers the dimensions U1 ÷ U8;
b) the solutions oriented to the structure and functions of the complex economic system, that considers the dimensions E1 ÷ E11, both these perspectives must be integrated in order to obtain a **global safety solution** of the complex economic systems, as in figure 4.

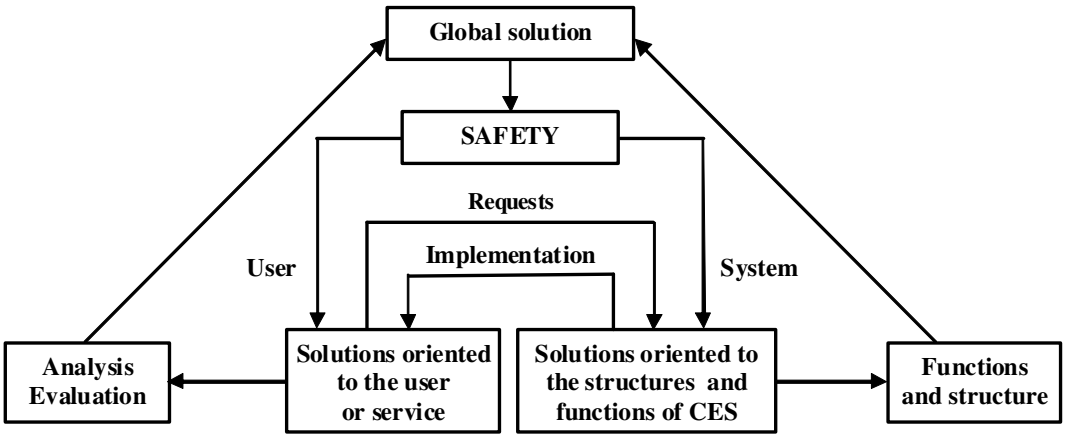

Figure 4. The global safety solution for a complex economic system (CES).

4. The fault-tolerance of the complex economic systems. The process oriented approach

The global safety solutions are implemented by developing the fault-tolerance concept that will represent the basis to develop complex economic systems able to work tolerable in the presence of defects and/or errors. The corresponding adopted definitions are:

Definition 3. The fault-tolerance of a complex economic system represents its capability to function in acceptable limits of performance in the presence of some specified defects or errors.

Definition 4. The fault-tolerance of a complex economic system represents a method of corrective (or preventive) maintenance that actions simultaneously with the service delivered by the system and in an invisible manner for the user.

According to the above definition, in [1] the main principles of the fault-tolerance development and implementation were determined, and these are applicable to the complex economic systems also:

Principle 1. The safety of a complex economic system is positively dependent with its reliability. Thus, the safety is improved if the intrinsic reliability is sufficiently high.

Principle 2. The fault-tolerance is obtained at the detailed structural and functional level of the complex economic system.

Principle 3. The efficiency of a fault-tolerance solution increase, and its action are effective for a longer period of time if the defective components are identified and replaced or repaired.

Principle 4. The development of any fault-tolerance solution should be process oriented, such that the structure of the complex economic system does not induce a segmentation of the constitutive processes.

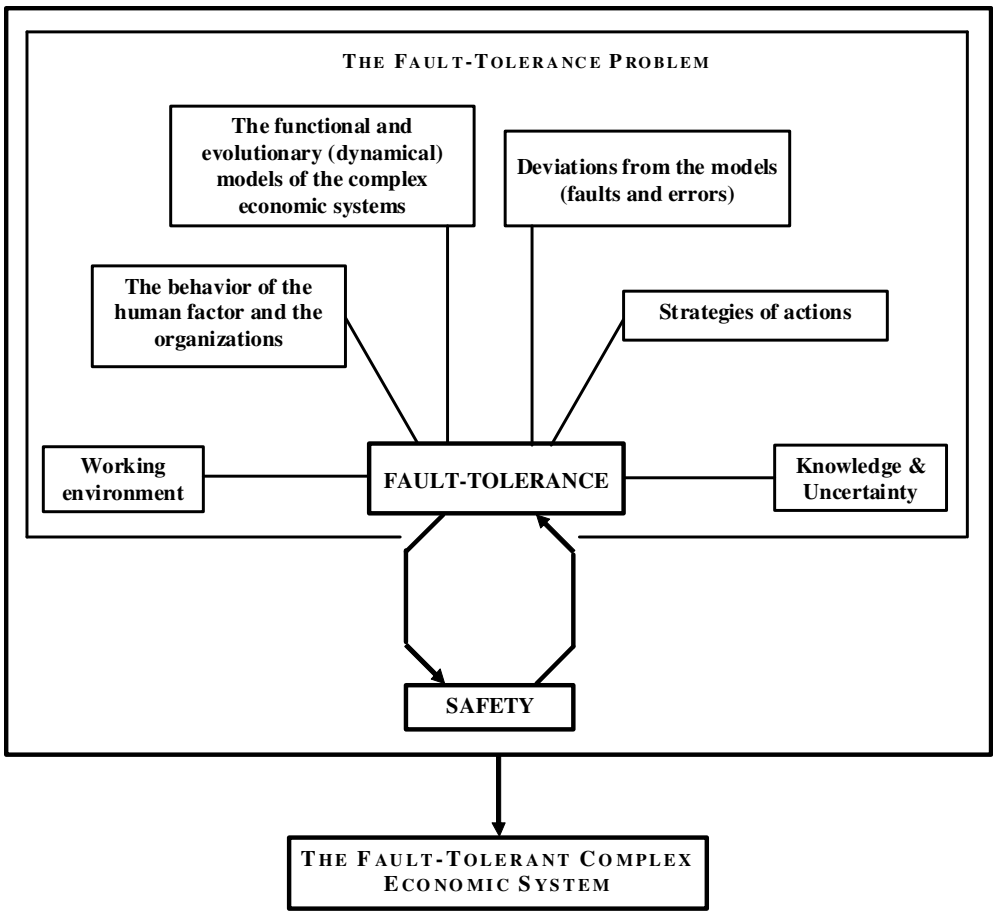

Figure 5. The framework of the relations between fault-tolerance and safety in developing the fault-tolerant complex economic system.

From this point of view, the relations between fault-tolerance and safety is according to the framework presented in figure 5, were are highlyghted the components of the fault tolerance problem:

- the working environment (cultural, technical, social etc.) of the complex economic system, and the relations between them;
- the behavioral characteristics of the human factor and organizations both as components of the complex economic system, and as its users;

- the functional and evolutionary (dynamical) models of the complex economic system, corresponding to the desired behavior of the system in time and space (environment);
- the types of faults and errors as the manifestations of the system's deviations from the models;
- the strategies of actions, their planning, that are executed at the internal level of the complex economic system;
- the knowledge requirements, and its limitations and uncertainties, considering that all the involved actions are generally characterized by incomplete knowledge.

According to the 4th principle determined in [1], results that for the complex economic systems the fault-tolerance should be developed in a process oriented manner, based on the process map represented in figure 6, were the processes are defined as in table 1.

Table 1

The definitions of the fault-tolerance processes

The fault tolerance process	Definition
The communication process	Data and information transmission between the complex economic system and the internal and external working environments, the human factor, and the organizations.
The detection process	A classification of the behaviors and/or states of the complex economic system, as accepted or erroneous relative to the function performed (delivered services).
The diagnosis process	The actions regarding the determination of faults causes and their locations.
The decision process	The solution identification of a problem, and the planning of the actions to be taken in order to implement the determined solution at the complex economic system level.
The reconfiguration process	The realization of the necessary actions for stopping the error propagation to the output of the system
The learning process	The human, organizational and/or artificial (artificial intelligence) actions of knowledge acquisition, organization, integration, and abstraction.

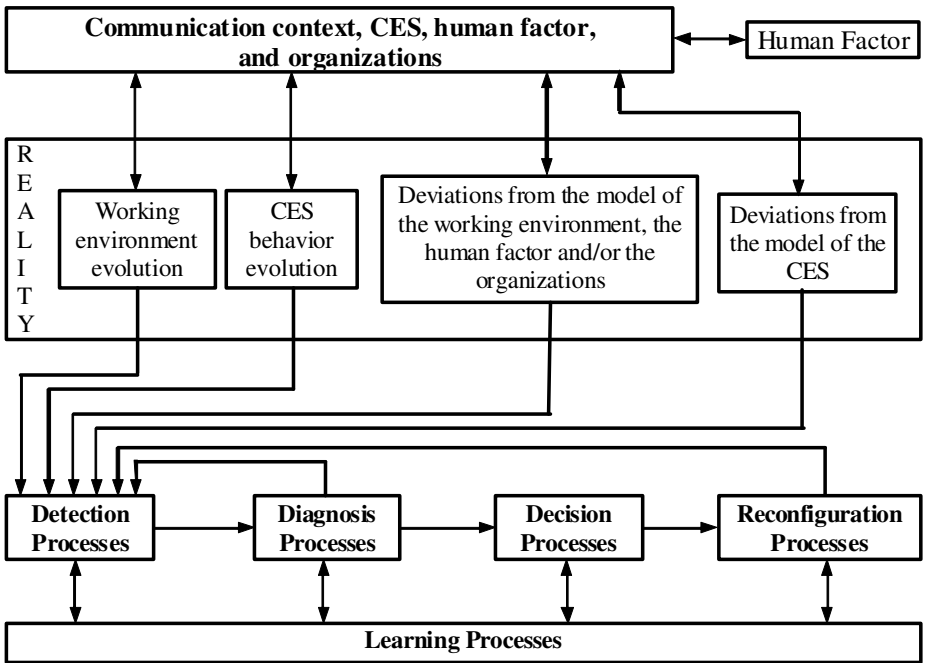

Figure 6. The process map of the global fault-tolerance solution of a complex economic system (CES).

The created context determines the necessity to develop / design the complex economic systems considering both their functions that deliver the corresponding services, and the functions that implement the process oriented fault tolerance (as in figure 6) that are able to 'deliver' the safety dimensions.

According to the general results in the process oriented fault-tolerance approach [1, 2], the development of the corresponding solutions for the complex economic systems must consider the following design principles:

DP-1. The fault-tolerance of any complex economic system is one of its functions, and accordingly must be correlated with the global functions determined by the definition of the service delivered by the considered system.

DP-2. All the functions (i.e., the global ones, and the fault-tolerance) will be represented by their dominant processes, and the corresponding process maps will be determined at both levels. This means that for the existing complex economic systems is necessary an reengineering stage to determine the corresponding dominant processes that will realize the global functions (service), in order to eliminate the useless processes or segmentations, and only after that the fault tolerance process map will be considered and developed.

DP-3. The processes determined at DP-2 will be unified, integrated and, eventually, if absolutely necessary, segmentation will be applied, such that a global process representation of the fault-tolerant complex economic system will be obtained.

DP-4. The corresponding relations between the processes of the global complex economic system representation will be integrated in the global process map of the fault-tolerant complex economic system.

DP-5. Based on the definition of the complex economic system at the process level, the corresponding architecture will be established and, consequently, the structural design including directions, organizations, and departments will be developed, such that the result will be the functional – structural fault-tolerant complex economic system.

According to these design principles, the general framework design of the fault-tolerant complex economic system will correspond to figure 7.

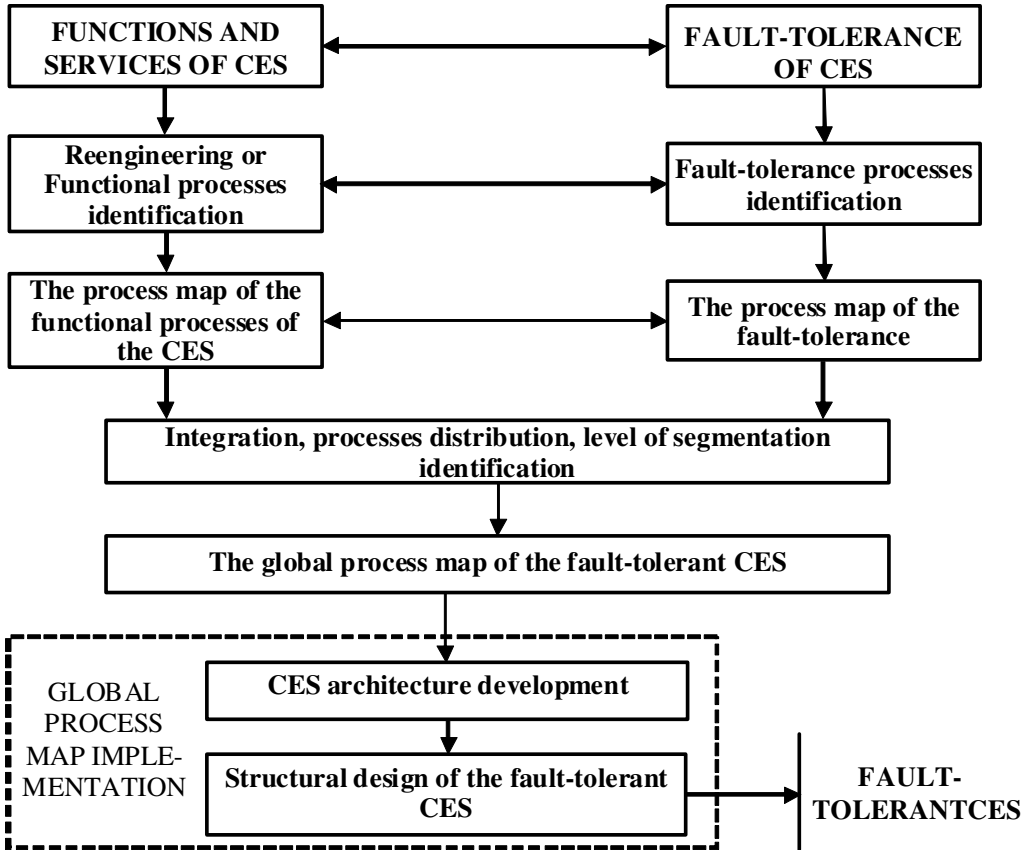

Figure 7. The general framework design
of the fault-tolerant complex economic system (CES).

5. Conclusions

The safety problem of the complex economic systems must be considered in the present context of globalization.

In the present paper a corresponding solution by using the process oriented approach for fault-tolerance design is developed. Thus, results that the complex economic systems can be modeled and developed in the general frameworks of design, such that the desired functions will be obtained and the effects of faults / defects and errors will be eliminated or diminished.

The proposed solution can be applied for redesign the existing complex economic systems or for designing new ones, is compatible to the general system theory, and represents a new vision of the complex economic systems as 'products' offered to the society as a base of its future evolution.

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