Chapter 1
Fuzzy Cognitive Maps in Reliability Modeling

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ABSTRACT

The fuzzy cognitive map is considered as a tool for the ranking of factors affecting reliability. The rank of a factor is defined as an equivalent of the Birnbaum importance index in the classical reliability theory. Models and algorithms are proposed for calculation of the importance indexes of single factors and their joint effects on the reliability. The method is exemplified by the reliability and safety of an automobile in the "driver-automobile-road" system subject to the driver's qualification, traffic situation, unit costs of operation, operating conditions, maintenance scheduling, quality of maintenance and repair, quality of automobile design, quality of operational materials and spare parts, as well as storage conditions. The advantages of the method include 1) use of available expert information with no collection and processing statistical data and 2) capability to take into account any quantitative and qualitative factors associated with people, technology, software, quality of service, operating conditions, etc.

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INTRODUCTION

Success in applied modeling problem solving largely depends on the chosen mathematical tools. Reliability theory is like medicine; medicine deals with human health, while reliability theory deals with "the health of man-made systems". The range of problems that may harm the reliability of system at the stages of design, production and operation makes reliability science an endless polygon, and presents opportunities for testing different mathematical theories and new methods for predicting, diagnosing and decision making.

Classical reliability theory [1, 2] arose in the middle of the 20th century when probability theory was the only way to formalize uncertainty. The models of classical reliability theory use the source data about failure probabilities and the laws of random value distribution of time between failures and repairs. It is assumed that these inputs are known from reference books or can be obtained experimentally. In practice, though, obtaining the source data and addressing all the influencing factors is a difficult and often impossible task. These difficulties often force us to substitute approximate source data into the complex probabilistic models, and make it impossible to predict accurately the probability of failure. As a result, engineers do not believe in their own reliability calculations (Barnard, 2012).

The appearance in 1965 an article by L. Zadeh (Zadeh, 1965) laid the foundation for a new method of describing uncertainty in the form of fuzzy logic. This aroused natural interest among specialists in reliability, and as a result, led to the emergence of an independent direction, which can be called Fuzzy Reliability. The first specialized collection of articles in this area is (Onisawa & Kasprzyk, 1995), and the first monographs include (Cai, 1996; Rotshtein & Shtovba, 1997; Utkin & Shubinsky, 1998).

Our experience in using fuzzy mathematics in reliability modeling shows that the following fundamental concepts and principles have the greatest application:

- *Fuzzy numbers* (Dubois & Prade, 1978) are a convenient means of presenting expert information about uncertain source data that are used in probabilistic reliability models (Onisawa et al., 1995; Rotshtein & Shtovba, 1997; Rotshtein & Shtovba, 1998).
- *The extension principle* (Zadeh, 1973) allows converting probabilistic reliability models to the form necessary for working with uncertain source data. It is important to emphasize that calculations with fuzzy numbers are much simpler than similar calculations with probabilistic distribution functions (Onisawa et al., 1995; Rotshtein & Shtovba, 1997; Rotshtein & Shtovba, 1998).

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