TSINGHUA SCIENCE AND TECHNOLOGY
ISSN 1007-0214 19/20 pp627-632
Volume 10, Number 5, October 2005

Fuzzy Multiple Attribute Decision Making for Evaluating Aggregate Risk in Green Manufacturing*

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Abstract: Industrial risk and the diversification of risk types both increase with industrial development. Many uncertain factors and high risk are inherent in the implementation of new green manufacturing methods. Because of the shortage of successful examples and complete and certain knowledge, decision-making methods using probabilities to represent risk, which need many examples, cannot be used to evaluate risk in the implementation of green manufacturing projects. Therefore, a fuzzy multiple attribute decision-making (FMADM) method was developed with a three-level hierarchical decision-making model to evaluate the aggregate risk for green manufacturing projects. A case study shows that the hierarchical decision-making model of the aggregate risk and the FMADM method effectively reflect the characteristics of the risk in green manufacturing projects.

Key words: green manufacturing; fuzzy multiple attribute decision making; aggregate risk; fuzzy logic

Introduction

Environmental pollution, resource allocation, and population growth are the three main problems confronting mankind. Environmental pollution is worsening and is becoming a serious threat to the survival and development of society. Sustainable development has become the key policy by which we can control environmental pollution and resource usage while still developing. Sustainable production and consumption will be the main characteristics of future societies to provide sustainable development and a sustainable society[1,2]. The manufacturing industry is one of the main sources of environmental pollution. Therefore, all industries are seeking to minimize the environmental impact of their industry[3]. Green manufacturing, which is an advanced manufacturing mode, is the application of sustainable science to the manufacturing industry. In the 21st century, the manufacturing industry must seek to minimize environmental impact and resource consumption during the entire product life cycle which includes design, production, processing, packaging, transport, and use of products in continuous or discrete manufacturing industries[4-6].

Industrial risk and the diversification of risk types have both increased with industrial development. At the same time, the risk acceptability threshold of the population has decreased. In response, industry has developed methodologies for risk prevention and protection[7]. Green manufacturing was first proposed about ten years ago, so there are few examples that can be used to evaluate risks and many uncertain factors. Because of this incomplete and uncertain knowledge, decision-making methods using probabilities to

Received: 2004-03-01; revised: 2004-12-20
* Supported by the National Natural Science Foundation of China (No. 50135020), the National High-Tech Research and Development (863) Program of China (No. 2001AA337010) and the Key Grant Project of the Ministry of Education, China (No. 0203)
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represent risk, which need many examples, cannot be used for green manufacturing projects. In addition, green manufacturing involves a very wide range of topics, such as environmental consciousness, life cycle thinking, and sustainable development, which increase the risk. Therefore, risk decision-making in green manufacturing projects must consider multiple indicators. With more than 4 indicators in a problem, the analytic hierarchical process (AHP) method cannot easily find a consistent condition for its judgment matrix[8-10], so that the AHP method is not appropriate for green manufacturing projects. Other general risk analysis methods are also not very effective. This paper uses fuzzy numbers to represent the uncertain risk information in green manufacturing projects and to integrate the available knowledge into a fuzzy multiple attribute decision-making (FMADM) method[11,12].

1 Hierarchical Structure Model of Aggregate Risk

Enterprises are implementing green manufacturing projects for sustainable production for four types of risk categories: technological, organizational, financial, and circumstancial. Each category is related to some risk factors. Analysis of typical risk factors in green manufacturing projects led to the hierarchical decision-making model of the aggregate risk shown in Fig. 1.

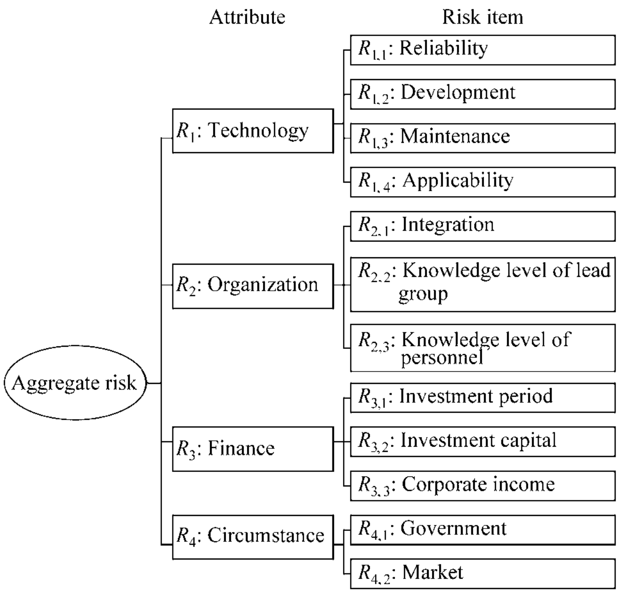

Fig. 1 Hierarchical decision-making framework of aggregate risk

Technological risk Since the concept of green manufacturing is relatively new, its theories and technologies are still being developed. Only experience will show whether or not each technology can be used in green manufacturing projects to create extended benefits for industry, society, and the ecology. Therefore, there are many technological risk factors, including its reliability, maintenance, and applicability.

Organizational risk Green manufacturing is a new manufacturing mode with the product cycle extending to the entire product life (raw materials, production, use, recycle, and disposal), so traditional management methods are not suitable. Therefore, the management system must be reformed to successfully implement green manufacturing which will lead to unpredictable risks. The main organizational risk factors are the integration of the management approach, the knowledge level of the lead group, and the knowledge level of the personnel.

Financial risk Green manufacturing projects require a very long investment period due to the length of the entire product cycle which increases the risk. Corporate income is gained by saving energy and materials, protecting the environment and workers, inproving productivity and product quality, reducing costs, and accurating market timing.

Circumstancial risk Green manufacturing projects are constrained not only by internal resources but also by external resources. Many uncertain circumstancial factors can cause critical risks. Such external factors include laws, regulations, macro economic changes, and industrial development.

2 Fuzzy Multiple Attribute Approaches

The hierarchical decision-making framework for the aggregate risk shown in Fig. 1 was used to develop an FMADM method for risk decision of green manufacturing projects. Linguistic values were used to denote the relative importance of each attribute and each risk item and to denote the risk grade of each risk item in the project. The linguistic values were then translated into normal triangular fuzzy numbers. The fuzzy average weighted method was then used to compute the aggregate risk for each project as a triangular fuzzy number. The centroid method was then