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Fuzzy theory applied in quality management of distributed manufacturing system: A literature review and classification

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ABSTRACT

Fuzzy theory has been regarded as a very important technique for quality management (QM) of distributed manufacturing system and attracts the attentions of academic and industry; however, there is a lack of a comprehensive literature review and a classification scheme for it. This paper is the first academic literature review of the fuzzy theory applied in quality management of distributed manufacturing system. It involves five most popular databases in this research area and covers more than 20 journals, proposes a classification scheme using clustering analysis method. Sixty-one journal articles were finally selected, reviewed and classified. Each selected article was classified firstly based on four QM dimensions (quality planning, quality control, quality assurance and quality improvement) and the elements/process of each dimension. Sequentially, articles were further classified by the nine fuzzy techniques which are fuzzy regression, fuzzy classification, fuzzy clustering, fuzzy control, fuzzy inference, fuzzy numbers, fuzzy optimization, fuzzy statistics and fuzzy data analysis. Among the four QM dimensions, quality improvement has the highest publications in recent years and fuzzy decision making and fuzzy number are the main techniques adopted in quality improvement.

1. Introduction

Quality management (QM) is a philosophy or a management approach comprising a set of mutually reinforcing principles, each of which is supported by a set of practices and techniques (Dean and Bowen, 1994).

One of the main areas of research in QM has concerned about how the QM practices affect the firm performance. The quality performance model presents several routes by which QM practice has an impact on quality, operational and business performance. QM proponents claim that the reduction of the manufacturing process variability due to the set of QM practices can enhance internal process quality and subsequently achieve product conformance quality. Utilizing statistical process control is one of the typical approaches. Moreover, by considering customer oriented QM practices, other product quality dimensions will be improved. Garvin (1984) defined product quality and showed how internal process quality and product quality performance can affect operational and business performance. Two main aspects for the impact of quality on business performance, that is, the manufacturing part and the market part, have been proposed.

From the manufacturing perspective, within the manufacturing network, good internal process quality management means fewer scrap, defects and rework, and leads to a better operational performance (e.g. lower manufacturing costs, more reliable processes), and substantial production improvement. Identifying order winner and order quantifiers in turn bring improvement in business performance, which is also the reason why quality management in manufacturing is so important (Sousa and Voss, 2002).

However, in practical manufacturing environment, it always happens that knowledgeable workers are usually confronted with uncertainty which is resulted from lack of information, lexical impression, incompleteness and inaccuracy of measurements. Such uncertainty is incurred by different level of quality problems. To solve these vague and fuzzy quality problems, fuzzy theory was introduced. With large number of fuzzy tools and techniques applied in quality management system, the unavoidable fuzzy information can be solved and many improved outcomes can be gained.

This paper presents a comprehensive review of literature related to application of fuzzy theory technique in QM for distributed manufacturing system. A classification of framework is also presented. In Section 2, the research methodology is presented; Section 3 presents the classification method and the detailed explanation for the QM and fuzzy theory technique; Section 4 shows the classification of articles with their distribution in this area; and finally, the conclusions, limitations and implications of the study are discussed.

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2. Research methodology

As the nature of research in fuzzy theory and quality management are difficult to be confined to specific disciplines, the relevant materials are scattered across various journals. Expert systems with application and engineering applications of artificial intelligence are the most common academic discipline for fuzzy theory research in QM. Under this condition, the following online journal databases were selected to search for a comprehensive bibliography of the academic literature on fuzzy theory and quality management:

- Science Direct
- Emerald management xplore
- IEEE xplore
- Academic Search Premier
- Engineering Village (Table 1)

The literature search was conducted based on the words "quality management", "fuzzy theory" and "manufacturing system", which originally produced results approximately as follows:

The full text of each article was reviewed to remove those that were not actually related to fuzzy theory applied in quality management of manufacturing system. The selection criteria were as following:

- Only those articles which clearly explained how the fuzzy theory technique could be applied to the mentioned manufacturing quality management system were selected.
- Only those articles that had been published in quality management, fuzzy technique and manufacturing system related journals were selected, as these were the most appropriate outlets for fuzzy theory applied to quality management of manufacturing system research and the focus of this review.
- Conference papers, master's and doctoral dissertations, textbooks and unpublished working papers were excluded, as academics and practitioners alike most often use journals to acquire information and disseminate new findings. Thus, journals represent the highest level of research (Nord and Nord, 1995).

3. Classification method

Quality management is the process of identifying and administering the activities necessary to achieve the organization's quality objectives. Quality management is focused not only on product quality, but also the means to achieve it. Quality objective is a statement of the desired result to be achieved within a specific time period. Objectives can be created to achieve stability or unprecedented new levels of performance which can be either short term or long term (Juran and Gryna, 1993).

According to Juran (1988), Ahire et al. (1995), Harvey (1998) and Pyzdek (2003), quality management (QM) can be generally divided into four dimensions:

1. Quality planning,
2. Quality control,
3. Quality assurance,
4. Quality improvement.

Table1
Articles published in 5 major online databases.

On-line database	Search results (the number of articles)
Science Direct	10
Emerald management xplore	490
Academic Search Premier	11
Engineering Village	120
IEEE xplore	0

These four dimensions can be seen as a sequent flow in a quality management system. When applying such quality management system into large distributed manufacturing system, the system will be highly complex whose behaviors are not well known and some approximate situations would happen. Hence, fuzzy theory is feasible to be implemented, which is very useful in two general contexts: (1) in situations involving highly complex system whose behaviors are not completely understood and (2) in situations where an approximate, but fast solution, is warranted. Fuzzy technique based on fuzzy theory can be applied in several aspects to help to solve the uncertain problems. Within the quality management area, each technique can perform one or more of the following functional model referring to the selected articles (Mehrabi and Kannatey-Asibu, 2001; Melin and Castillo, 2007 and other references):

1. Fuzzy numbers
2. Fuzzy AHP
3. Fuzzy decision making
4. Fuzzy programming
5. Fuzzy data analysis
6. Fuzzy optimization
7. Fuzzy clustering
8. Fuzzy QFD
9. Fuzzy inference
10. Fuzzy control

A graphical classification framework on fuzzy theory technique applied in quality management of distributed manufacturing system is proposed and shown in Fig. 1. It is based on a review of the relevant literature (Mehrabi and Kannatey-Asibu, 2001; Melin and Castillo, 2007). For all the QM dimensions and fuzzy techniques, a brief description and some references for further details are discussed in the Sections 3.1 and 3.2.

3.1. Classification framework—QM dimensions

In this study, QM is defined as the process of identifying and administering the activities necessary to achieve the organization's quality objectives through the sequent flow including quality planning, quality control, quality assurance and quality improvement.

1) Quality planning establishes the design of a product, service, or process that will meet customer, business and operational needs to produce the product before it is produced (Juran, 1970). The elements of quality planning involve a number of universal steps:
   1. Determine who are the customers and target markets.
   2. Determine the needs of the customers.
   3. Develop product features which respond to customers' needs.
   4. Develop processes which are able to produce those product features.
   5. Transfer the resulting plans to the operating forces (Juran, 1970).
2) Quality control is the process used by the operating forces as an aid to meet the product and process goals. It is based on the feedback loop and consists of the following steps:
   1. Evaluate actual operating performance
   2. Compare actual performance to goals
   3. Act on the difference between goal and performance (Pyzdek, 2003)