ELSEVIER

Journal of Materials Processing Technology 146 (2004) 365–376

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

AHP as a strategic decision-making tool to justify machine tool selection

Mustafa Yurdakul*

Department of Mechanical Engineering, Faculty of Engineering and Architecture, Gazi University, Maltepe, 06570 Ankara, Turkey

Received 6 January 2003; received in revised form 24 November 2003; accepted 24 November 2003

Abstract

Machine tool selection has strategic implications that contribute to the manufacturing strategy of a manufacturing organization. In such a case, it is important to identify and model the links between machine tool alternatives and manufacturing strategy. This study presents such a strategic justification tool for machine tools. With the new strategic justification tool, the evaluation of investment in machine tools can model and quantify strategic considerations. AHP and ANP are applied in calculation of the contributions of machine tool alternatives to the manufacturing strategy of a manufacturing organization. Hierarchical decision structures are formed in the application of the AHP and ANP approaches. Ranking scores which are used to rank the alternatives are obtained as outcomes of the applications. Application of the ANP approach also enabled the incorporation of interdependencies among the components of decision structures. An illustrative example is provided. The company management found the application and results satisfactory and implementable in their machine tool selection decisions.

Keywords: Machine selection; Strategic consideration; Analytic network process; Analytic hierarchy process; Manufacturing strategy; Machine characteristics

1. Introduction

For manufacturing companies, one of the starting points to achieving high competitiveness in the market is the selection of machine tools. Generally, return on investment (ROI) method is applied in justification of machine tools [10,11,24]. Investments in machine tools are often accepted as stand-alone replacement projects, which do not improve the performance of a company enough to affect its strategic positioning against its competitors in the market [18,21].

However, the newest machine tools, namely machining centers, work independent of human operators, combine multiple machining operations performed by several conventional machine tools previously, and handle tool exchange, part exchange, and many activities automatically. They combine cost and time reducing efficiency features of specialized machines with the flexibility of conventional non-dedicated machine tools. The capability of accepting any one of a range of parts in random order provides advantages that have major implications for a firm in the market against its competitors, such that a strategic justification is necessary to incorporate the strategic benefits into the selection process of machine tools.

In the literature, there are papers proposing models for machine tool selection problems. For example, Atmani and Lashkari [3], Tabucanon et al. [26], and Wang et al. [28] studied the machine selection problem for flexible manufacturing systems (FMS). However, a thorough study of the strategic implications of the machine tool selection decision is not available in the literature to the best knowledge of the author. This paper is along the lines of justifying stand-alone machine tools, and it focuses on the strategic implications of the machine tool selection decision and develops a model in which the strategic benefits of the machine tool selection decision are identified and quantified.

In a strategic approach, it is necessary to build a bridge between manufacturing strategy and individual machine tool options [2]. A multi-level decision hierarchy and intermediate decision levels are required to link machine tool properties with the company's manufacturing strategy. Furthermore, different types of evaluation criteria will exist in the decision hierarchy. Among the available multi-attribute approaches, only the analytic hierarchy process (AHP) approach has the capabilities to combine different types of criteria in a multi-level decision structure to obtain a single score for each alternative to rank the alternatives.

* Tel.: +90-312-231-74-00x2414; fax: +90-3122308434.
E-mail address: yurdakul@gazi.edu.tr (M. Yurdakul).

0924-0136/$ – see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmatprotec.2003.11.026

In the literature, Arslan et al. [1], Lin and Yang [14] and Oeltjenbruns et al. [19] proposed AHP for machine selection problem. However, the proposed AHP models are limited in terms of strategic implications of their selection decisions. Another important observation related with the proposed AHP models is that none of them has the ability to handle interdependencies, or interrelationships, among the evaluation criteria. The justification criteria are assumed to be independent of each other, and their weights in the achievement of the company's goals are calculated ignoring contributions to each other. However, to calculate real weight of a criterion, interdependencies among the criteria must be identified, quantified, and included into the calculation of weight of criteria in the machine tool justification problem. AHP cannot incorporate interdependent relationships among and within the levels of criteria. In such a situation, the general form of AHP, ANP (analytic network process), need to be applied along with AHP (see [4,16,17]).

2. Application of the AHP and ANP in strategic justification of machine tools

Structuring decision hierarchies for machine tool selection problem, pairwise comparison and determining the weights (contributions) of the components of the hierarchies, and synthesis to reach overall ranking scores for machine tool alternatives are the three functions performed step by step in the application of the AHP approach.

2.1. Development of decision hierarchies

As a first step of the application of the AHP approach, decision hierarchies are developed. The first hierarchy has a two-level structure and links the competitiveness goal of the company to the manufacturing priorities and is used to measure the weight of manufacturing priorities (Fig. 1).

The other three hierarchies link manufacturing priorities with alternative machine tools which are represented in terms of the machine tool characteristics (Figs. 2–4). At the lowest levels of the three hierarchies, alternative machine tools in terms of their characteristics are placed. The hierarchical structures link the alternative machine tools to the manufacturing strategy placed at the third level through an intermediate level of manufacturing benefits. The first four machine tool characteristics (i.e. process quality, actual machining time of a typical part, set-up time of an activity, and number of operations/parts that can be performed at the machine tool) are benefit-related and ultimately contribute to all three manufacturing priorities in terms of savings in cost and time and improvements in efficiency. They are causes of the manufacturing benefits, and the differences in the characteristics of different machine tool alternatives lead to different levels of achievements in manufacturing benefits [15,20]. On the other hand, the last two characteristics (i.e. initial and running costs) are the expenses that are necessary to purchase or operate the alternative machine tools. In the hierarchies developed for cost and delivery priorities, it should be noted that the manufacturing benefits are interrelated. As an example, the relationships among manufacturing lead time, lot size and inventory level can be presented. In a manufacturing plant, any reduction in manufacturing lead time will lower inventory levels and lot sizes. In return, lower inventory levels and lot sizes further reduce manufacturing lead time. At the same time, lower lot sizes reduce inventory levels. Therefore, in the calculation of the weight of a benefit with respect to a manufacturing priority, its contributions on other benefits should be added to its independent weight.

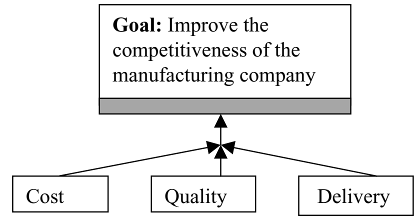

Fig. 1. The decision hierarchy of manufacturing strategy.

The manufacturing priorities are parts of the manufacturing strategy. Quality priority is important in achieving tighter specifications in terms of surface quality and tolerances and better conformance with defined specifications.

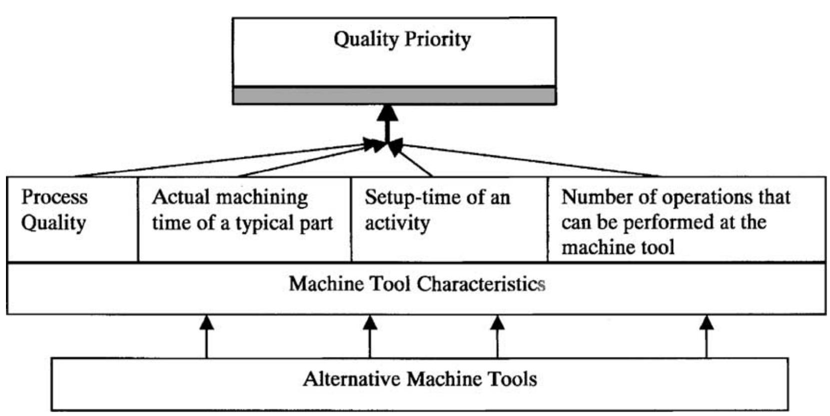

Fig. 2. The decision hierarchy of quality priority.