



# Towards a taxonomy of search patterns of manufacturing flexibility in small and medium-sized firms

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## Abstract

Manufacturing organizations are experiencing a wide range of forces which make it necessary for them to continuously adapt their operations and consider the consequences of their production activities on customer expectations, supplier constraints and changes in the law. This paper presents an empirical verification of knowledge levels and the perceived strategic relevance of manufacturing flexibility. A questionnaire survey was conducted with a sample of 89 manufacturing firms located in the area around Brescia, one of the most industrialized areas in Europe. Initial results gave a better understanding of which type of flexibility is preferred when facing different environmental challenges. In addition, insights into managerial approaches were brought out through clustering and discriminant analysis which have made it possible to emphasize some significant differences between firms in the search patterns of manufacturing flexibility. © 2000 Elsevier Science Ltd. All rights reserved.

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## 1. Introduction

In general terms, manufacturing flexibility has been defined as the ability of a manufacturing organization to deploy and redeploy its resources effectively in response to changing environmental and internal conditions [1]. Manufacturing flexibility has been emphasized as a major competitive concern in operations management [2] and its improvement is frequently an important issue on the manufacturing manager's agenda [3]. The manufacturing flexibility choices made by firms are aimed at improving compe-

tiveness when faced with rapid changes [4,5]. With globalization the company must consider international markets and still maintain a certain threshold of flexibility to adjust quickly and cost-effectively to local markets requirements, evolving technical standards and changes in the law [6]. Manufacturing flexibility can also be directed towards speeding up the introduction of products, which is critical in situations of increased uncertainty where products have short market lives. But even when product innovation capability is not critical (in established industries where fewer product changes occur), manufacturers often have to face considerable environmental uncertainty (due, for instance, to safety and environmental legislation or compliance to quality certification requirements).

Despite the vast amount of research carried out on manufacturing flexibility over the last decade, common definitions and shared concepts still remain elusive.

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Many different classifications of the concept are proposed (e.g.[7–10]), and it is clear that approaches to operational flexibility have not yet reached a paradigmatic stage. Furthermore, some empirical evidence seems to confirm that, despite the wide proliferation of flexibility types and definitions proposed in the literature, flexibility tends to be unidimensional when operationalized [6]. Even when adopting a specific taxonomy, the basic types of flexibility are not unrelated [5]: new product introduction and mix flexibility interact in a fairly strict manner, tend to reinforce each other and influence common elements in operational domains such as the possibility of reusing components and the involvement of personnel. It also appears to be the case that mix flexibility can reduce the need for volume flexibility by decreasing volume swings [11].

The research illustrated below addresses the issue of whether it is possible to track meaningful uniformity in the search patterns of manufacturing flexibility adopted by small and medium-sized enterprises. The underlying assumption is that the organizational adaptive behavior, when faced with external contingencies, is largely *firm-specific* (depending on the firm's physical and managerial structure and organizational resources and capabilities) and *path-dependent* (depending on its previous choices and past history) [12]. After more than a decade of research into manufacturing flexibility, it is now recognized that flexibility and the measures used to express it are user- and/or situation-specific [13].

This paper is divided into three parts. The first tries to identify the nature of environmental changes that firms are currently facing. The second part provides a measurement of the perceived effectiveness of each dimension of manufacturing flexibility when facing major environmental challenges. The third section illustrates an attempt to build a taxonomy of small and medium-sized enterprises (SMEs) based on their approach to manufacturing flexibility. The data refer to a sample of 89 SMEs located in the province of Brescia, one of the most industrialized area of northern Italy. The basic research model relies on the assumption that, by identifying specific environmental sources of uncertainty and the responses of the firms, one can a priori identify critical dimensions of manufacturing flexibility.

Previous work in this area, in assuming that managers face the task of balancing manufacturing flexibility and external uncertainty, have generally aimed at building operational frameworks for the analysis of manufacturing flexibility, where managers are allowed to delineate each of the types of flexibility with which they may be concerned.

Both quantitative and qualitative approaches have been followed when dealing with the measures of manufacturing flexibility types [14]. Quantitative physical

measures are based on actual production data (related to product, machines, processes, etc.). The relevant literature is extensive. Excellent reviews are presented [9,15,16].

Two types of qualitative research can be identified based on whether perceptual scales are used or not. In the former case, major international surveys aimed at measuring flexibility investment and performance are presented, for instance, in Refs. [17] and [18]. On the other hand, qualitative studies without perceptual scales have usually been placed in a framework in such a way that first the dimensions of change and the time horizon are identified, and then the critical elements of flexibility are derived [2]. Dynamic equilibrium models have been used to visualize changes in external positioning, assessing the balance between flexibility and external uncertainty, and establishing long-term and short-term action plans. These models have been used together with audit checklists of external uncertainty and manufacturing flexibility [19–21]. The practical benefits of these studies include the provision of a less ambiguous frame of reference for discussing the various flexibilities the firm needs to manage.

## 2. Research framework and methodology

Two major objectives were pursued via the research outlined below. First, to gain an understanding of which dimensions of manufacturing flexibility are perceived as being most effective and, as a consequence, are pursued by successful small and medium-sized firms. Second, to explore the different patterns of flexibility search followed by the firms and relate these patterns to the characteristics of the firms and the nature of the industry where they operate.

The results presented in this paper are derived from a broad research program performed in three main stages: initial survey design, questionnaire development and data collection and analysis.

### 2.1. First stage: initial survey design

The first stage was aimed at the identification of major dimensions of manufacturing flexibility and the generation of items able to capture the specific domain of interest. An inductive approach was used to identify items for inclusion in the scales, and the available literature was used to provide the theoretical foundations.

The first step was aimed at splitting the overall construct (manufacturing flexibility) into its component subconstructs (dimensions). The attempt to classify manufacturing flexibility has involved many researchers (for an exhaustive review, see [15]). The problem

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