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Measuring dimensions of manufacturing flexibility

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Abstract

Even though many managers and academics have cited flexibility as a key competitive capability, efforts to measure and understand this complex construct continue. Consequently in this paper, we address the issue of manufacturing flexibility measurement, and then use these measures to better understand flexibility. Churchill's [J. Market. Res. 16 (1979) 64] paradigm is used to develop psychometrically sound measures for six oft-used dimensions of manufacturing flexibility: machine, labor, material handling, mix, new product, and modification. Previous research shows that each of these dimensions, in turn, is comprised of four elements. The resulting 24 scales (6 dimensions × 4 elements) demonstrate the desired properties of unidimensionality, reliability, and validity. We show further that the four elements of any given manufacturing flexibility dimension can be grouped into two conceptually separate factors representing "Scope" and "Achievability" of flexible responses. Scope and achievability factor scores can be used to compare a subset of firms with respect to their flexibility choices, and observe the trade-offs firms make both within and across flexibility dimensions. Along with scale development, establishing scope versus achievability relationships between flexibility elements provides a better basis for measuring and creating a holistic understanding of this complex concept.

Keywords: Manufacturing flexibility; Measurement; Empirical research

1. Introduction

The potential competitive impact of flexibility is well recognized (Cox, 1989; De Meyer et al., 1989). However, both managers and academics have noted the lack of appropriate measures for it (e.g., De Toni and Tonchia, 1998; Parker and Wirth, 1999; Koste and Malhotra, 1999; Beach et al., 2000) as well as the need to better understand the relationships among different types of flexibility (e.g., Parker and Wirth, 1999; Beach et al., 2000). While efforts have been made to address the measurement gap, good, generalizable measures that span multiple industries are still lacking (Gerwin, 1993), which in turn hinders the effective management of this key capability. This study seeks to address this need by creating generalizable measures for six different dimensions of manufacturing flexibility and then using these measures to further our understanding of manufacturing flexibility.

A number of recent studies have measured flexibility objectively, using industry specific measures

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(e.g., Dixon, 1992; MacDuffie et al., 1996; Suarez et al., 1995, 1996; Upton, 1995, 1997). Unfortunately, these measures are not broad-based and are applicable only to the industries within which they were created. Consequently, three other studies have attempted to develop flexibility measures that span multiple industries. Two of these were empirical, but they were exploratory in nature. Gupta and Somers (1992) provided the first effort at scale development. They culled eleven flexibility dimensions and 34 items from the existing literature. Exploratory factor analysis (EFA) resulted in the retention of nine factors, some of which were composites of the original flexibility dimensions. Several of the measures thus developed were single-item measures and the flexibility dimensions lacked a well-defined theoretical domain.

A more recent effort by D'Souza and Williams (2000) partially addresses this concern. The authors were consistent in specifying the domain for the volume, variety, process and material handling flexibility dimensions included in their study. However, while prior research indicates that the domain of flexibility consists of more than two elements (e.g., Gupta and Buzacott, 1989; Slack, 1983, 1987; Upton, 1994), the authors used only two to assess each flexibility dimension. Single or dual items from the literature were chosen to capture the range and mobility elements of each of them. EFA demonstrated that the items loaded on the two factors as anticipated. While this study advanced the empirical efforts toward scale development, a concern exists with respect to the fact that D'Souza and Williams (2000) operationalized only two elements. This concern is significant, and mandates additional efforts in measuring flexibility.

A study by Parker and Wirth (1999) took a different approach. The authors examined the intended purpose of a given flexibility measure and used evaluative criteria to identify "best" measures for several different types of flexibility. They found two types of flexibility lacked good measures and subsequently created models to assess them. While insightful, the underlying assumptions behind the models were fairly restrictive, potentially limiting their use in industry.

The above studies focused solely on flexibility, although this concept has been operationalized in a broader context in other empirical research. Pagell and Krause (1999) examined the relationships between operational flexibility, uncertainty, and firm performance. Narasimhan and Das (1999) examined the effect of strategic sourcing on advanced manufacturing technologies (AMT) and on three specific types of flexibility, as well as the relationships among the flexibility dimensions. Brandyberry et al. (1999) also examined the relationship between AMT and market-oriented flexibility. However, since flexibility was not the primary focus of these studies, the operationalization of this construct was fairly limited. Two of the studies combined multiple dimensions of flexibility into one measure (e.g., Pagell and Krause, 1999; Brandyberry et al., 1999) or focused on limited aspects of the dimensions (e.g., Narasimhan and Das, 1999 measured flexibility for all dimensions with respect to the mobility element only). While these studies provided insight and advanced their respective research fields, they would have been strengthened considerably by a fuller, multi-faceted approach to measuring flexibility, an objective we intend to pursue in this study.

2. The flexibility construct

While many different types of flexibility have been identified in the literature, prior research indicates that the domain of any flexibility dimension is comprised of four elements: range-number, range-heterogeneity, mobility, and uniformity (Slack, 1983, 1987; Upton, 1994; Koste and Malhotra, 1999). The range-number (R-N) element of flexibility is a strict numerical count of the number of possible options that a system or resource can achieve. The range-heterogeneity (R-H) element addresses the degree of difference between different options. The mobility (M) element represents the ease with which the organization moves from one state to another. For each change of state within the range, mobility is assessed via transition penalties. The uniformity (U) element of flexibility captures any alteration or deterioration of the system associated with invoking a flexible response. As such, a large number of performance measures can be used to assess the similarity of performance outcomes within the spanned range. For both transition penalties and changes in performance, the net sum of changes must be considered.

In this study, we focus on six flexibility dimensions: machine, labor, material handling, mix, new product and modification. Machine, labor, and