Fit, Flexibility and Performance in Manufacturing:
Coping with Dynamic Environments

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Abstract

This research develops the notion of environmental fit and flexibility and illustrates the importance of such fit empirically using survey data from 101 manufacturing firms. Two dimensions of environmental dynamism are identified and the fit between them and different approaches to flexibility are assessed. Hierarchical regressions provide evidence that flexibility is a stronger predictor of performance in more dynamic environments. Specifically, presence of the unpredictability or the volatility aspects of environmental dynamism each warrant the use of different types of manufacturing flexibility strategies. Statistical results are interpreted with the caveat that while implemented capability must be used to study performance effects, this study uses perceived importance scales for flexibility.

Keywords: environmental dynamism, flexibility, fit
1. Introduction:

In the last three decades, the focused factory concept (Skinner, 1974) has evolved into the idea of flexible factories (Upton, 1995; Skinner, 1996) capable of responding quickly to changing environments. Further, the advent of the internet has forced manufacturing to become responsive to customer needs that are communicated in real time (Dewan et al., 2000). Surviving in today’s highly competitive and rapidly changing environments often requires firms to develop strategies that provide the right kind of flexibility to succeed in their specific environments, thus achieving fit between the type of flexibility pursued and the demand placed by the environment. For example, flexible manufacturing can lead to strategic capabilities of ‘surprise’ and ‘speed’ (D’Aveni, 1995) that enable firms to deal successfully with unpredictable and volatile environments.

Several researchers have established that manufacturing flexibility is multi-dimensional and have presented classifications that reflect those dimensions (e.g. Sethi and Sethi, 1990; Koste and Malhotra, 1999; D’souza and Williams, 2000). A review of the literature shows that the idea of fit between specific environmental conditions and particular dimensions of flexibility has been considered to a lesser extent (Gupta and Somers, 1996). We address this gap in the literature via an empirical study of manufacturing firms’ positions with respect to flexibility, their environments, and their performance.

In particular, we focus on dynamic environments and two specific aspects of dynamism, unpredictability and volatility. We also suggest two different flexibility strategies that can be employed to cope with the different aspects of environmental dynamism. Finally, we
demonstrate empirically the association between fit and performance. The specifics of coping with dynamic environments are particularly timely because of well documented trends toward environmentally-induced hypercompetitive conditions (D’Aveni, 1994). Although there is a considerable literature on business responses to hypercompetition, manufacturing strategy consideration of the topic has been largely neglected.

The external environment, as a contextual factor has long been, and remains a subject of interest in management literature (e.g. Pugh and Hickson, 1969; Mintzberg, 1980; Porter, 1980; Miller, 1988; Yasai-Ardekani and Haug, 1997; Joshi and Campbell, 2003; Nahm et al., 2003). Alignment between environment and manufacturing strategy is critical for firms to achieve success (Skinner, 1969; Hayes and Wheelwright, 1984). In an early empirical study of operations strategy, Swamidass and Newell (1987) find support for the impact of the environment and its interaction with manufacturing flexibility, on manufacturing performance. An alternative argument made by Pagell and Krause (1999, 2004) is that manufacturing flexibility is a universal phenomenon in high performance firms regardless of the environment that they operate in. Their view is provocative because it contradicts a vast body of literature that connects flexibility with an environmental imperative. In this paper we seek to reconcile these points of view and present empirical evidence towards this end. We illustrate that better fit between the type of environmental dynamism and type of flexibility pursued is associated with better business performance.

We make three essential conceptual arguments. First, the use of flexibility is one way to cope with dynamic environments, the others being avoidance of uncertainty and buildup of slack (Womack et al., 1990). Second, we argue that flexibility is not free (Jack and Raturi, 2003) and that manufacturers should choose to build flexibility capabilities only if the environment requires
it. Our third argument is that both environment and flexibility are multidimensional, and firms must match the type of flexibility pursued with the nature of environmental dynamism they face. These arguments are based on an extensive literature that we discuss below. Following conceptual development, we illustrate our model empirically and discuss the implications of our findings.

2. Environment-strategy co alignment:

The criticality of fit between external environment and elements of strategy has long been stressed in management literature (e.g. Lawrence and Lorsch, 1967; Bourgeois and Eisenhardt, 1988; Venkatraman and Prescott, 1990a; Child, 1997). The main sources of change in the environment are the market, competitors, technology and regulatory agencies (Duncan, 1972). The strategic effectiveness of an organization depends on fit, which is the compatibility of structures and processes both within the firm, and with the environment in which it operates (Miller, 1992). Describing today’s rapidly changing, unpredictable and complex business environments as “hypercompetitive”, D’Aveni (1994, 1995) suggests a set of managerial tools to cope with such challenging environments. D’Aveni (1995) emphasizes that firms have to choose among these tools on the basis of fit. Thus, the necessity for fit between strategy and environmental characteristics continues to be a major tenet of management thought.

Manufacturing strategy literature suggests that it is similarly critical that manufacturing strategies of firms are suited to the external environments in which they operate (e.g. Skinner, 1969; Leong et al., 1990; Hill, 2000). The necessity of fit of the manufacturing strategy with external environmental factors is supported by empirical research (e.g. Swamidass and Newell, 1987; Eisenhardt and Schoonhoven, 1990; Ward and Duray, 2000). These studies show that various dimensions of the environment cause organizations to react differently. Depending on
the extent and sources of dynamism, firms devise strategies to tackle them in different ways. They might avoid uncertainty by establishing long term contracts, or they might maintain slack resources such as inventory buffers or a capacity cushion, or they might cope with the turbulence by installing flexible manufacturing systems and gearing up for pursuing manufacturing flexibility as a priority.

2.1 Slack as response to environmental dynamism:

Buffers or slack constitute one way to tackle the effects of environmental dynamism (Cyert and March, 1963; Thompson, 1967; Yasai-Ardekani, 1986; Cheng and Kesner, 1997). Bourgeois (1981) argued that contingent upon the requirements of the environment, slack could play a detrimental or beneficial role. Nohria and Gulati (1996, 1997) warned against a total reduction of slack without considering its consequences on investments for the future. The assessment of the costs and benefits of slack highlight a valid argument that can be extended to the study of flexibility in manufacturing. As the environment dictates the amount of slack that firms might maintain, it also affects the type and extent of manufacturing flexibility that is appropriate.

2.2 Volatility and unpredictability aspects of environmental dynamism:

Miller and Friesen (1983) described dynamic environments as consisting of two distinct characteristics, ‘rate of change’ (velocity or volatility) and ‘unpredictability of change’. Using the same characterization Bourgeois and Eisenhardt (1988) identified different features of structural strategies for handling occurrences of high unpredictability and volatility. They noted that highly unpredictable environments warranted organic and flexible structures (Burns and Stalker, 1961; Lawrence and Lorsch, 1967) whereas highly volatile environments called for centralized and mechanistic structures.
Volberda (1996) used a similar classification for hypercompetitive environments (D’Aveni, 1994), describing two characteristics of the environment that he labeled as dynamism and/or complexity, and uncertainty. He also related these environmental characteristics to different methods that would be suitable for attaining organizational flexibility.

2.3 Flexibility as response to dynamic environments:

The success of the Toyota production system and JIT helped bring about a change in the approach to dynamic environments, popularizing the idea of incorporating flexibility in manufacturing systems without sacrificing efficiency. At the same time, flexible automation promised improved capabilities to achieve economies of scope (Goldhar and Jelinek, 1983, 1985) and modular designs enhanced customer responsiveness by facilitating faster product development and assembly (Robertson and Ulrich, 1998). As a result, the strategic approach of manufacturing firms has changed, with a new focus on building capabilities to effectively deal with dynamic environments instead of simply trying to avoid uncertainties. A slack-oriented strategy involves the use of buffers in human and other resources. With the spread of JIT and lean manufacturing, the option of buffers is a less attractive choice for firms, thus necessitating finding ways to achieve manufacturing flexibility.

Following industrial developments, emphasis in academic research has turned to the use of manufacturing flexibility as a response to dynamic environments. Miles and Snow (1978) argued that a proactive approach is required of firms that operate in dynamic environments. Bourgeois (1985) argued against Thompson’s (1967) view that “buffering the technical core” enables firms to deal with environmental dynamism. Bourgeois (1985) empirically demonstrated the pitfalls of such an approach by showing that reducing the need for flexibility by using long-term contracts and buffers would only be beneficial in stable environments. Vokurka and
O’Leary-Kelly (2000) proposed that firms that achieve an appropriate fit between a composite of strategy, organizational attributes, technology and environmental factors, and manufacturing flexibility would exhibit higher levels of performance. Their point was that in order to be of any use, flexibility in manufacturing technology needed to be congruent with both internal and external contextual factors.

Investment in manufacturing flexibility has been assessed using ‘real options’ valuation in place of the traditional Net Present Value (NPV) technique (e.g. Bengtsson, 2001; Amram et al., 2003; MacDougall and Pike, 2003). Researchers incorporated environmental uncertainty by adjusting discounting rates for future cash flows. Their analyses showed that the downside of higher discounting values (uncertainty) could be compensated by the upside created by payoffs from investments in flexible strategies (Kogut and Kulatilaka, 2001). These studies and their results further point out the importance of environmental uncertainty as a correlate for any strategic decisions including those related to the extent and type of manufacturing flexibility.

2.3.1 Flexible technology investments and strategic initiatives:

An increasing number of companies today pursue the ‘flexible factory’ idea that enables them to decrease customer response time, increase product range, and develop new products effortlessly and at efficient costs (Koste and Malhotra, 1999, Boyer and Lewis, 2002). Boyer (1999) noted that the level of investments in flexible automation had increased over time, suggesting an increasing interest in industry in flexibility enhancing technologies. Dean and Snell (1996) did not find a relationship between advanced manufacturing technology (AMT) investment and performance, and they suggested that strategy was the missing link between AMT investments and performance benefits. Upton (1997) presented evidence showing that strategic orientation of managers towards manufacturing flexibility was a significant factor in
making use of flexible technology. Berry and Cooper (1999) and Sawhney and Piper (2002) showed that the alignment of manufacturing strategy in terms of mix flexibility with the requirements of the market was essential to achieving good performance. In short, many studies indicate that strategy is a key element in achieving flexibility even in the presence of investments in flexible automation.

3. Strategic fit in dynamic environments:

The literature discussed above makes the case that there is need for fit between environment and strategic flexibility, and such fit pays off in performance. We add specificity to that general advice. The research model in Figure 1 shows the constructs that we develop empirically. We introduce two dimensions of environmental dynamism that are associated with high velocity or hypercompetitive environments: unpredictability and volatility. We also consider two aspects of strategic flexibility: mobility and range. We will argue below that the interaction effect between these dimensions on performance is a good measure of fit i.e., fit as moderation, (Venkatraman, 1989).

3.1 Environment:

Environment is a multidimensional concept comprised of factors relating to the market, government regulations, technology and location among others. In an empirical study of Aldrich’s (1979) categorization of the environment, Dess and Beard (1984) used factor analysis and extracted three aspects of the environment, which they labeled munificence, dynamism and complexity. Munificence captures the capacity of the industry in comparison to growth in the market. Dynamism covers both stability-instability (unpredictability) and turbulence (volatility).
The complexity factor is comprised of homogeneity-heterogeneity and concentration-dispersion. Subsequent research has used Dess and Beard’s (1984) descriptions of environment, either as is or with some modifications.

The measure of environment that we seek to assess here is dynamism as described by Dess and Beard (1984). Further, following the suggestions of Miller and Friesen (1983), Bourgeois and Eisenhardt (1988) and Volberda (1996), we divide the dynamism scale into unpredictability and volatility, in order to capture these distinct characteristics of dynamism.

3.2 Flexibility:

Several researchers have provided flexibility typologies (e.g. Sethi and Sethi, 1990; Gerwin, 1993). It is difficult to use the different types of flexibility for analyses across different industries because the taxonomies do not capture local nuances of flexibility (Upton, 1994). As a result a capability that signifies “modification” flexibility in one industry might be significant enough to be classified as “new product flexibility” in another. To avoid the pitfalls of such overlapping classifications and selecting from different disaggregating schemes, flexibility can be classified on the basis of its underlying elements of ‘range’ and ‘mobility’ (Upton, 1994; Koste and Malhotra, 1999). Mobility implies the ability to alter production while range suggests the ability to manage product and / or process diversity. Managers who assign importance to mobility are interested in achieving production changes in reaction to the demands of the environment (ease of movement in Slack’s (1987) parlance). On the other hand managers interested in offering a wide range of products need inbuilt capabilities to produce diverse products in reaction to fast paced changes in the environment.

Upton (1994) provides examples and arguments for conditions under which the elements of range and mobility would gain more importance. Using the business situation of a mechanical
seal manufacturer, John Crane U.K. Ltd. as an example (p.82), he demonstrated how changes in technology and in competitors’ strategies forced the company to build capabilities to switch between products and volumes, thus emphasizing the mobility element. On the other hand the ‘customization’ need of the existing customers forced the company to pay attention to the range element and add features to their product. Thus, the range element can also be thought of as a more immediate response to volatile changes, whereas the mobility element represents a relatively longer-term emphasis on maintaining abilities towards changing mix and volume with low transition penalties in response to unpredictable changes.

4. Hypotheses:

Despite the clear connection between environment and manufacturing strategy, most previous research on flexibility strategy has either concentrated on classifications of flexibility, or has focused on one particular type of flexibility and the measurement of its costs and benefits without consideration of context. Although there is general agreement in the literature that different types of flexibility are suited to different environments, there is little research on the specific matching of the aspects of environment and flexibility. On the basis of theoretical support from strategy research and the classification of manufacturing flexibility, we suggest hypotheses regarding the choice of flexibility that will better equip firms that are faced with higher levels of a particular aspect of environmental dynamism.

The question of environmental fit is particularly important in the dynamic environmental conditions faced by many firms that have been described as hypercompetition (D’Aveni, 1994). D’Aveni (1995) suggests two operational elements to cope with hypercompetitive environments: surprise and speed. Surprise deals with creating advantages and stretching the period before they get copied. Speed “disrupts the status quo” and provides temporary advantages against
competitors. Volberda (1996) conceptualized a model to match the flexibility mix of organizations with their environments. In unpredictable environments capabilities must be directed towards non-routine technologies, and providing managers with the authority and resources to innovate in response to unpredictable stimuli. Thus, according to Volberda (1996), ‘adaptive maneuvering capability’ is needed for unpredictable environments. On the other hand, in fast changing but relatively predictable environments, ‘routine maneuvering capability’ would be suitable. In such volatile environments organizations need to build information processing capacities and develop routines to handle possible scenarios. Translating D’Aveni’s (1995) and Volberda’s (1996) propositions to manufacturing strategy, unpredictable environments would necessitate the ability to maneuver capabilities in response to changes, whereas volatile but more predictable environments would warrant maintaining an ability to respond quickly within a broad range of product features and volumes.

In unpredictable environments there are several factors that cause the unpredictability, e.g. market, competitors, technology and government regulations. Incorporating the complete horizon over which each of these constituents of the environment fluctuates would require that capabilities be maintained for a large number of scenarios. This would translate into large amounts of surplus capacity resulting in high costs. Therefore, firms with the capability to allow movement between different product designs, modifications and volumes, instead, are expected to be more successful. Their emphasis would be on systems that allow mobility between different items and volumes rather than on capabilities to handle the complete range of fluctuations efficiently within the same systems.

An appropriate manufacturing strategy for unpredictable environments therefore requires an inherent ability to make changes in manufacturing systems with respect to product features,
variety of products, and volumes. The mobility element of manufacturing flexibility equips firms with the ability to make the required changes while incurring low penalties of time and costs. In unpredictable environments, firms that have manufacturing strategies with an emphasis on mobility-flexibility will achieve better performance than those that do not.

**Hypothesis 1:** Environmental unpredictability has a positive moderating effect on the relationship between managerial emphasis on the mobility element of manufacturing flexibility and performance.

On the other hand, when the pace of change in a firm’s environment is high, it follows that the manufacturing facility and the supporting infrastructure must be prepared to provide a wide variety of products and volumes without requiring changes to the systems. A suitable flexibility strategy for such environments must be aimed at maintaining a manufacturing system that can handle different products and volumes. In such volatile environments there is simply no time to make any changes to the system and therefore the inbuilt capability of providing a wider range is valuable. In volatile environments firms that have manufacturing strategies with an emphasis on range-flexibility will achieve better performance.

**Hypothesis 2:** Environmental volatility has a positive moderating effect on the relationship between managerial emphasis on the range element of manufacturing flexibility and performance.

The hypotheses stated above broadly follow from the conceptual model shown in Figure 1. Our specific hypotheses are with respect to fit, which we define in terms of moderation and define operationally as the interaction between mobility and unpredictability, and between range and volatility. The expected positive signs of these coefficients are attributed to fit.
5. Data and scales:

5.1 Data:

Data for the study were obtained from a survey of U.S. manufacturing firms conducted in 1994 (Ward et al., 1994; Ward and Duray, 2000). The primary product of these businesses is in one of three sectors: fabricated metal products, electrical devices and electronic controls (SIC codes 34, 36 and 38). Both privately and publicly owned firms were included in the sample. The unit of analysis was the plant to which the survey was mailed. Only businesses with more than 150 employees at the location were included in the sample. Initial contact was made by telephone to identify the top executive on location and to request their participation. Upon consent, they were requested to provide names and addresses of three executives: (i) plant manager, (ii) marketing manager, and (iii) manufacturing manager / engineer.

Four different forms were mailed to each firm. Each question in the survey was put to two respondents at each plant. The response rate achieved with 101 usable responses consisting of two responses to each question was 37%. Sales volume and number of employees for non-respondent firms were compared industry-wise with those of the respondent firms. Non-significant t tests confirmed that the non-respondent firms did not differ substantially from firms that did respond to the survey; this helped rule out non-respondent bias. Post survey telephone calls revealed that lack of time and the possibility of revealing proprietary information were the most common reasons for non-participation. Similar reasons for non-response have been reported in earlier empirical studies (Vickery et al., 1993; Miller and Roth, 1994).

The survey was designed to elicit paired responses. Significant correlation coefficients (listed in table 4) at $a = 0.01$ between responses from two independent raters provided evidence of inter-rater reliability and assured against single-rater bias. Inter-rater correlation coefficients
for two single-item performance measures were also significant \( p < 0.001 \) and measured 0.76 for Market Share and 0.59 for Sales Growth. The scores on each question were then averaged over the two responses for subsequent analyses. Responses to some questions were missing for nine of the respondents. Because deleting these cases listwise would lead to discarding valuable information, we imputed the missing values using regression (Little and Rubin, 1987).

5.2 Scales:

Bourgeois (1980) argued that perceived environmental dynamism is conceptually relevant to strategy, because it is based on managers’ perceptions that they make strategic decisions. In this study we use perceptual measures of the environment. Several of the previous studies that used perceptions to measure environment combined it into one measure. Here we seek to distill two different conceptual characteristics of environmental dynamism in managers’ perceptions. The first dimension of the environment is the unpredictability of change in the different elements that constitute the external environment: market, product and technology innovations, and labor. The second environmental measure of volatility is aimed at capturing velocity of change and is based on Miller and Friesen’s (1983) division of the dynamism dimension. Volatility is described as the degree of instability in the various factors that constitute the firm’s environment. The volatility scale therefore asks managers to indicate the rate of change in the different factors that constitute the environment.

We constructed scales to assess plants’ flexibility on the basis of the two underlying elements of mobility and range. The items in the scales address the strategic orientation of the plants on the two elements. The mobility items captured the importance assigned to making transitions in volumes and design. The range items were aimed at capturing the product variety and features that a plant is geared to offer. Items used in the scales are shown in the appendix.
5.3 Validity and reliability:

Content validity was assessed on the basis of previous literature as described in the development of the constructs in the preceding paragraphs. The literature review for each of the constructs, and previous instances of the use of similar scales provide proof of the validity of the items comprising the scales. An assessment of the propensity for flexibility is appropriate to gauge the strategic emphasis placed on flexibility (Dixon, 1992; Koste and Malhotra, 1999). Following previous research on manufacturing capabilities (Ferdows et al., 1986; Boyer et al., 1997) and on flexibility in particular (Kathuria and Partovi, 1999) our scales asked respondents to rate the degree of emphasis placed in their plant on different aspects of manufacturing flexibility.

Performance was measured using two single item perceptual measures, market share and sales growth. Business performance measures are often used in the literature to assess the effects of manufacturing strategy elements (e.g. Swamidass and Newell, 1987; Boyer et al., 1997; Nahm et al., 2003; Rosenzweig and Roth, Forthcoming). Venkatraman and Prescott (1990b) pointed out that different performance measures are appropriate for firms operating under different environmental conditions. In highly concentrated and slow growth industries market share is an appropriate measure of business growth (Schendel and Patton, 1978) whereas in fragmented industries, sales growth is an appropriate indicator. Firms that are start-ups and/or are operating in a developing industry may have sales growth but might not have achieved high market share. Older firms and/or firms in mature industries will find it harder to maintain growth in sales, and might perform well in terms of market share. The survey instrument also asked for information on objective performance measures, which less than half of the respondents provided. Managers are reluctant to provide these data due to concerns about revealing confidential information.
Correlations between objective and perceptual performance measures were found to be significant (p < 0.01) using a method similar to that described in Vickery et al. (1993).

Following a methodology suggested by Ahire and Devaraj (2001) and Flynn et al. (1999), we conducted statistical tests to assess the construct validity of the four scales used to measure the environment and flexibility constructs. Confirmatory factor analysis (CFA) using maximum likelihood estimation was conducted to assess convergent validity of the constructs. The hypothesized model of relationships between scale items and latent variables, shown in Figure 2, was estimated as a structural equation model (SEM) using the RAMONA module in SYSTAT (2002). The availability of goodness-of-fit measures in SEM makes it an appropriate technique for assessing scale validity. Correlations among all the scale items used for the CFA as well as for the two single-item performance measures are shown in Table 1. The CFA was conducted using the model depicted in Figure 2.

Inserted Table 1 here
Inserted Figure 2 here

The fit measures obtained are reported in Table 2. The Chi-squared, adjusted for degrees of freedom, was below the suggested maximum of 3 (Carmines and McIver, 1981), the root-mean-square error of approximation (RMSEA) of 0.09 was less than 0.10 indicating mediocre fit (MacCallum et al., 1996), and the non-normed fit index (NNFI) of 0.94 passed the recommended rule of thumb of 0.9 (Bentler and Bonett, 1980). The comparative fit index (CFI) of 0.89 was close to the recommended cutoff of 0.90 (Bentler and Bonett, 1980). All the items had significant factor loadings (p<0.01) (Table 3) although the unpredictability construct had two
loadings (UNP1: 0.40 and UNP4: 0.39) that were less than the rule-of-thumb weight of 0.50. Overall the CFA provided adequate support for the existence of convergent validity of the constructs.

Within-scale principal component analyses (PCA) was also conducted for each of the scales and resulted in eigen values greater than 1 and factor loadings greater than 0.40 on a single factor for each of the constructs, providing support for unidimensionality (Hair et al., 1998). Ahire and Devaraj (2001) suggest that such a within scale PCA also provides additional evidence of convergent validity.

Cronbach’s alpha reliability coefficients (Nunally and Bernstein, 1994) for each of the scales on environment and manufacturing flexibility were calculated (see Table 4). All the scales, except one, had alpha values above the generally accepted rule of thumb of 0.70 for previously used scales. The unpredictability scale had an alpha of 0.59. We constructed this scale on the basis of its definition and operationalization provided by previous researchers, mainly Bourgeois and Eisenhardt (1988). We did not find any multi-item scales in the literature for perceptual measurement of this dimension; therefore, we decided to retain the scale, as constructed, because the composition of the scale was supported by its earlier definitions. Moreover, the Cronbach’s alpha coefficient for the scale was close to the cutoff point of 0.60 recommended for new scales (Nunally and Bernstein, 1994).
Divergent validity or the ability of the scales to discriminate between the different constructs being measured was confirmed using three tests (Flynn et al., 1999; Ahire and Devaraj, 2001). Referring to Table 4 the Cronbach’s alpha coefficients for the scales were greater than their correlations with other scales. The average item to total correlations with items not in the scales were substantially lower than the average item to total correlations with items within the respective scales. Finally the percentage variance extracted using within scale PCAs were greater than the squared interscale correlation for each of the scales. Correlations among the summated scales are shown in Table 5.

6. Analysis and results:

Both our hypotheses state that the impact of a causal variable, manufacturing flexibility strategy, on a dependent variable, performance, is dependent on the level of a third variable, the environment. Venkatraman (1989) described such a perspective of fit as ‘moderation’ and discussed the use of moderated regression analysis as one of the methods for assessing the level of moderation. In the case of analyses with two predictors, a multiplicative term consisting of the product of the ‘moderator’ variable and the ‘causal’ variable can be used to analyze the strength of moderation in the relationship (Baron and Kenny, 1986). A moderation hypothesis is supported if the coefficient for the interaction term is found to be significant.

We used hierarchical regression analysis (Cohen et al., 2003) to test the hypothesized moderating effect of environment on the relation between flexibility and performance. For each
measure of performance, market share and sales growth, hierarchical regression equations were estimated. Predictors were entered into the regression equation in three steps: environmental unpredictability and volatility were entered first, manufacturing flexibility-mobility and range were then added, and finally multiplicative interaction terms, i.e. cross products of unpredictability and mobility, and volatility and range were entered.

The incremental F statistics and the t tests for the coefficients of the interaction terms provide indications of the strength of the interactions as predictors of performance. Such variance partitioning procedures are commonly used to assess the incremental effects of interactions and to study fit as moderation (e.g. Miller and Dröge, 1986; Dean and Snell, 1991; Boyer et al., 1997; Tatikonda and Montoya-Weiss., 2001).

Aiken and West (1991, p. 35) recommend centering the variables (subtracting the means) to ameliorate multicollinearity caused by multiplicative interaction terms. Deviation scores were computed for each of the independent variables (IVs), and these recoded IVs were also used to compute the multiplicative interaction terms. The variance inflation factors (VIFs) in all the regressions were found to be acceptable at just over 1.0 (Hair et al., 1998). Table 6 shows the results for the two hierarchical regressions with market share and sales growth as dependent variables.

6.1 Environment unpredictability and mobility-flexibility:

6.1.1 Market Share:

In the first model (1a in Table 6), unpredictability was negatively associated with market share (p < 0.01). The addition of the manufacturing flexibility variables in the second model (1b:
Table 6) did not result in a significant increase in variance explained; the change in $R^2$ was not significant. The coefficient for the mobility term was non significant, thus no impact is attributed to mobility alone. Entering the interaction terms in the final model (1c: Table 6) resulted in a significant increase in the variance explained (total $R^2 = 0.18$) with a significant F change ($p < 0.05$). The positive coefficient for the interaction term of unpredictability and mobility was significant ($p < 0.05$) and the overall F statistic for model 1c (Table 6) was significant ($p < 0.01$).

This indicates that mobility’s effect on market share performance is moderated by environmental unpredictability. In essence, the incremental explanatory power achieved by adding the interaction term to the model can be attributed to “fit”, or more specifically, fit as moderation (Venkatraman, 1989). As predicted, the performance effect of a mobility-flexibility strategy is enhanced as unpredictability increases. The fact that there is no significant main effect of mobility on market share for mobility makes this an instance of “pure moderation” (Sharma et al., 1981).

6.1.2 Sales Growth:

For the second set of regressions predicting sales growth, the results were similar. In the first model (2a: Table 6), unpredictability had a significant negative effect on sales growth ($p < 0.01$) and explained 9% of the variance ($p < 0.01$). In this instance, the addition of the two terms for manufacturing flexibility as predictors in the second model (2b: Table 6) resulted in a significant increase in the variance explained to 17% ($p < 0.01$ for the regression and $p < 0.05$ for the step change in $R^2$) and a significant positive coefficient for mobility ($p < 0.05$). Further, the addition of the interaction terms (Model 2c: Table 6) significantly increased the variance explained to 29% ($p < 0.01$ for the overall regression and also for the $R^2$ change) with a
significant positive coefficient for the interaction between unpredictability and mobility
(p < 0.05). For sales growth, unpredictability partially moderated the effect of mobility on
performance because the main effect of mobility in the second model (2b: Table 6) was
significant (p < 0.05).

Thus, for both performance variables, increased unpredictability is associated with an
increased effect of a mobility-flexibility strategy on performance, as predicted in Figure 1.
These results provide evidence in support of the first hypothesis regarding the moderating effect
of environmental unpredictability on the relationship between mobility in the manufacturing
strategy, and performance. The positive and significant coefficients for the interaction terms in
both regressions indicate that when the environment is characterized by unpredictability, the
implementation of mobility in manufacturing strategy results in performance benefits. In
addition, significant increases in the variance explained when the interaction terms are added
indicate that there is a moderating effect of unpredictability on the mobility-performance
relationship. These significant positive interaction terms indicate fit between environment and
flexibility strategy appears to “pay off” in performance.

6.2 Environment volatility and range-flexibility:

Table 6 also shows the results for tests of the second hypothesis that proposes a
moderating effect of environmental volatility on the relationship between range-flexibility and
performance. Volatility alone was not a significant predictor of either market share or sales
growth (Models 1a and 2a: Table 6). Range-flexibility was a significant predictor of market
share in model 1b (p < 0.10). For sales growth (Model 2b: Table 6) the main effect of range-
flexibility was not significant. The interaction of volatility and range, however, had a significant
positive relationship with both market share and sales growth (p < 0.05 and p < 0.01; Models 1c and 2c: Table 6 respectively).

These results indicate that there is significant positive interaction effect and that the interactions explain a significant amount of incremental variance. Results support the existence of a pure moderation effect of environmental volatility in the relationship between range-flexibility and sales growth (Models 2b and 2c: Table 6) while in the case of market share the relationship is characterized as partial moderation (Models 1b and 1c: Table 6). Again, these results show that fit between environment and flexibility strategy relates to business performance.

In order to confirm the nature of the environment – flexibility interactions we split the sample at the medians of the two environment constructs, one at a time, and regressed the performance variables on flexibility measures (i.e. dividing the sample at the median of volatility and using range flexibility to predict market share and performance; the same analyses was repeated for unpredictability and mobility). The four interactions are graphically depicted in Figure 3.

As evident in three of the four graphs in Figure 3, the split sample regressions were significant for higher levels of dynamism and non-significant for lower levels. For the equations predicting market share from mobility, regressions were non-significant at both levels of unpredictability. All eight split sample regressions were estimated using small sub samples of about 50 observations and we believe that a larger sample size would enable us to present stronger empirical evidence for our theoretical propositions.
We also tested additional regression models by including all possible two-way interaction terms (adding multiplicative terms for [unpredictability * range] and [volatility * mobility]). The addition of these terms did not explain a significant amount of additional variance in either performance measure and the coefficients for the additional interaction terms were not significant. These results confirm that the significant unpredictability-mobility and volatility-range interactions truly reflect the hypothesized effects.

7. Discussion:

Hill (2000) posits that the pursuit of process flexibility is often the result of the inability of managers to decide among alternatives. According to Hill, the use of flexible processes to cope with doubt about what the future holds “(are) tantamount to strategic cop-outs” (2000, p. 142). Similarly, Upton (1994) points out that blind pursuit of advantage through “flexible” automation is fallacious. What these authors, among others, are arguing is that the pursuit of flexibility in itself does not lead to advantage. In general, management literature is fairly clear: flexibility is one capability that managers can develop to cope with a dynamic environment in which the behaviors of customers, suppliers, or competitors are difficult to predict (e.g., Bourgeois, 1985). In addition, the management literature describes a number of well-developed dimensions of environment that describe different possible modes of variation (e.g., D’Aveni, 1994). Further, operations scholars have classified the ways in which manufacturing can be flexible (e.g., Gerwin, 1993).

What has been largely missing is practical advice on which types of flexibility best fit with the various dimensions of environmental flux that companies face. Further, development of empirical evidence of the value of such fit has also been neglected. We have begun to address the issue of fit between the type of environmental conditions faced by the firm and the
manufacturing flexibility approach that will best help the firm to cope with those conditions in three ways. First, based on a diverse literature, we argue that environmental fit is a key variable in explaining business benefits achieved from any approach to flexibility. Second, to illustrate our argument, we develop operational definitions for two specific dimensions of environmental dynamism, unpredictability and volatility, and two types of flexibility approaches, mobility and range. Third, we develop and test hypotheses about the importance of environmental fit in moderating the relationship between flexibility and business performance. In so doing, we provide evidence that fit does indeed explain a significant amount of variance in performance. In fact, in three out of four cases, fit as measured by moderation appears to account for more variance than flexibility itself.

7.1 Managerial implications

Hill’s (2000) cautionary words about the seeming failed promise of flexible processes and Upton’s (1994) somewhat more general observation about the lack of success by companies in achieving desired flexibility may be explained in part by poor fit between the type of approach to flexibility and environmental conditions that a company is facing. Environmental dynamism is generally revealed to manufacturing only when actual orders do not conform to expectations and the specific dimensions of dynamism are not usually obvious.

Imagine, for example, a firm faced with coping with one sort of dynamic environment that we have described earlier. Actual orders are vastly different from scheduled and the sales force can provide little guidance about what orders will be next month. The only answers might seem to be either to maximize flexibility through investments in equipment and people or to avoid the issue by outsourcing as much manufacturing as possible.
However, further analysis may show that the company faces an environment that is indeed dynamic, but that the dynamism is mostly restricted to a range of reasonably familiar products. Changes in product design and improvements in functionality may be frequent in the industry but the changes are mostly incremental rather than revolutionary. Similarly, there may be season-to-season or year-to-year fluctuations in demand volume. Thus unpredictability regarding mix, detailed design, and volume prevails but there is less unpredictability about the essence of the products sold. We have described such a dynamic environment as volatile (but not unpredictable).

In coping with such an environment, neither large investments in flexible automation nor abandoning manufacturing in favor of out-sourcing are necessarily good solutions. Volume fluctuations may obviate the possibility of sufficient projected cash flow to justify the capital investment implied by flexible automation. Extensive out-sourcing can be a problem because when demand is high, out-sourced capacity often is at a premium and prices charged by suppliers may be generally higher than internal costs would be.

More likely, in the case of volatile environment described here, the kind of flexibility that would be most helpful would be fast-reaction type flexibility that would include the ability to make rapid, low-cost changeovers; the ability to adjust capacity incrementally; and the ability to quickly launch products with incremental changes within certain parameters in response to market needs. We refer to this approach to flexibility as range flexibility. It is interesting to note that the essentials of lean manufacturing (Womack et al., 1990) provide a well-established route to achieving range flexibility.

On the other hand, we might imagine a situation in which managers are faced with a dynamic environment that seems similar to the situation described above, but where the
dimensions are quite different. Management finds that the environment is truly unpredictable and forecasts are no more than wild guesses. In such an environment the dominant design for the product market is really in flux, design changes are often discontinuous, and the possibilities for customers’ preferences are numerous. Similarly, new processes and or materials might be emerging with no clear indication of which will win out (Abernathy and Utterback, 1975).

In this instance, environmental changes are dramatic. Manufacturers need to be able to react to such environmental changes by making major adjustments in response to the marketplace and finding ways to execute products to fulfill customer demand. We have characterized this sort of dynamic environment as unpredictable and argued that the appropriate response is mobility flexibility that allows companies to alter the use of their facilities and change their product offerings.

Achieving such mobility flexibility probably will require being able to outsource key components and to forge supply chain partnerships with other companies that face similar unpredictabilities. More important, a firm facing such an environment needs to develop capabilities for scanning the environment for cues about what will happen, thus allowing actions that may preempt rivals (Stoffels, 1994; Yasai-Ardekani and Nystrom, 1996). Once the market equilibrates, the manufacturer will be challenged to build other sorts of capabilities to win in the new marketplace.

The point of these illustrations is that two different dimensions of environmental dynamism can suggest very different responses in terms of approaches to flexibility. The fit between environment and flexibility is not necessarily obvious but our evidence indicates that fit explains a significant portion of the observed performance differences. An effective flexibility
strategy requires that managers discern the specific environmental challenges faced by their business and choose an approach to flexibility that fits the challenge.

7.2 Theoretical implications

In addressing the issue of fit and flexibility we bring together insights from a large management literature related to describing environmental conditions and requisite coping mechanisms with a more specific literature on manufacturing flexibility. We buttress our arguments by developing two distinct dimensions of environmental dynamism and suggesting a form of flexibility that fits with each. We then demonstrate empirically that these two instances of environmental fit with flexibility are associated with better business performance.

The major theoretical implication of our research for theory in operations is simply that fit between environmental conditions and flexibility strategy matters with respect to business performance. Although research in operations has been rich in identifying flexibility types, theory on how specific types of flexibility are useful in coping with various aspects of the external environment has been largely lacking.

Although our research begins to tackle the issue of environmental fit and flexibility, a number of outstanding research issues remain. Three issues seem particularly salient. First, there is a need for a broader theoretical map of dimensions of environmental conditions and the types of flexibility that appear to fit with those conditions. We began the process by working with two dimensions of environmental dynamism (unpredictability and volatility) that we considered quite important, especially during times in which hyper-competition is under discussion. Many other environmental dimensions are identified in the literature, however (e.g. Dess and Beard, 1984). In particular, developing ideas about various dimensions of
environmental complexity and munificence (or hostility) and their fit with specific flexibility approaches seems particularly worthwhile.

A second issue is the very nature of fit. We chose to use fit as moderation because moderation is often used in assessing environmental fit in the literature. There are a number of other approaches that can be taken to assess the fit between environment and flexibility such as mediation, matching, gestalt, etc. Venkatraman (1989) provides a useful survey of types of fit and suggests appropriate operational methods for each type.

A third issue revolves around how to build capabilities that correspond to each type of flexibility that is identified as important. Some practitioners and researchers appear to consider computer-automated technologies to be synonymous with flexibility. However, such ideas are convincingly dashed on the rocks of data provided by Upton (1994) and Boyer et al. (1997) that show that other, infrastructural elements are required to achieve flexibility. Existing typologies that define multiple dimensions of manufacturing flexibility need to be fleshed out to show how each type of flexibility can be achieved in practice.

7.3 Limitations:

It is important to view our statistical results in context of certain limitations that arise mainly from the use of perceptual scales. First, our scales for flexibility measure “importance” assigned by respondents to different aspects of manufacturing flexibility. In relating importance measures of manufacturing flexibility to business performance we make the assumption that the two are closely related, although this might not be true – managers who consider manufacturing flexibility to be important might not necessarily implement it to a corresponding degree. Strategic importance thus needs to be combined with realization of flexibility (Voss and Winch, 1996), and including both aspects (emphasis and implementation) is necessary for
comprehensive assessment of the relationship between flexibility and performance. This is a limitation in our research especially in the light Boyer’s (1998) empirical result that emphasis on flexibility was not related to implementations in his sample. Further, our scales measure the elements of mobility and range without distinguishing between the different dimensions over which manufacturing flexibility can be measured e.g. machine, labor, material handling, mix etc. (Koste et al., 2004). The aggregate scales we use mainly assess product-related flexibility. We do not capture other types of flexibility like process and changeover flexibility. We look forward to future research incorporating such richer constructs for manufacturing flexibility and studying their relationships with environment using a larger sample that would be needed for such a study.

Second, although the use of perceptual scales for environment is common and has been validated in business strategy literature, we did not find any instances of such scales for the unpredictability and volatility aspects of dynamism. The scale for environmental unpredictability had a low Cronbach’s alpha coefficient of 0.59, which is below the threshold suggested for new scales (0.60). It would be useful to develop a scale for this construct with higher internal reliability. Our scales are based on theoretical reasoning and would benefit from replications in further research.

Third, although we had some theoretical justification for estimating regressions using each of the two performance variables separately, the high correlation between the two measures seemed to indicate that these were indicators of a common variable. The regression results need to be interpreted with this drawback in mind. Caveats of the limited sample size and the period of data collection must also be kept in mind while deriving managerial implications from the results.
7.4 Conclusion:

Our study shows that in addition to making investments in flexibility capabilities, managers need to be wary of the state of the environment that they operate in, and its multiple elements (e.g., unpredictability and volatility), and to accordingly match the types of flexibility required by their firm. The results obtained from our analysis support and extend the findings of Boyer et al. (1997) who found that infrastructural elements are crucial in deriving performance benefits from investments in advanced manufacturing technologies (AMTs). The vast body of previous research discussed in our literature review supports the idea that environmental factors are related to building suitable infrastructures.

Our results show that the environment plays a crucial role in determining the types of flexibility strategies that would be suitable. Although the variance explained in the regression analyses was modest (18 and 29 percent), the models do demonstrate that fit is both significant and primary in explaining performance differences in the context of flexibility strategy. The addition of other elements of competitive strategy and contextual factors such as organizational structure and technology investments in explaining performance can be explored in further research and will probably increase the explanatory power of the models. More important, however, is to recognize the importance of environmental fit when considering flexibility.
References


SYSTAT (2002), Copyright: *SYSTAT Software Inc.*, http://www.systat.com


# Table 1
Correlations between scale items

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*p < 0.01, **p < 0.05
Table 2
Goodness-of-fit statistics for CFA

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CFA Parameter Estimates and Descriptive Statistics for Summated Scales

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n=101. All factor loadings significant at p<0.01
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<th>Range</th>
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*** p < 0.01
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*p* < 0.01
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Regression results

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<th>DV: Sales Growth</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1a</td>
<td>1b</td>
</tr>
<tr>
<td><strong>Environment:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unpredictability</td>
<td>-0.26**</td>
<td>-0.22**</td>
</tr>
<tr>
<td>Volatility</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Flexibility:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobility</td>
<td>-0.15</td>
<td>-0.18</td>
</tr>
<tr>
<td>Range</td>
<td>0.21*</td>
<td>0.25**</td>
</tr>
<tr>
<td><strong>Interaction terms:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNP * MOB</td>
<td></td>
<td>0.21**</td>
</tr>
<tr>
<td>VOL * RNG</td>
<td></td>
<td>0.21**</td>
</tr>
<tr>
<td><strong>F for the change:</strong></td>
<td>3.68**</td>
<td>2.06</td>
</tr>
<tr>
<td><strong>F for the regression:</strong></td>
<td>3.68**</td>
<td>2.91**</td>
</tr>
<tr>
<td>R2</td>
<td>0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>Adjusted R2</td>
<td>0.05</td>
<td>0.07</td>
</tr>
</tbody>
</table>

n=101, ***Significant at p<0.01, **Significant at p<0.05, *Significant at p<0.10
Figure 1. The moderating effect of environmental dynamism on the relationship between manufacturing flexibility and business performance
Figure 2. Hypothesized SEM for CFA
Interaction between Volatility and Range predicting Market Share

Interaction between Volatility and Range predicting Sales Growth

Interaction between Unpredictability and Mobility predicting Market Share

Interaction between Unpredictability & Mobility predicting Sales Growth

Figure 3. Interaction graphs
Appendix

Scales

**Environment Dynamism:**

Unpredictability:
How would you rate the predictability of the following?
*(Reverse coded such that higher scores indicate more unpredictability)*

<table>
<thead>
<tr>
<th></th>
<th>Un-Predictable</th>
<th>Highly Predictable</th>
<th>N/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Business unit upswings and downswings</td>
<td>1 2 3 4 5 6 7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>2. Rate of product innovation in your industry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Rate of innovation in operating processes in your industry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Business unit labor relations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Volatility:
Indicate the rate of change for the following

<table>
<thead>
<tr>
<th></th>
<th>Slow</th>
<th>Rapid</th>
<th>N/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The rate at which your products and services become outdated</td>
<td>1 2 3 4 5 6 7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>2. The rate of innovation of new products and services</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The rate of innovation of new operating processes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. The tastes and preferences of customers in your industry</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Flexibility:**

For your manufacturing plant how important is the ability to:

<table>
<thead>
<tr>
<th></th>
<th>No Importance</th>
<th>Very Important</th>
<th>Absolutely Critical</th>
<th>N/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. make rapid design changes</td>
<td>1 2 3 4 5 6 7</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. adjust capacity quickly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. make rapid volume changes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Range:

4. offer a large number of diverse product features
5. offer a large degree of product variety
6. adjust product mix
Performance:

Compared to your competitors, indicate your position on the following dimensions.

<table>
<thead>
<tr>
<th>Significantly Lower</th>
<th>Significantly Equal</th>
<th>Significantly Higher</th>
<th>N/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

- Market share
- Sales growth