Creating a Volume Flexible Firm

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Executive Summary

Volume flexibility is an important but not very well understood concept that allows a firm to leverage its scarce resources for optimal utilization with upswings and downswings in business. Our research using 3 different research methods suggests that the key problems in developing a volume flexible response are related to: the inability of firms to define and measure volume flexibility capability and the unavailability of a methodology that allows the firm to zero in on the appropriate volume flexibility responses. In this paper we define what volume flexibility is and give examples of ways by which firms can become more volume flexible. We identify the strategic payoffs derived from developing volume flexible responses as well as identify the key factors that allow a firm to identify when it needs greater flexibility in adjusting output levels. Finally we present a framework that allows managers in firms to deploy a volume flexible response – this includes identifying key variables that create a need for a volume flexible response, choosing tactics that leverage the firm's key strengths for generating this response, and auditing on an ongoing basis the effectiveness of the adopted approach.

1.0 Introduction

It is difficult to open a business newspaper or periodical today and not find something related to downsizing, retrenchment, explosive growth, or wide deviations from quarterly forecasts of publicly traded firms. On February 5, 2001, Fortune magazine boasts on its cover "How to manage for the slowdown". The January 2001 issue of Entrepreneur advises on how not to be a "Dot-Bomb". Table 1 summarizes other articles over the last two months that, in some way, suggest that it is normal for firms to be unprepared for the swings in the economy, Christmas rush, or even outbreaks of epidemics such as flu.

Table 1: Recent Press Articles on Issues Related to Volume Flexibility

News Item	***Source***	***Date***
Reduction in backlog of orders means next day source for Dublin customers	The Wall Street Journal	Nov 2, 2000
Flexible production is planned at Chrysler	Financial Times	Nov 24, 2000
Chrysler moves to cut inventory	The Associated Press	Dec 2, 2000
Detroit tightens belt as unit sales drift lower	Financial Times	Dec 4, 2000
Airlines cancel flights as pilots decline overtime	Cincinnati Enquirer	Dec 6, 2000
Deliveries of faster chips could be delayed	Financial Times	Dec 6, 2000
Hospitals plan for flu attack	Cincinnati Enquirer	Dec 8, 2000
Frustration over late deliveries	Financial Times	Dec 8, 2000
GM joins rivals in inventory cutback	Cincinnati Enquirer	Dec 8, 2000
How to be present and correct for the high Christmas surge	Financial Times	Dec 10, 2000
Timely delivery a vital key to on-line retail success	Financial Times	Dec 12, 2000
Frustration over late deliveries	Financial Times	Dec 12, 2000
Delta denied injunction against pilots	The Associated Press	Dec 12, 2000
Business gives careers a break: Companies are starting to see the benefits of flexible policies for employees who look after elderly relatives	Financial Times	Dec 12, 2000
GM idles four plants	The Associated Press	Dec 24, 2000
Accounting firm find flextime success	Cincinnati Enquirer	Dec 25, 2000
Microsoft ruling shows they must give benefits to perma-temps	The Dallas Morning News	Dec 25, 2000

At the heart of all these stories is the managerial nightmare called demand variability. It is difficult for firms to forecast demand for new products and services and even for existing ones given the socio-economic uncertainties underlying consumers' purchase decisions. The reality of uncertain demand is never going to disappear – and containment strategies that buffer the firm from such vagaries have often been written about.[1] These containment strategies have two different perspectives. First, a firm may respond to uncertain demand by using "buffers". Slack capacity and inventory are two kinds of buffers that are frequently deployed in the manufacturing sector. Alternatively, a firm may develop capabilities in the firm's resources and infrastructure to deploy a volume flexible response to the demand uncertainties.

Volume flexibility is defined as the ability of an organization to change volume levels in response to changing socio-economic conditions profitably and with minimal disruptions. Firms deploy varying strategies for creating volume flexible responses – these include using overtime and temporary workers, cross training workers, developing complementary product portfolios, improving forecasting and planning systems as well as leveraging the firm's ability to negotiate on volume with suppliers and customers. While it can be argued that firms make these choices for a variety of reasons, from a volume flexibility perspective, it is not clear how such choices should be made and what benefits do they generate given the different kinds of needs and capabilities that a firm may have. In this paper we try to answer three basic questions:

(1) What is the strategic value of volume flexibility and why do firms need it?
(2) How do firms become more volume flexible given constraints on the level of buffers that they can deploy effectively?
(3) Are there any specific insights into the nature of volume flexible response and choices made by a firm contingent on its pre-existing conditions?

We rely on four sources of research for making our conclusions in this study. First, we rely on existing research to develop a contingency model for developing a volume flexibility strategy. Second, we rely on in-depth case studies in three firms that allow us to map and refine this approach by exhaustively evaluating the alternative sources of volume flexibility. Third, we rely on a survey of 140 managers who are primarily responsible for developing systems and infrastructure for generating a volume flexible response. In our survey we gauge the effectiveness of alternative sources of volume flexibility. Finally, using 20 years of Compustat data on 550 firms in 29 capital goods industries, we test the effectiveness of alternative sources by developing concrete measures of volume flexibility and relating it to firm performance.[2]

The following case illustrates the situation in a typical manufacturing firm:

Case: Baldwin Piano and Organ Company

At the Baldwin Piano and organ Company, the variation in forecasts is predictable (e.g. seasonality) or unpredictable (e.g. Asian crisis in 1998). As such, the operational challenge of responding to such variation requires different kinds of volume flexibility. Inventory buffers can easily

accommodate the predictable seasonal variations but unpredictable variations require capability to do overtime, reallocate resources quickly, develop supplier capability to respond to volume changes, and other innovative ways to become volume flexible. The manufacturing plant has sufficient mix flexibility but little or no volume flexibility. There are several reasons for this. First, the skilled workforce required for the task cannot be hired at will. Second, training times are substantial (12-18 months at the minimum). Third, overtime policies limit incremental resource acquisition should a crisis occur. Also, the consolidation of manufacturing from two plants to one may have exaggerated the problem somewhat: the single plant provides fewer production options. The top management is interested in assessing the need for volume flexibility in their industry, what is the competitive leverage provided from it, and ways by which volume flexibility can be increased in their plant, e.g. innovative shift scheduling, overtime policy etc.

The Baldwin Piano example highlights the dynamic challenges that firms face in developing a volume flexibility strategy. Environmental uncertainty leads to fluctuating output levels, and firms are challenged towards the efficient use of resources to respond to these uncertainties. While small firms (with smaller overhead cost and less bureaucratic decision-making) may be more efficient at responding to these challenges, arguably they are unable to significantly fluctuate their output levels because of both financial and physical resource limitations. On the other hand, many large firms want to clone the processes of small firms and rid themselves of non-value added and bureaucratic hurdles in order to become more responsive to customer needs. At the same time, large firms may have an inherent economy of scale and scope advantages because they can afford larger inventory stockpiles, they can dictate responsiveness from suppliers, and they can hire more easily in tight labor markets. However, at the heart of these deliberations in many manufacturing firms lie unanswered questions about volume flexibility: What is it? How do we measure it? Does it impact the bottom line? And if so, how?

The rest of this paper is organized as follows. In section 2 we evaluate the key reasons why firms need to be concerned about a volume flexible response. In section 3 we outline the main sources of volume flexibility as well as address critical questions related measuring current needs and abilities as well as deploying alternative strategies depending on the gap between existing needs and abilities. In section 4 we further refine this contingency model to suggest that on an aggregate there are four basic alternatives for every firm: in dealing with demand uncertainties, they can contain the uncertainty, mitigate it, absorb it or remove it from their environment. We conclude with key conclusions about volume flexibility, its effect on firm performance and a strategic response system that should be deployed in firms facing the dilemma of how to deal with demand uncertainty.

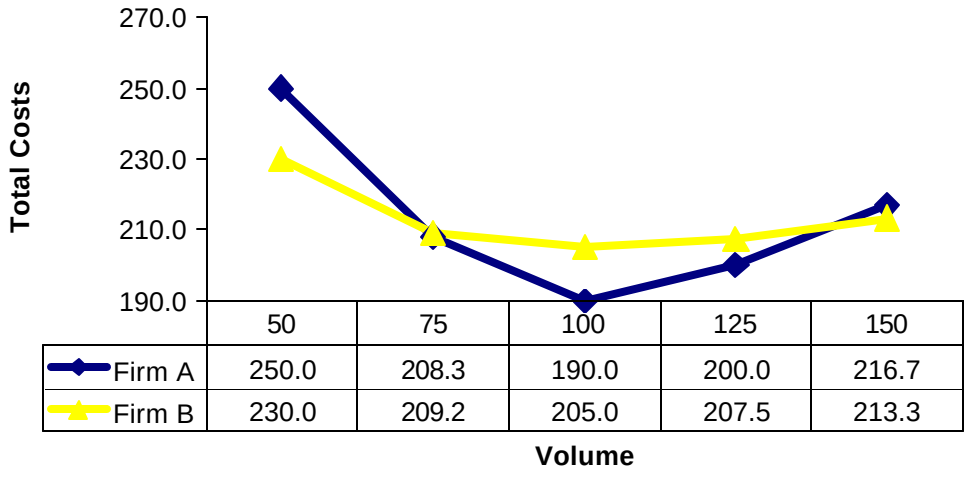
2.0 Why do firms need volume flexibility?

Flexibility is easy to define but hard to measure.[3] Researchers have identified 11 different types or dimensions of flexibility.[4] In this paper we focus exclusively on volume flexibility. Most definitions of volume flexibility of a firm center around "*its ability to be operated profitably at different output levels*." Thus volume flexibility is concerned primarily with a firm's ability to efficiently fluctuate output

level for its current products or services. Other researchers have shown that firms can also use product mix flexibility (a broad portfolio of products) or new product flexibility (a reliance on new products) to respond to demand fluctuations. However, empirical research shows that volume flexibility responds to a different dynamic.[5] Volume flexibility enables a firm to effectively increase or decrease aggregate production levels in response to customer demand.[6] Volume flexibility also enables a firm to maintain a high level of delivery reliability by preventing out-of-stock conditions for products that are suddenly in high demand.[7] Conversely, in periods of slow demand, a volume flexible firm is not saddled with excess inventories and\or surplus capacity.

Early economists have identified the inherent tradeoffs involved in a volume flexibility strategy by suggesting that a firm is more volume flexible if it has smaller cost fluctuations associated with changes in output volume.[8] In Figure 1, Firm B has a higher minimum efficient cost ($2.050/unit) than that Firm A ($1.90/unit) but a flatter cost function over the range of output. Clearly, Firm B incurs a smaller penalty in deviating from its optimal output than Firm A and is more volume flexible. This trade-off associated with trying to accomplish a smaller value of minimum efficient cost as well as a smaller variation in cost over a wide range of volume is complex and not very well understood.[9]

Figure 1: Total Costs at Varying Volumes



	50	75	100	125	150
Firm A	250.0	208.3	190.0	200.0	216.7
Firm B	230.0	209.2	205.0	207.5	213.3

The different response function to changes in volume levels in Figure 1 is based to some extent on the differences in production technologies and operating policies used by the two firms.[10] In this example, Firm B with less dedicated equipment and perhaps more labor-intensive technology may well be positioned for greater volume flexibility. On the other hand, Firm A with dedicated technology and processes and greater economies of scale may promote efficient capital utilization and setup managerial incentives that reduce the ability to cope with volume fluctuations. We have found several situations where this has been the case.[11]

3.0 How do firms become volume flexible?

We have done three separate research projects to assess the factors that allow firms to become more volume flexible (see box). The overall strategic framework for measuring current needs, measuring the current abilities of the firm as well as identifying other innovative sources for becoming volume flexible is shown in Figure 2. This is based on our extensive research that relates sources of volume flexibility to firm performance as well as identifies the appropriate methods for measuring volume flexibility capability.

Box 1: Three Research Studies on Volume Flexibility

Study 1: Measuring and Comparing Volume Flexibility of Small and Large firms
This research presents a theoretical rationale for measuring volume flexibility and relating these measures to firm performance. The main argument in this study is that ANY measure of volume flexibility must simultaneously evaluate the range of sales variability of a firm (measure of environmental uncertainty) as well as cost and inventory variation (measures of technological capability) required to sustain this variation in sales. Thus a reasonable measure of volume flexibility of a firm is the variance of its sales divided by the variance of its cost of goods sold. We refer to such measures as "process based" measure of volume flexibility since they factor in sales variability as well as the firm's capability to handle such variation in one index.

We develop and test four process based measures of volume flexibility and relate them to performance across small and large firms. Using 20 years of Compustat data on 550 firms in 29 capital goods industries, we find that small firms judiciously use their resources in response to similar levels of environmental uncertainty. Thus small firms are able to cope with higher variation in sales with, say, a smaller variation in inventory levels. However, when we incorporate financial performance directly into our new measures, we find that large firms are more volume flexible. Thus large firms retain higher profitability despite the fact that they have concomitant increases in cost and inventories with changes in demand. We conclude that while small firms are more efficient in responding to environmental uncertainty, large firms have "deeper pockets" to cushion performance when sales levels vary.

Study 2: Identifying Drivers and Sources of Volume Flexibility
In this second study, we conduct in-depth studies in three manufacturing firms to assess the need and sources of volume flexibility. Using a structured interview methodology, we find that in all three firms, there is significant concern among managers for gaining competitiveness through volume flexibility. We find that deployment of volume flexible response is dependent on not just the availability of resources and systems that enhance volume flexibility but also on the drivers for volume flexibility. For example, the need for volume flexibility varies significantly across firms depending on:

- external drivers such as number of market segments served, lead time desired by customers and emphasis on delivery reliability, as well as variability of demand, and'
- internal drivers such as core competencies, forecasting ability and available systems and methods to deal with volume fluctuations.

This is an interesting finding in that it uncovers linkages between market variables such as the propensity of customers to vary order sizes to operational variables such as the choice between using overtime and temporary help. Our propositions derived herein are used for a quantitative assessment of predefined constructs related to drivers and sources of volume flexibility through a survey.

Study 3: Relating Drivers and Sources of Volume Flexibility
To verify the propositions in Study 2 we undertook a field survey that measured the importance firms place on volume flexibility as well as the corresponding actions they take to remain volume flexible. A large sample of operations managers in the Southwest Ohio area provides such insights from a wide assortment of industries and businesses. Our critical finding is that short-term and long-term sources of volume flexibility have a positive, albeit differential, impact on a firm's performance. In general, we observe the dominant use of short-term sources in both the case studies and the field survey. Key conclusions made here include firms with dynamic product change are more concerned with creating a volume flexible response and are likely to use (1) long-term sources as compared to firms with stable product change; (2) capacity buffers as opposed to inventory buffers; and (3) cross-training as opposed to overtime, temps and shift schedules. We find that overtime and cross training are the two most popular devices for creating volume flexibility in the short term. We also corroborate the "inventory buffers first, and then capacity buffers" argument made at each of the 3 case sites (Study 2). In general, we observe the dominant use of short-term sources in both the case studies and the field survey. We validate that volume flexibility has a positive impact on financial and delivery performance

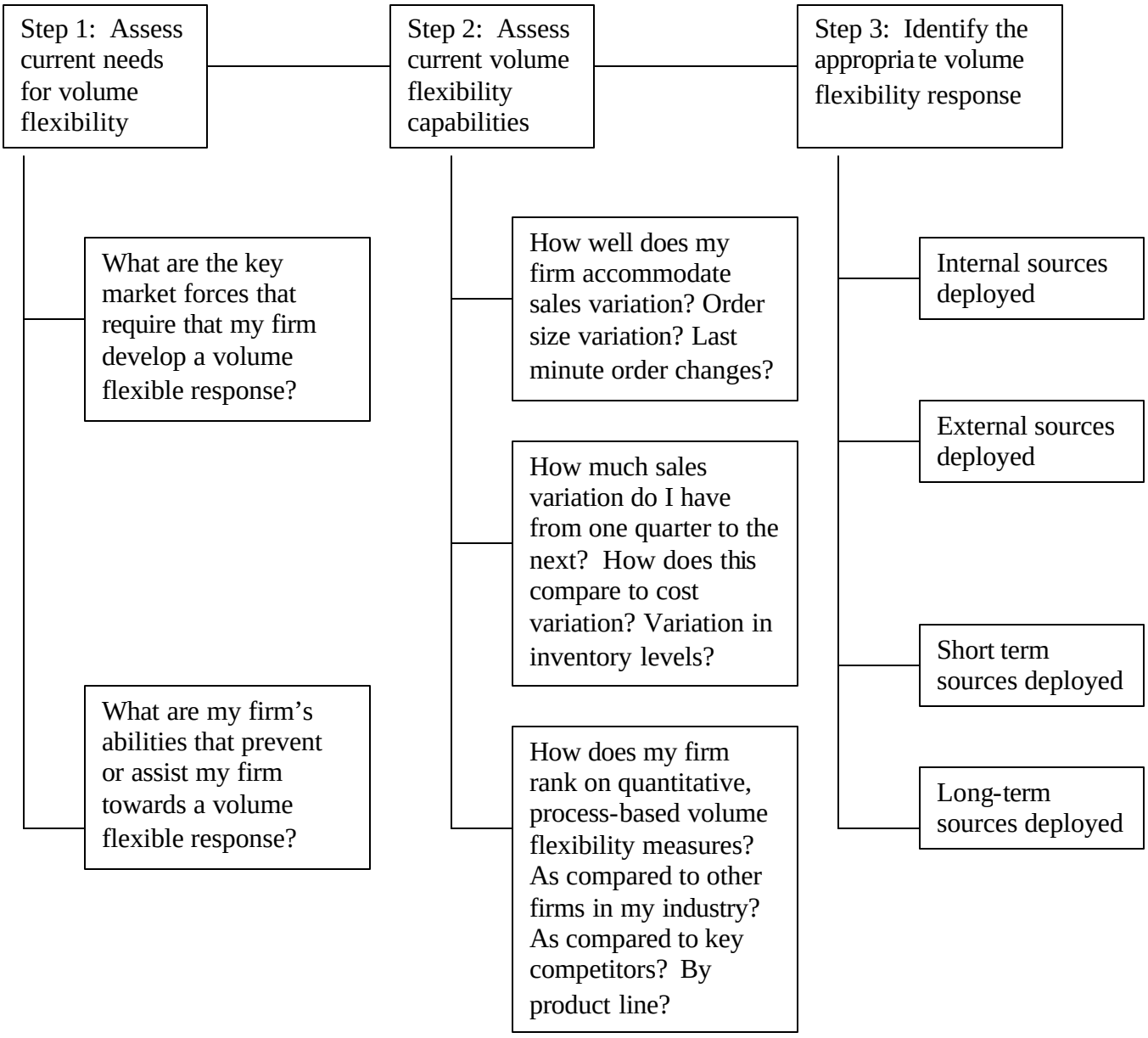
The first step in building a volume flexible response is to critically identify the main drivers that require a firm change volume levels by SKU, product group or factory. These may be market forces such as large customers that change order sizes at will, inadequate forecasts, product life cycle changes and/or macroeconomic changes in specific sales territories. It is important for firms to assess the extent of risk exposure due to all the environmental circumstances here. Internal capabilities (or lack thereof) may also trigger a need for volume flexibility. For example, unionized plants may find it much more difficult to change work schedules or overtime policies. Thus the rigidities that confine a firm's response space must be assessed alongside the capabilities.

The second step in the methodology for creating a volume flexible response is the benchmarking and quantitative assessment of the firm's capability vis-à-vis that of their competitors. A critical ingredient of this step is the identification of an appropriate measure of volume flexibility that allows the firm to benchmark itself against its key competitors. We suggest the use of process-based measures that assess the amount of environmental uncertainty alongside the firm's capability to respond to this uncertainty effectively. We exemplify with a few process-based measures that have allowed us to benchmark firms in several industries.

The assessment of needs and capabilities naturally points to the third stage of the proposed methodology – an assessment of the gaps in the needs and capabilities and the deployment of an appropriate tactic for making the firm more volume flexible. We suggest several effective tactics for long-term or short-term flexibility needs as well as those that are based on internal capabilities or those that rely on external stakeholders (suppliers, distributors, temporary staffing agencies etc.).

The rest of this section outlines the details of our methodology.

Figure 2: A Methodology For Improving Volume Flexibility



3.1 Measuring current needs

What are the key factors that drive a firm to adopt a volume flexibility strategy? The theoretical answer to this question could be traced back to the work of Stigler (1939) who argues that flexibility and adaptability are related in that "the greater the adaptability, the less the need for flexibility." Therefore, Stigler suggests that the real need for flexibility clearly arises when there is partial adaptability. A firm's adaptability is considered partial when it is unable to react efficiently and effectively to uncertainties in the competitive environment. Therefore, the greater the extent of uncertainty in the business environment, the more the firm will be driven to adopt a volume flexibility strategy. Researchers have identified hyper-competitive forces that characterize the most heightened state of uncertainty in the competitive environment such as : market stability threatened by short product life cycles, short product design cycles, reliance on new technologies, frequent entry by unexpected outsiders, repositioning by incumbents, and radical redefinition of market boundaries as diverse industries merge.[12]

Internet..people can order anytime…search and seek costs are reduced.
Supply chain disintermediation…on one hand reduces the bullwhip effect but on the other also reduces the buffers as in Jit shipments leading to exaggerated variations in factory schedules…bundling and buffering are both lost

We have chosen to describe the key drivers of volume flexibility by organizing them into two categories: external market-driven forces and internal competitive capabilities of the firm.

External Market-Driven Forces: When we consider the external market forces we can identify four factors that drive a firm to adopt a volume flexibility strategy:

- High number of market segments,
- High variability in demand,
- Short delivery lead time, and
- Extent of product customization.

For example, differences in customer segments drive the need for volume flexibility -- the more segments that a company attempts to serve; the more this company will be driven to adopt a volume flexible strategy.[13] A small computer cables manufacturing firm is driven to adopt a volume flexibility strategy because it chooses to compete in three segments where customers have significantly different needs: retail customers, OEMs, and commercial customers. There is also ample evidence to suggest that variability in order size is a driver of volume flexibility.[14] In the case of a small computer cables manufacturer, there is significant disparity in the order sizes from customers in each market segment wherein a retail customer may order a single cable from an on-line catalog, but an OEM customer may demand a truckload.

Closely related to the factors of market segments and order sizes is the issue of delivery lead-time. With short delivery lead times, a firm is exposed to market variations in demand immediately. With longer delivery lead times, a firm has more time to adjust.[15] Therefore, if customers in each segment are demanding short delivery times, then this small firm will be driven to adopt a volume flexibility strategy. Finally, product customization typically leads to higher production lead-time, which means that all the tenets of high production lead-time firms apply here.[16] Also, if there is simultaneous pressure on delivery lead-time, this creates even more of a need for volume flexibility.

Internal Capabilities: The internal competitive capabilities of a firm are also drivers of volume flexibility. For example, three key capabilities that have a significant impact on the decision to adopt a volume flexibility strategy are:

- Demand forecasting challenges,
- Delivery reliability, and
- Core competencies.

The greater the internal challenges in forecasting the demand for its products, the more a company will be driven to adopt a volume flexibility manufacturing strategy.[17] For example, in the hyper-competitive computer parts manufacturing industry, forecasting demand is a perpetual challenge. Firms may choose to dedicate a lot of resources to develop a reliable forecasting system that can help secure a competitive advantage.[18] Some researchers suggest that when faced with significant forecasting challenges, firms should proactively attempt to stabilize demand.[19] However, the reality is that the combined effect of short product life cycles, the proliferation of new products, and increasing number of competitors make forecasting in this environment a very significant challenge. Therefore, firms in this industry are driven to adopt a volume flexibility strategy.

Another factor that drives a firm to adopt a volume flexible strategy is its delivery reliability.[20] To the extent that delivery reliability (as defined by service levels) is a competitive choice that a firm makes in order to satisfy its customer base and sustain a competitive advantage, then the higher the delivery reliability goal, the more this firm will be driven to adopt a volume flexibility strategy.

A third internal factor that drives a firm to adopt a volume flexibility strategy is the core competency of the firm. The narrower the focus of the core competency of the firm, the greater the need for volume flexibility exists. For example, to the extent that the need for volume flexibility is created by erratic demand patterns placed on the business, if a firm has a wide product line (i.e. a broad core competency) then the portfolio effect of these products might mitigate the need for volume flexibility.[21]

3.2 Measuring current abilities on volume flexibility

Volume flexibility has been shown to be a source of competitive advantage for many firms. A firm that can vary volume and order sizes at minimal cost is by definition more volume flexible. To hedge against known demand variability, firms generally use safety stock, safety lead-time, overtime and other operational measures. However, if a firm carries excessive safety stock, it is hedging against environmental uncertainty at an unnecessarily high cost. Similarly, if a firm deploys overtime more than it needs to (with labor costs at 150% of regular wages) one can argue that it is spending its money ineffectively. Therefore, the dilemma for many firms is in determining how to strike the correct balance in order to sustain a competitive advantage. Thus, the question that we address is how do we characterize the performance of a volume flexible firm by simultaneously accounting for the environmental (demand) uncertainty that it faces and how effectively it hedges against that uncertainty.

A Framework for Measuring Volume Flexibility: If we had data on the cost of production at different volume levels then it would be easy to compare the volume flexibility of two firms in the same industry. However, several researchers have cautioned that perhaps volume flexibility may not be measurable because it represents a potential that may never be exercised.[22] Evaluations of potential flexibility are likely to come from internal assessments within the firm. Actual flexibility is determined from performance data. Therefore, while required volume flexibility may be captured by variation in demand (not variations in sales), potential volume flexibility must be measured by the ability to ramp up and ramp down production within certain cost limits. Actual volume flexibility may be measured by the actual performance of the firm.

If we focus on the actual or demonstrated volume flexibility, we can develop measures that consider the inherent trade-offs involved in responding to sales fluctuations over a given period.[23] Therefore, if the focus of an analysis is on the design of the firm's overall strategy, one would include external factors (variability in market conditions) into the specification of the environment while other considerations, which directly measure technology, will be used to define flexibility. When we decompose the measure of volume flexibility into its separate environmental and technology components in this way, we can derive process-based measures of volume flexibility. For example, firms that can respond to variations in sales with lower cost and/or lower inventory levels are more flexible. Thus, flexibility is high if the following conditions are met simultaneously: sales are high (fewer stockouts); profitability is high; costs are low (less under-utilization); inventory is low (under-stocking).

To demonstrate how we developed our **process-based measures**, consider the simple example that is summarized in Table 1.[24] If we measure output fluctuations as the standard deviation of sales over the 3-yr period, the output of firm B fluctuates more than that of firm A. If we take the natural logarithm of these fluctuations, we get an output fluctuation (OF) measure; which is 3.22 for A and 5.52 for B. An alternative to measuring the standard deviation of sales is to use the

coefficient of variation, which is the same (0.2) for both firms. But, if we consider how the firms use their inventory buffers to support their sales fluctuations, we can measure their volume flexibility as the ratio of the standard deviation of sales divided by the standard deviation of inventory. This measure gives a dimensionless index because the standard deviation of sales and the standard deviation of inventory are both measured in the same units. Then, taking the natural logarithm of this measure, we get our first process-based measure, F1. Table 2 suggests that the firm A is more efficient in using their inventory buffers to support their sales fluctuations (the F1 measure for firm A is 1.39 and for firm B it is 0.69). Our simulated data for these two firms indeed assumes that firm A is able to cope with the same coefficient of variation in sales with lower inventory.

	Small Firm (A)			**Large Firm (B)**		
Periods	**1**	**2**	**3**	**1**	**2**	**3**
Sales	100	125	150	1000	1250	1500
Fixed_Cost	40	50	60	500	625	750
Var_Cost	40	50	60	200	250	300
F&V_Costs	80	100	120	700	875	1050
Inventory	25	31.25	37.5	500	625	750
Inventory_Cost	5	6.25	7.5	100	125	150
Total Cost	85	106.25	127.5	800	1000	1200
Net Income	15	18.75	22.5	200	250	300
Return on Sales (ROS)	0.15	0.15	0.15	0.2	0.2	0.2
Statistics						
Avg_Sales			125.00			1250.00
StdDev_Sales			25.00			250.00
Log(StdDev_Sales)			3.22			5.52
StdDev_(Total_Cost)			21.25			200.00
StdDev_Inventory			6.25			125.00
StdDev_Net_Income			3.75			50.00
VF_Measures						
OF			3.22			5.52
F1			1.39			0.69
F2			0.22			0.36
F3			0.18			0.15
F4			0.026			0.030

Table 1. Measuring Output Fluctuations and Volume Flexibility

F2 measures a firm's volume flexibility as the natural log of the ratio of the standard deviation of sales divided by the standard deviation of total costs. In our example, we reiterate that firm B can tolerate the same coefficient in variation of sales as firm A, with lower costs (total costs are 70% of sales for firm B and 80% of sales for firm A). Our F2 measure indicates that firm B is more cost flexible - 0.36 for firm B as compared to 0.22 for firm A. In other words, for the 3 scenarios considered, firm B has lower variation in costs for a similar variation in the sales level than firm A has. F3 is a composite measure of volume flexibility that incorporates variation in sales, costs and inventories. F4 measures the combined effect of costs and inventory variation with sales variation as well as the return of assets for the firm. F4 is increased for a firm that can simultaneously:

- Provide a high return on asset, while,
- Tolerating a high variation in sales, and,
- Minimizing variations in costs and inventory.

It is instructive to note that the performance of the firms is fairly similar in this example. While the coefficient of variation in sales is similar, firm B produces a higher return on sales. But this firm is penalized for the high financial leverage it creates by carrying excessive inventory. Any need for volume flexibility can be removed by creating inventory buffers (at least for manufacturing firms). We deliberately do not factor in the varied costs of carrying inventory since this would depend on many complicating factors including the firm's capital structure, warehouse space etc. In other words, we do not capture the volume flexibility created by a firm, say by negotiating a lower capital cost for inventory with its banks, thereby allowing it to carry more inventory.

When we look at the relative size of these firms, we can characterize this result as the "Wal-Mart supplier effect," - large customers often choose large firms as their suppliers because these supplier firms are able to significantly adjust their output levels to meet fluctuations in customer demand. In another study, we analyzed 500 firms in 29 industries and the results show that large firms are able to fluctuate their output more profitably that small firms can.[25] One explanation for this difference between large and small firms is that large firms are more adept at using their network of plants, overseas suppliers and network of vendors and distributors to respond to fluctuations in output. When viewed from a purely resource dependence perspective, one might surmise that small firms have less bargaining power in the competitive arena and survive primarily by accommodating the environment: if a large customer demands small shipments one day and large shipments the next, they have no choice but to adjust. The question is, can they do this profitably?

Process-based measures account for the cost implications of doing this. The result suggests that large firms are able to fluctuate their output more profitably than small firms can. This is also intuitive if one argues that while small firms can adjust to small variations in output quickly, they really do not have the capability to move to second and third shift operation quickly. Nor do they have the financial and resource leverage to accommodate dramatic highs and lows in volume fluctuation.

To summarize, the process-based measures of flexibility simultaneously measure the ability of a firm to cope with high variation in sales without a concomitant increase in the variance of costs or inventory. Further, they incorporate the logic that a firm is more volume flexible if it can profitably operate over a wider range of possible sales outcomes.

3.3 Alternative sources of volume flexibility

The sources of volume flexibility are embedded in how a firm uses its resources to respond to uncertainties in its competitive environment. The resources available to each firm include manpower, money, materials, machinery, and time. Each firm uses a different mix of these resources and transforms them into products and services through a transformation process and a planning and control system. Some of the strategies deployed for increasing volume flexibility include:

- Using overtime and temporary workers,
- Cross training workers,
- Developing complementary product portfolios,
- Creating and maintaining slack resources,
- Improving planning and control systems, or
- Leveraging the firm's ability to negotiate on volume with suppliers and customers.

- Improving sales-forecasting methods
- Improving the order entry system
- Coordinating sales and manufacturing more closely
- Leveling manufacturing flow
- Reducing planning and manufacturing lead times
- Reorganizing the parts management system
- Synchronizing purchasing and manufacturing
- Optimizing inventory holding levels
- Adopting a kanban system with suppliers

Indeed, these volume flexibility strategies are essentially options that small and large firms use to gain competitive advantage. In the following sections, we present these sources of volume flexibility from two perspectives. First, the sources of volume flexibility are categorized into internal and external sources of volume flexibility. Then, we can also consider the time dependence of volume flexibility strategies by categorizing them into short-term and long-term sources of volume flexibility.

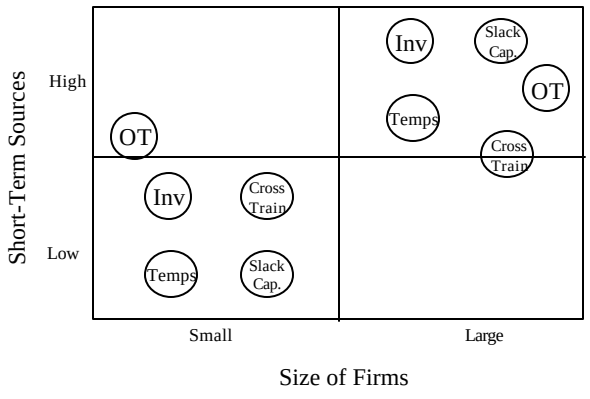
Internal Sources of Volume Flexibility: In analyzing a firm's internal manufacturing or operational capabilities we note that the range of options available to the firms are embedded in the wide variety of production processes, equipment, and internal planning and control procedures. The full range of options available to each firm is dictated by the industry setting and by how the firm chooses to deploy its resources to achieve a desired competitive advantage. In this regard, several

researchers have identified key internal sources of volume flexibility that include: slack production capacity, slack scheduling, production equipment, layout, and inventory buffers.[26] For example, the greater the extent of slack production capacity, the greater the source of volume flexibility available to the firm. Also, the higher the level of internal inventory buffers, the greater the capability that the firm has to respond to sales fluctuations without high stock-out levels.

External Sources of Volume Flexibility: The external sources of volume flexibility are embedded in how efficiently the firm leverages its relationships and alliances with its external network of suppliers and vendors. Many firms have recognized that the key tenets of supply chain management can be used as external sources of volume flexibility. For example, Stevens (1989) defines a supply chain as "a connected series of value activities concerned with the planning and controlling of raw materials, components and finished goods from supplier to customer." Supply chain management seeks to enhance competitive performance by closely integrating the internal functions within a company with the external operations of suppliers and channel members. Effective supply chain management allows a firm to efficiently use its network of suppliers and vendors to respond to uncertainties in demand. The ability of a supplier to absorb demand fluctuations lessens the need for a firm to carry high levels of safety stock. The lower the amount of safety stock a firm carries, the less inventory costs are incurred in responding to demand fluctuations. Consequently, firms can use their supply chain network as a source of volume flexibility.[27]

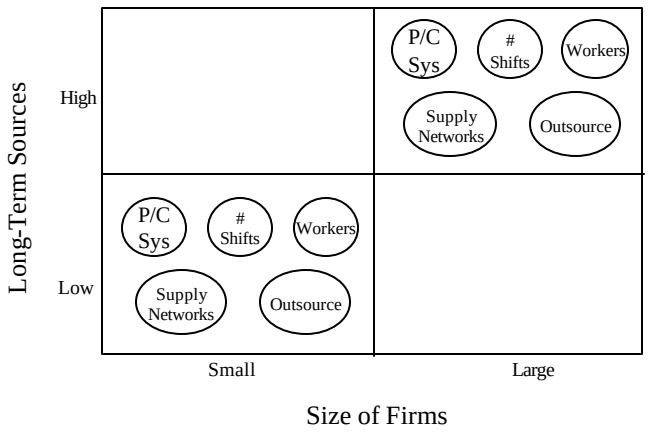
Short-Term Sources of Volume Flexibility: If we define the short-term to be less than one operating quarter (3 months), then we can identify the following short-term sources of volume flexibility: current high-volume production equipment, inventory and capacity buffers, and workforce flexibility. In response to high sales fluctuations, managers will first use their inventory and capacity buffers, then their labor flexibility. The sources of this labor flexibility are manifested in three ways: (1) overtime; (2) cross-trained workers; and (3) temporary employees. But, in order to respond to high up-shifts in sales, firms must have the processes and equipment in place to be able to respond efficiently.

Figure 4: Short-Term Sources versus Firm Size



Long-term Sources of Volume Flexibility: If we define the long-term to be more than two operating quarters (> 6 months), then we can identify the following long-term sources of volume flexibility: planning and control systems, workforce and shifts expansion, network of plants, network of vendors and suppliers, and distribution networks.[28]

Figure 5: Long-Term Sources versus Firm Size



4. A Risk Management Approach

All the sources of volume flexible response – whether they be internal or external or short-term or long term , accomplish the task of allowing a firm vary its output level effectively in response to a varying demand. The question is how does the firm handle demand uncertainty – does it contain it, mitigate it, absorb it or remove it. We briefly discuss these alternatives before outlining the contingency model for a firm's volume flexible response in the next section. The discussion of these strategies follows in the order of severity; less severe responses first (absorb it) and most severe responses last (remove it).

Absorbing uncertainty: The traditional and least severe form of uncertainty reduction is absorbing it. There are several alternatives to absorbing demand uncertainty. Traditionally firms hold safety stock in inventory to absorb demand fluctuations and a plethora of inventory models are available centered on this approach. Service businesses do not have this luxury and typically absorb uncertainty by deploying surplus resources. One would expect that absorbing uncertainty in demand in such a way would cushion the factory from uncertainties – however, our analysis as well as other economic studies prove the contrary. In a number of industries, the firm just passes along this uncertainty to the supplier. This practice, at best, is effective to the extent that inventory is maintained for lower value added items – it does not absolve the supply chain of inefficiencies since no proactive choices have been made to contain or reduce uncertainty.

Containing Uncertainty: The second option for a firm is to contain the uncertainty through innovative workforce and human resource policies, by deploying volume flexible technology as well as innovative scheduling. The advent of better information technologies that are centered around quick response (such as Enterprise Resource Planning Systems) allow firms to contain the uncertainty levels

through artificial means such as more effective rescheduling while minimizing the disruptions in work flow and prevention of severe degradation of resource utilization levels. Similarly, in workforce policies, the deployment of temporary workers, innovative shift schedules, creative use of overtime policies and through cross-training, firms are able to contain the damaging influences of uncertainty.

Mitigating Uncertainty: At the next level of volume flexible responses are approaches that mitigate the level of uncertainty that the operations of the firm are exposed to. A common approach here is risk pooling. A firm with inversely correlated complementary products (or a product portfolio) hedges the demand uncertainty by pooling the product lines under one roof. Thus when demand for one product is high, the demand for the other product is low, allowing the firm to use its resources effectively at all times. Similarly, firms with a network of plants can move production from slow economy locations to areas where demand is aggressive thereby pooling there risk across different geographical locations. Many alternatives for mitigating the propagation of demand uncertainty through the supply chain are available. Some of these are;

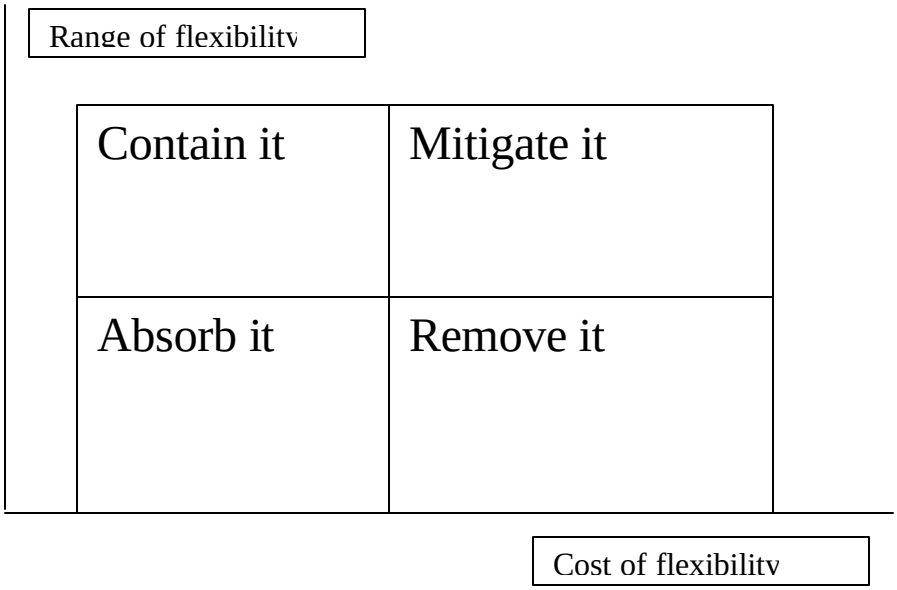
- Push systems for distribution with innovative allocation schemes
- Improving accuracy of information systems
- Removal of batching of orders
- Using time fences to freeze production levels in the near term to allow more "level" scheduling of production.
- Use it or loose it pricing schemes.
- Reservation systems

Removing Uncertainty: This alternative prescribes identifying the sources that exaggerate demand uncertainty and removing those sources from the value added chain that provides goods and services to the consumer. For example, it is well known that price promotions, couponing and other sales incentives artificially drive up demand uncertainty through the phenomenon commonly referred to as the "bullwhip effect". Every Day Low pricing (EDLP) allows firms to focus on driving out this artificial source of demand variability. Another common approach to removing these artificial sources of uncertainty is using sales incentives programs that provide rewards based on "sales upto" a period as opposed to "sales in" a period. This refocuses the salesforce to pay attention to cumulative sales as opposed to trying to sell a lot in a given period. Shortening the supply chain and Vendor Managed inventory (VMI) are other examples of removing uncertainty.

The four alternatives for creating a volume flexible response are outlines in Figure 6. The x-axis plots the cost of creating such a response while the y-axis plots the range of flexibility created by such a response. As can be seen from the Figure, a firm must assess its innate capability for a volume flexible responses (in terms of range and cost) before establishing which alternatives to pursue for alleviating its problems. Thus a firm that has a high cost of creating a volume flexible response and a small range, it should look into removing demand uncertainties. On the other

hand, if this same firm can allow wide variations in production, albeit at a high cost, it should look into mitigating the sources of uncertainty.

Figure 6: Types of Volume Flexible Responses based on Cost and Range capabilities of a firm



With a low cost of creating a flexible response, the firm should look into absorbing it if a low range is demanded but containing it if a high range of volume flexibility is demanded. When the range of volume fluctuation is low as well as the cost of creating a flexible response (such as slack resources, inventory buffers) is low, the firm has the easiest solution.

What follows from the above discussion is a contingency framework that allows a firm to assess its need for volume flexibility, assess its capabilities in terms of creating a volume flexible response and then develop its strategy on the choices/alternatives for mitigating the ill-effects of high demand variation. We conclude our paper with this contingency model.

5. Putting it all together

We present a framework in Figure 7 that firms can use to evaluate their volume flexibility needs and take corrective action to adopt a volume flexibility strategy . The key steps involved in this assessment are as follows:

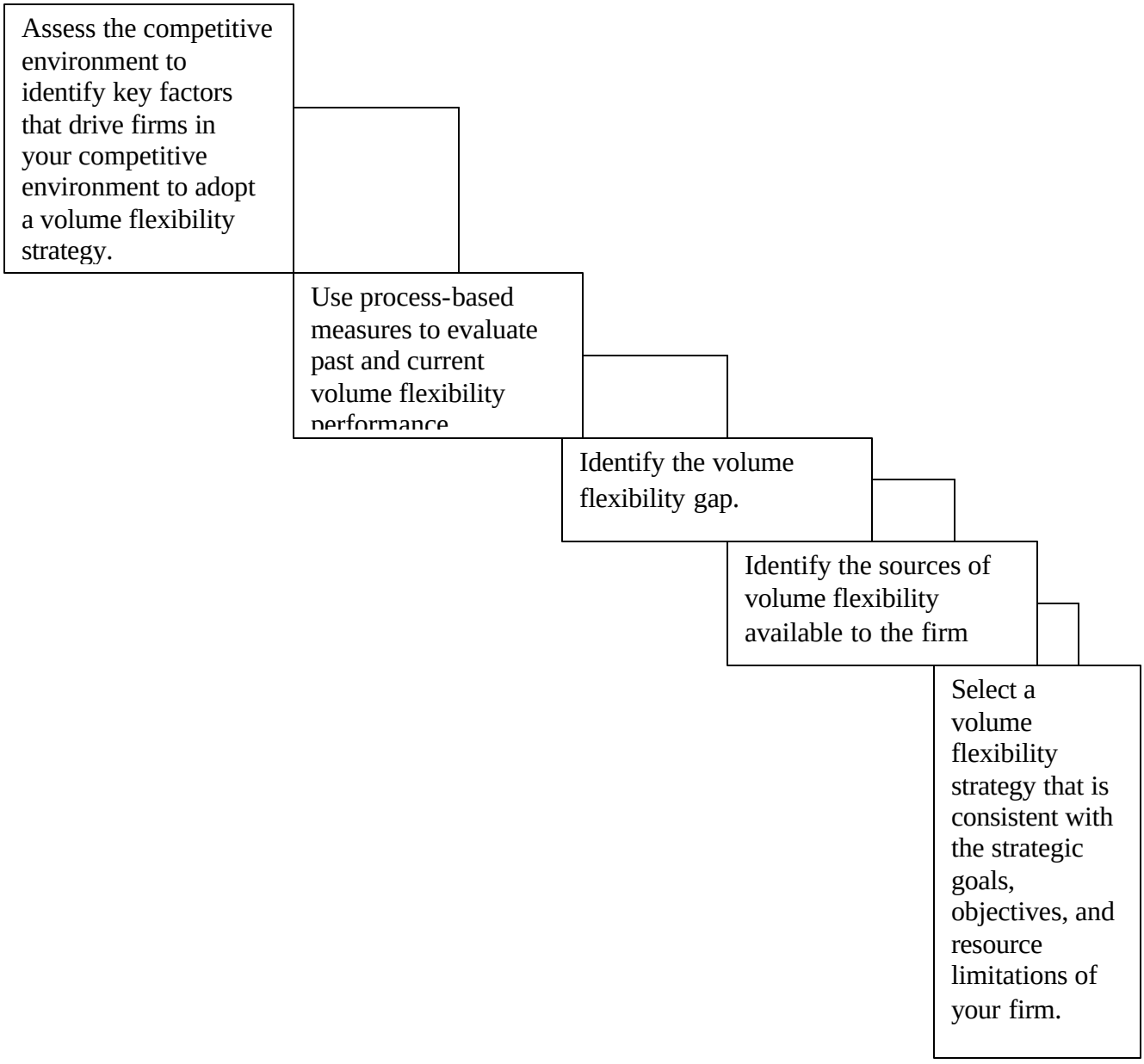
1. Assess the competitive environment to identify key factors that drive firms in your competitive environment to adopt a volume flexibility strategy.
2. Use process-based measures to evaluate past and current volume flexibility performance.
3. Identify the volume flexibility gap.
4. Identify the sources of volume flexibility available to the firm

5. Select a volume flexibility strategy that is consistent with the strategic goals, objectives, and resource limitations of your firm.

In assessing the competitive environment for key factors that drive firms to adopt a volume flexibility strategy, we suggest that managers should consider both the market driven forces and the internal competitive capabilities of the firm. Managers can then use four process-based measures to measure their actual volume flexibility performance and identify their volume flexibility gap. These process-based measures can also be use to benchmark a firm's volume flexibility performance with that of its competitors. Once this gap has been identified, managers can develop a volume flexibility strategy by selecting key sources of volume flexibility from the appropriate mix of resources (manpower, money, material, machinery and time). To minimize the risk to the firm, managers should consider emphasizing both internal and external sources of volume flexibility. Here, we suggest that there are significant potential payoffs from external sources of volume flexibility if firms can leverage the external relationships and strategic alliances within their supply chain. In addition, special attention should be given to the timeframe over which this volume flexibility is to be achieved. Therefore, we have also categorized the sources of volume flexibility into the short-term and long-term contexts. Finally, managers should rely on teams to implement, execute, and enhance their volume flexibility strategy in order to gain and sustain competitive advantage.

Tetris ---performing actions in the world than by performing computational actions in the head alone more quickly, easily, and reliably solves certain cognitive and perceptual problems. We have found that some of the translations and rotations made by players of this video-game are best understood as actions that use the world to improve cognition. These actions are not used to implement a plan, or to implement a reaction; they are used to change the world in order to simplify the problem-solving task. Thus, we distinguish pragmatic actions---actions performed to bring one physically closer to a goal---from epistemic actions---actions performed to uncover information that is hidden or hard to compute.
Resolution can be pragmatic (provide for flexibility) or epistemic (anticipate uncertainty).
As the speed of the game increases, only pragmatic actions work! Even knowing which piece will come down does not help unless one develops meta-rules on how one will react to different shapes!

Figure 7: A Contingency Model for a Volume Flexible Response



Endnotes

[1] The classic work of Holt, Modgiliani, Muth and Simon (1960) describes a production planning model that tries to minimize factory costs given the demand uncertainties. Holt, C., Modigliani, F., Muth, J., and Simon, H. (1960). Planning Production, Inventories, and Work Force. Prentice Hall Inc., Englewood Cliffs, NJ.

[2] These three studies are now documented as the following working papers: "Sources of Volume Flexibility in Manufacturing Firms: A Case Study and Field Survey Analysis", "Measuring and Comparing Volume Flexibility of Small and Large Manufacturing Firms" and "Volume flexibility in context: a review of the research and business literatures" all by Eric P. Jack and Amitabh Raturi, Department of QAOM, ML # 130, University of Cincinnati, Cincinnati, OH 45221-0130.

[3] See Slack (1983), Gerwin (1993), and Upton (1994).

[4] See Sethi and Sethi (1990).

[5] Suarez et al (1995 and 1996) studied 31 plants in the printed circuit board industry and their results show that volume flexibility appear to be orthogonal to mix and new product flexibility.

[6] (Hayes and Wheelwright, 1984).

[7] Jordan and Graves, 1998

[8] Stigler (1939)

[9] Gerwin (1993) suggests that research on flexibility needs to have more of an applied focus to complement the existing theoretical work. He also suggests that the main stumbling block to advances on both the theoretical and applied fronts is the lack of measures for flexibility and its economic value.

[10] This discussion of the relationship between flexibility and technology is elaborated in de Groote and Jordan and Graves. Both papers demonstrate effectively that any definition of flexibility must be based on a simultaneous specification of environmental uncertainty as well as the capability of the technology to deal with this uncertainty. Thus a firm that hedges demand uncertainty with higher inventories or lower resource utilizations is not necessary more flexible – a flexible firm is one that simultaneously caters to high levels of demand uncertainty with greater service levels and lower inventories/higher capacity utilization.

[11] Volume flexibility has been shown as positively related to a firm's performance. For example, Vickery et al (1999) study the furniture industry and they show that volume flexibility is a source of competitive advantage for firms operating in highly cyclical and/or seasonal markets.

[12] Miller and Droge (1986) and D'Aveni (1995).

[13] For a detailed discussion of these arguments,see Miller and Roth (1994) and Safizadeh and Ritzman (1997).

[14] For a detailed discussion of these arguments, see Fiegenbaum and Karnani (1991) and Cox (1989). Hayes and Wheelwright (1984) suggest that the variability of order volume in a highly cyclical industry drives the need for volume flexibility.

[15] For example, Stalk and Hout (1990) argue that "competing on time-based measures requires a value delivery system that is two to three times faster and more flexible than the competition." Other authors for example, Blackburn (1991) argues that cycle-time compression translates into faster asset turnover and increased output flexibility.

[16] See McCutcheon et al (1994) for a detailed discussion of the customization responsiveness squeeze.

[17] For a detailed discussion of these issues, see Raturi et al (1990).

[18] The expense of adjusting the work force and other aspects of production capacity is well established in the literature; e.g., see Holt, Modigliani, Muth and Simon**.** Hence, it is natural to consider ways to alter the time-varying demand. A familiar method is time-varying pricing, such as lower telephone rates during off-peak hours. The demand over time can often be smoothed (leveled) by having lower prices during periods of otherwise low-demand.

[19] Mather (1995) suggest a more proactive approach to demand smoothing.

[20] For a detailed description of these issues, we cite the work of Blackburn (1991) who showed that in a time-based competitive environment, delivery reliability issues could drive a firm to adopt a flexible manufacturing strategy. Also Vickery (1993) tested a measure of production competence using 31 components of production competence such as delivery speed and process flexibility. The notion of delivery reliability is similar to that of service level. For example, Jordan and Graves (using a multiple

product and multiple plant networking strategy) suggest how a volume flexible strategy can lead to higher service levels and higher capacity utilization simultaneously.

[21] For a detailed discussion of these arguments, we cite the work of Prahalad and Hammel (1994) and Whitney (1995). For example, Prahalad and Hammel (1994) define core competence into three categories: collective learning, diverse productive skills, and multiple production processes. These authors suggest, "the real sources of advantage are to be found in management's ability to consolidate corporate-wide technologies and production skills into competencies that empower individual businesses to adapt quickly to changing opportunities."

[22] [e.g. (Slack, 87) and (Gerwin, 93)] In fact, Gerwin (93) makes a distinction between required, potential and actual flexibility. Gerwin suggests that required flexibility can be gleaned from customer surveys and other marketing feedback mechanisms.

[23] de Groote (1994b) develops this argument further by making an important distinction between flexibility and diversity in the environment. deGroote defines diversity as the variability, variety, or complexity in the environment. As such, diversity can be related to the variability of market conditions as characterized by a stochastic or a seasonal demand or random input prices. deGroote defines flexibility as a hedge against the diversity of the environment. As such, a particular technology is said to be more flexible than another is, if an increase in the diversity of the environment yields a more desirable change in performance than the change that would be obtained with the other technology under the same conditions. deGroote defines technology broadly to include any aspect of the firm's production resources, control procedures, and overall strategy

[24] . Firm A is a relatively small firm with relatively low fixed cost (40% of sales), variable cost (40% of sales), inventory buffers to cover one operating quarter (25% of sales), and inventory carrying cost of 20%. Firm B is a relatively large firm with higher fixed cost (50% of sales), lower variable cost (20% of sales), and larger inventory buffers covering two operating quarters (50% of sales), and inventory carrying cost of 20%. The average annual sales is 125 for firm A and 1,250 for firm B. The standard deviation of sales over the 3-yr period is 25 for firm A and 250 for firm B.

[25] Jack et al (2000) paper under review at the Strategic Management Journal.

[26] For a detailed description of these arguments, we cite the work of Cox (1989), Suarez et al (1995), Ward et al (1995), and Safizadeh and Ritzman (1997).

[27] . [Stevens (1989), Bowersox (1989), Cooper et al (1997)] Further evidence of the value of strategic sourcing can be found in the work of Narasimhan and Das (1999). These authors define strategic sourcing as "the use of supplier competencies to achieve flexibility goals." Narasimhan and Das (1999) argue that strategic sourcing will have a positive influence on volume flexibility.

[28] These long-term sources are supported by researchers such as Jordan and Graves (1995) who showed that limited flexibility, configured the right way, yields most of the benefits of total flexibility. They also showed that limited flexibility has the greatest benefits when configured to chain products and plants together to the greatest extent possible. Therefore, they argued that the right way to add flexibility is to create fewer longer plant-product chains. Other authors, for example Bowersox et al (1989) looked at marketing strategies such as outsourcing and postponement and show that integrating channel-wide marketing strategies can provide enhanced potential for strategic leveraging of channel efficiency and effectiveness. Other authors [Gentry (1996), Choi and Hartley (1996), Cooper et al (1997)] look at the buyer-supplier strategic partnerships and show that outsourcing can enhance the effectiveness on the supply chain and provide a competitive advantage.