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Synergy, Tradeoff and the Dimensions of Supply Chain Responsiveness

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Abstract

This paper examines the fundamental tenet of the supply chain responsiveness-cost efficient frontier that the relationship between supply chain cost and responsiveness is characterized by tradeoff. The paper presents evidence that that relationship is substantially characterized by synergy, and it identifies some of the most significant areas of synergy and the factors that drive these. The synergistic relationship is further brought to the fore by an identification of the many dimensions of supply chain responsiveness. Three key conclusions emerge from the analysis. The first is that by focusing on identification and exploitation of synergy, supply chain managers are in a better position to identify and take actions that simultaneously drive responsiveness up while driving costs down. The exploitation of these synergistic relationships is one of the most promising avenues for pushing the responsiveness frontier out. The second is that inventory is a net destroyer of supply chain responsiveness rather than an enhancer of it. And the third is that by focusing on specific dimensions of responsiveness managers increase the potential to identify synergistic relationships that can be exploited for competitive advantage. Further, depending on the market segment in which a company competes, it cannot position itself on responsiveness as a whole but on specific dimensions of it.

Introduction

Over the last decade or so, the design and management of the supply chain to achieve high levels of responsiveness has emerged as one of the most critical issues in deploying the supply chain to strategically position a company. It is increasingly being recognized that the competitive performance of companies such as Toyota, Dell, Amazon.com, Walmart and McDonald's, to name only a few, derives substantially from the particular capabilities they have designed into their supply chains and the effectiveness with which they exploit the unique characteristics of the supply chain design to provide high levels of responsiveness on an on-going basis. Dell, in particular, has received much attention for designing and deploying what is often referred to as one of the most responsive supply chains in the computer manufacturing industry, and many observers credit the company's superior competitive performance to the effectiveness of its supply chain management system in responding to changing customer requirements.

Based on the research in the area, reports of management practice and anecdotal evidence, it is now well established that supply chain responsiveness is a major driver of competitive performance. However, there is some ambiguity both in the literature and in practice as to the true nature of supply chain responsiveness, in general, and the tradeoff relationship between efficiency and responsiveness, in particular. Although there are some exceptions, the overwhelming research emphasis has been placed on different aspects of time as a barometer of supply chain responsiveness. Notwithstanding that emphasis, it is implicit in the concept of supply chain responsiveness that is presented in the literature that high levels of responsiveness and efficiency are at opposite ends of a supply chain performance continuum and, therefore, increasing the level of responsiveness can only come at the expense of lower levels of efficiency. In what follows, we examine and probe the nature of the relationship between supply chain responsiveness and efficiency and evaluate the extent to which it is driven by tradeoff as opposed to synergy. Moreover, we propose that supply chain responsiveness is not a

single, undifferentiated factor but, on the contrary, is composed of many dimensions. We argue that companies almost never compete on a single dimension of responsiveness, neither on all aspects of it, but rather on a limited number of dimensions that are crucial to their customers or market segments and on which they have chosen to or succeeded in cultivating core competency. Further, we critically evaluate the role of inventory in the achievement of supply chain responsiveness and our evaluation suggests that, contrary to generally accepted thinking in theory and practice, inventory either has little positive impact on responsiveness or, in the vast majority of cases, is detrimental to it.

Anatomy of Supply Chain Responsiveness

Chopra and Meindl (2: 2003) define supply chain responsiveness in the following terms; "Supply chain responsiveness includes a supply chain's ability to do the following; Respond to wide ranges of quantities demanded; Meet short lead times; Handle a large variety of products; Build highly innovative products; Meet a very high service level; Handle supply uncertainty". This definition is in line with what prevails in the supply chain management literature (1,1991;3,2004;10,1992;11,2002;14,1994;17,1989;19,1995; 20,1996;24,1988;25,1990) which views responsiveness as being multidimensional and multifaceted. A similar view exists in the Total Quality Management literature, where quality as a strategic differentiation requirement is averred to be multi-dimensional (5, 2005; 8,1983; 9,1991). Because firms competing on responsiveness use it as an important aspect of a generic differentiation strategy, we can expect the sources of responsiveness advantage to be variegated as well (21, 1980; 22,1985; 23,1986). Due to this multidimensional nature of responsiveness, and in line with the central tenets of the generic strategies framework, a firm can increase its responsiveness-based differentiation advantage through deployment of either a responsiveness-focus or a responsiveness-differentiation strategy (22, 1985). A responsiveness-focus strategy involves the firm in the design and exploitation of the supply chain for performance depth on a limited number of responsiveness dimensions. In that case, the firm focuses the development of its core responsiveness competency in a few areas that are known to significantly drive performance, and then leverages these core competencies to deliver the few, particular dimensions of responsiveness that are valued by customers in narrowly targeted market segments. This is the type of responsiveness strategy deployed by FEDEX for whom responsiveness is speed and reliability of delivery, while other dimensions such as variety are either absent or not emphasized in the company's value proposition.

Alternatively, a firm can pursue a responsiveness-differentiation strategy by developing and exploiting core competency in a large number of areas in order to deliver high performance on a broad range of responsiveness dimensions. The firm seeks responsiveness performance breadth, that is, the mastery of a broad range of responsiveness-related skills, and develops the capability to identify and exploit a large number of sources of responsiveness differentiation. Contrary to the widely held view, we will argue that Walmart is such a company that competes, not only on the basis of cost, but also on the basis of high performance on a few dimensions of responsiveness.
The concept of responsiveness espoused in the literature (3: 2004) views efficiency/cost and responsiveness as existing on opposite ends of a responsiveness-efficiency/cost spectrum or a responsiveness-cost efficiency frontier, which forces a company to tradeoff higher levels of responsiveness against lower levels of efficiency (higher levels of cost). From that vantage point, higher levels of responsiveness can only be achieved

at increasingly higher cost, and one would not expect to find companies that are simultaneously high responsiveness and low cost competitors in their industries. In terms of the responsiveness-cost efficient frontier framework, a high responsiveness-low cost company would occupy an above-frontier position which as we will demonstrate, is not sustainable over the long run in a competitive market.

There are some fundamental consequences of the responsiveness-cost efficient frontier as conceived of and promulgated in the theory and practice of supply chain management, two of which are important for our purposes. First, the total emphasis on tradeoff as the driver of the relationship between supply chain cost and responsiveness has blinded management theory and practice to other aspects of the relationship that could be nurtured and exploited for competitive advantage. In that vein, we conjecture that much of the relationship between supply chain responsiveness and cost is characterized by synergy between the two, and that uncovering, nurturing and exploiting such synergy is a crucial mechanism for deriving strategic power from a supply chain. Second, the categorization of companies like Walmart and McDonald's as exclusively cost-focus competitors and not as responsiveness-differentiators is also a direct consequence of this narrow view of the responsiveness efficiency-cost frontier as being based exclusively on a tradeoff relationship between cost-efficiency and responsiveness. It is widely accepted that Walmart is highly successful in achieving the lowest cost position in its industry. Therefore, on the basis of the literature, specifically the responsiveness-cost efficient frontier framework, one should not expect Walmart to be a high-responsiveness company as well. But we shall demonstrate that, contrary to accepted notions, Walmart is achieving high performance on a respectable number of dimensions of responsiveness, which, to the chagrin of its so-called responsiveness-driven competitors, went unnoticed for over two decades. McDonald's is still characterized as a cost-focus company even while many observers were predicting its downfall because it was broadening its product offering. Paradoxically, it was a significant broadening of its service offering to include a number of low fat-low carbohydrate menu items that brought the company back from a dangerously declining market share position. Based on these and significant other evidence to be presented subsequently, we conjecture that the relationship between supply chain responsiveness and cost may be more complex than that captured by the responsiveness-cost efficient frontier framework, and that the relationship between the two is also, at least substantially, driven by synergy instead of tradeoff alone.

The arguments in support of the position that the relationship between responsiveness and cost/efficiency is not exclusively based on tradeoff but also on synergy come from three sources. First, because the idea of tradeoff between cost-efficiency and responsiveness has been entrenched in the literature through the responsiveness-cost efficient frontier framework, we will examine its central tenets and critically evaluate whether its fundamental implications obtain or can hold in a competitive market. If there is strong managerial rationale why the central tenets of the framework cannot hold in a competitive market, then the underlying relationship between cost-efficiency and responsiveness that it proposes must be viewed with some skepticism. Second, we will examine the supply chain performance of well-known, end-of-spectrum companies that are accepted to be industry benchmarks in their respective industries in terms of supply chain performance known some companies that are widely acknowledged to be the benchmark of their industries and that are executing highly responsive strategies, and we will evaluate the extent to which their supply chain performance conforms to the pattern predicted by the responsiveness-cost efficient frontier. By end-of-spectrum

company we mean one that competes on either extremely high levels of responsiveness or extremely low cost. Based on the responsiveness-cost efficient frontier framework that postulates one, and only one frontier for an industry, we expect end-of-spectrum responsiveness companies to be necessarily also their industry benchmarks in terms of supply chain performance, whether it be cost or responsiveness. Thus, Walmart is accepted to be an end-of-spectrum low cost company, while FEDEX is viewed as an end-of-spectrum high responsiveness company.

If a benchmark, end-of-spectrum-responsiveness company is also a better-than-high-cost competitor, or if a benchmark end-of-spectrum cost company is a better-than-low responsiveness competitor, then this will be an indication that the relationship between responsiveness and cost is not necessarily or exclusively based on tradeoff but could also be characterized by synergy. If at least some of these companies have also achieved high efficiency (low cost) or even cost parity, then this would be a strong indication that the relationship between responsiveness and cost-efficiency is more complex than commonly accepted and at least partially driven by synergy rather than tradeoff alone. And third, we will attempt to identify as broad a range as possible of the dimensions of supply chain responsiveness and evaluate the relationship between some of them and supply chain cost-efficiency to see whether the drivers of at least some of the dimensions of high responsiveness are also drivers of low cost. If some dimensions of high responsiveness and low cost respond to a common set of drivers, then this will be some evidence that the relationship between responsiveness and cost-efficiency is characterized, at least in part, by synergy and not only by tradeoff. In particular, we will examine whether inventory enhances all dimensions of supply chain responsiveness or is destructive of at least some of them.

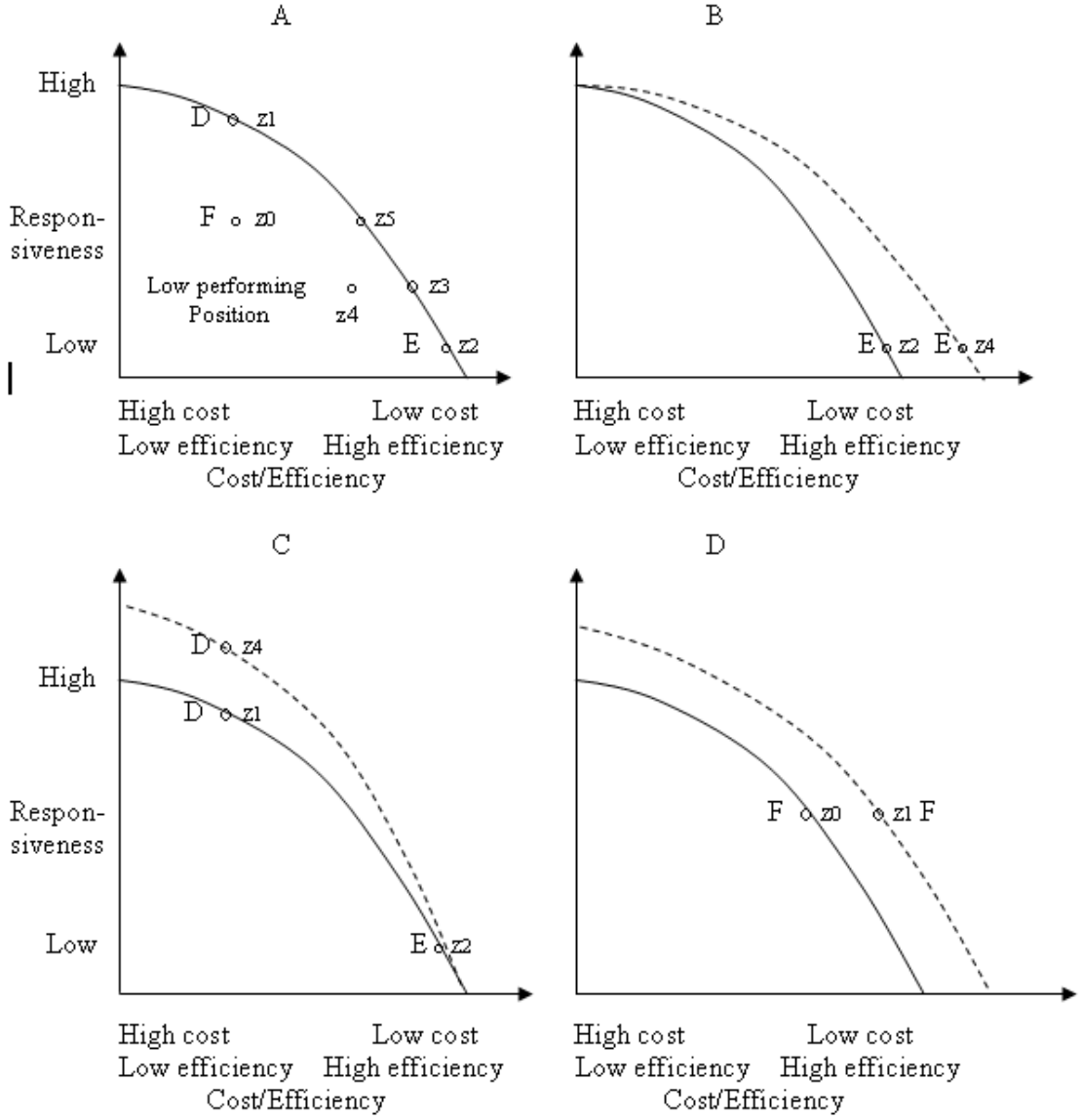
Re-Evaluation of the Cost-Responsiveness Efficient Frontier

Figure 1-A shows the framework of the Cost-Responsiveness Efficient Frontier as commonly presented in the literature (3, 2004). According to that model, a supply chain can be designed, configured and operated to pursue two fundamental strategic objectives, cost and responsiveness. These two objectives represent the two opposing ends of the supply chain performance continuum which theoretically means that greater levels of responsiveness only come at higher cost, while the pursuit of low cost through supply chain management actions forces the firm to sacrifice some responsiveness. In that scheme of things, supply chain design, structuring and management actions that aim to build an efficient supply chain will inescapably result in lower levels of responsiveness and vice-versa. Trade-offs must be made between these two opposing objectives, and the best trade-offs exist on the cost-responsiveness efficient frontier shown in Figure 1-A. Implicit in the framework is the notion that the frontier position is occupied by best-in-class supply chain companies that have found the most efficient way to execute a given level of responsiveness and even these can only achieve superior responsiveness at higher costs or, analogously, lower efficiency. By adduction, best-in-class firms exist all along the frontier, which means that firms D and E in Figure 1-A are competing in different segments of the market, the first targeting segments where customers value responsiveness, even at a higher price, while the second is focusing on segments that value a lower price but at a lower level of responsiveness. Also, the inescapable conclusion that can be drawn on the basis of the framework, firms D and E have each found market segments where there is a high degree of fit between segment responsiveness-cost requirements and their core competencies (3, 2004). Thus, we can

adduce that firm D's core competency gives it the capability to execute high levels of responsiveness while firm E has mastered supply chain activities that deliver low cost.

Although it is generally accepted that some companies can occupy the space below the cost-responsiveness efficient frontier (3, 2004), analysis tells us that these positions are clearly not sustainable in the long run in a competitive market. Competitive supply chain positions that lie on the frontier deliver greater value to the customer than those that exist below the frontier. For any position below the frontier, firm F at z_0, for example, there is an equivalent superior position on the frontier such that the company executing the frontier position is creating and capable of delivering greater value to customers, either in the form of lower cost/price for the same level of responsiveness such as position z_3, or higher levels of responsiveness at the same cost/price, as in the case of position z_4. These frontier companies can always leverage their value positions to entice customers away from their below-frontier, inferior competitors. A company that moves to z_3 from z_4, as in Figure 1-A has lost its advantage based on responsiveness because it is achieving the same level of responsiveness at higher cost. Hence, in a competitive market, z_0 obviously is an unsustainable position which implies that the frontier positions are superior.

Figure 1
Tradeoff, Synergy and the Responsiveness-Cost Efficient Frontier



But although it is not prima facie evident, an analysis of the framework also leads us to conclude that a company will most likely lose its competitive advantage if it simply tries to move along the frontier by moving to a position like z_5 from z_3, as in Figure 1-A, for example. This is so for at least two reasons. First, a company picks a particular position on the frontier by matching its existing capabilities or those that it can develop within a competitively defensible time frame with the responsiveness and cost requirements of that unique position. These responsiveness and cost requirements match those of a unique, identifiable and significant segment of the market. Analogously, every position on the frontier matches the requirements of a unique segment with unique requirements, and it is safe to assume that in a competitive market these positions are occupied by existing, entrenched companies that have targeted them by valid competitive strategies whose execution is based on the mastery of the core competencies required by the corresponding market segment. Therefore, moving along the frontier always requires

greater mastery of one or the other set of core competencies, whether that related to cost or that related to responsiveness. So, when a company attempts to move along the frontier, it is explicitly trading off a level of performance of one requirement whose requisite core competency it has mastered to take on a higher level of performance of the other requirement whose requisite core competency it has not yet mastered. The company is likely to find that it cannot sustain the frontier position as it tries to move along the frontier because it must master a different set of competencies. Companies that try to move along the frontier are likely to drift towards a below-frontier, inferior position. Consequently, most attempts to move along the frontier are likely to destroy competitive advantage and fail. Examples abound of precisely this phenomenon; Barnes and Noble's move against Amazon.com, Kmart responding to Walmart, Hewlitt trying to imitate Dell.

Second, most attempts to move along the frontier are likely to destroy rather than create competitive advantage and fail because of the observation made earlier that in a competitive market, every frontier position is expected to be occupied by entrenched competitors that have matched their capabilities with the requirements of the unique segment from which the frontier position derives. We can assert this because, in a competitive market, there should be no or very few underserved segments. Consequently, as a company moves along the frontier, its shifting position brings it closer and closer to head-on competition with companies that have already mastered the required core competencies, are competing in well-served segments and, because they are on the frontier, have the capability to execute these requirements efficiently. These companies are likely to react to the competitive threat and deploy strategies and resources to nullify it. A company that tries to move along the frontier can expect a vigorous attack from the competition and this is likely to dissuade most potential competitors from such a strategic move. Of course, the exception to that observation is where a company uncovers new segments and requirements based on new bases of segmentation of the market, which means that no existing company has mastered the core competency to perform the unique requirements of that segment. In that case, a company that has the required level of resources has the time to redeploy these to create and master the requisite core competency with little fear of retaliation from existing entrenched competitors. Successful movement along the frontier is particularly advantageous where the company does not have to abandon its existing niche but simply targets another segment as a differentiation move. Thus, Walmart's entry into the wholesale-retail market segment through the creation of Sam's Clubs is a clear case of successful movement along the frontier that was a differentiation move.

The insights developed based on the above analysis may prove to be significant for supply chain strategy formulation and deployment. It instructs us that when a company has an established and entrenched supply chain strategic position in a competitive market, changing that strategy is likely to be a long, drawn out and slow process that has a high probability of failure. This may also explain why it is tough to catch up to and surpass a company that, at inception, got the supply chain strategy right -achieved a high degree of fit, in the language of Chopra and Meindl (3, 2004) -and built an entrenched position based on it. Dell, Walmart, Amazon.com are all excellent examples of such companies that have all left competitors (Gateway, K-Mart, and Barnes and Noble) struggling, and as yet wholly unsuccessful, to equal their benchmark positions. These entrenched, benchmark supply chain companies must stumble very badly, or the fundamental structure and dynamics of competition in the industry must change in a

rather dramatic way, before a competitor that is differently positioned on the frontier can hope to achieve supply chain performance parity with them.

The above analysis shows that the responsiveness-cost efficient frontier tends toward stability, where every company occupies the position that is best suited to its core competency and which it is able to defend. But, in a competitive market, it is inevitable that some maverick companies will not accept the status quo and will try to break from the pack. They can do so by achieving higher levels of responsiveness at the same cost, increasing responsiveness performance faster than cost, decreasing the cost of maintaining a given level of responsiveness, or simultaneously increasing responsiveness and decreasing cost. All of these ways to increase competitive advantage from responsiveness and cost result in some outward movement of the responsiveness-cost efficient frontier (Figure 1-B, 1-C and 1-D) and violate the premise of tradeoff between responsiveness and cost. The outward movement of the responsiveness-cost efficient frontier is driven by two factors, technology and continuous improvement, both of which operate to break or relax the supply chain constraints that make it necessary for a company to make tradeoffs between cost and responsiveness. The achievement of economical small lot production that is prerequisite to the implementation of pull production is one classic example of the capability to simultaneously increasing responsiveness and decreasing cost in the operations/production stage of the supply chain through the breaking of the fundamental constraint that forces a company to make tradeoffs between responsiveness and cost. Figure 2 illustrates the relationships. The initial optimal production lot size is $Q_{o,1}$, and one notes that the lot size determines both the initial level of cost, as measured by the total inventory associated cost, TC_1, and responsiveness as measured by the flow time due to cycle inventory and its impact on lead time.

We recall that flow time is given by T_f, where,

$$T_f = Q/2r \quad \ldots\ldots 1$$

Q=Economic production lot size
r=Requirements (demand) per time period

We also know that the flow time is a component of the lead time, TL because,

$$TL = Tq + Tp + Tm \quad \ldots\ldots 2$$

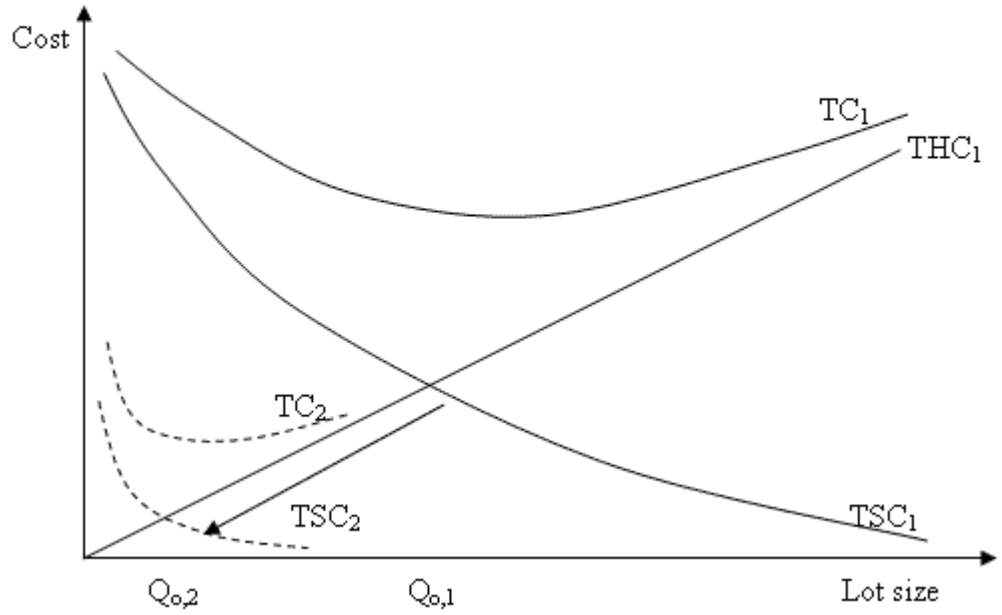
Tq=queue time
Tp=production time
Tm=move time

and,

$$Tq = f(Q, I/O) \quad \ldots\ldots 3$$

where I/O measures the input rate scheduled on the production system compared with its output rate or capacity. If I/O is less than or equal to one, there is no overloading of the production system and no buildup in the queue or lengthening of the queue time. Where I/O is greater than 1, the queue time will increase beyond what is embedded in the production lot size. Therefore, by systematically decreasing the economic production

Figure 2
The Relationship between Lot Size and Total Inventory Costs



lot size towards the small lot production level that is required by a JIT/Pull process, a company can simultaneously decrease cost and increase lead time responsiveness. There are many other areas where the relationship between cost and responsiveness is characterized, not by tradeoff, but by synergy.

If one accepts the notion that the relationship between responsiveness and cost is characterized only by tradeoff, there is no opportunity for a company to try to reduce lot sizes, since it would be achieving greater responsiveness only at increasingly higher cost. But the power of JIT-Pull systems comes from the now widely recognized fact that a company can break the setup constraints that force it to tradeoff responsiveness and cost and, in fact, achieve greater levels of responsiveness at lower cost. This is done by recognizing and exploiting synergy between setup cost and lot sizes because these have a common driver, the setup time, which is determined by the efficiency with which setups are executed. We note that when we examine the relationship between cost and specific dimensions of responsiveness at the micro-level, the tradeoff relationship is less critical to supply chain performance whereas the synergistic relationship becomes both more evident and more crucial. Moreover, it is evident that continuous improvement in supply chain performance, just like continuous improvement in a production system to push it towards JIT/Pull, is not driven by the acceptance of tradeoff as a fait accompli, but by the search for and exploitation of synergy. A central conjecture of this paper is that the more a company breaks responsiveness into its micro-level dimensions and probes the relationship amongst these, the more it can find synergistic relationships between cost and responsiveness that can neutralize, and ultimately reverse the tradeoff impacts, exploit synergy and thus push the responsiveness-cost efficient frontier outward..

In addition, at a more fundamental level, one can assert that the cost to achieve any given level of responsiveness is a measure of the extent to which a company has built into its supply chain the systems, processes and practices that give it the innate flexibility to respond, at ever decreasing cost, to the changing requirements of a competitive market. Upon closer examination, one is constrained to conclude that the very concept of responsiveness must obligatorily embody the connotation of the cost to respond. If a supply chain must incur ever higher levels of cost to respond to changing market and technological conditions and customer requirements, then, by virtue of that fact alone, that supply chain is not responsive at all. It is the inability to respond effectively to changing market and technological conditions and customer requirements that makes it costly for the supply chain to do so, when it must change. It is the rigidity of the supply chain system that makes it costly for it to respond fluidly to changing market conditions and customer requirements. When we say that a company is responsive, we mean that its cost to respond to changing market conditions and customer requirements is low compared to other companies in its market or market segment that are competing on the basis of similar levels of responsiveness performance. Increasing cost to respond means there is excess weight, friction, inertia and inefficiency, which are characteristic, not of responsive systems, but of unresponsive ones.

Consequently, the relationship between supply chain responsiveness and cost is more complex than what is captured by the concept of tradeoff alone. While at the general level the relationship between supply chain responsiveness and cost is characterized by tradeoff, at the micro-level there are supply chain activities where the relationship between responsiveness and cost is characterized by synergy. Hence, at least partially, a company can improve supply chain responsiveness and cost simultaneously by identifying and focusing on these synergistically critical activity sets. Focusing on the general, macro-level relationship between responsiveness and cost blinds management to the latent, micro-level synergies that may be exploited to amplify the impact of continuous improvement by shifting the whole responsiveness-cost efficient frontier outward. The idea that relationships that appear to be based on tradeoff when viewed at the macro-level may also embody synergies at the micro-level is not new: It was at the base of a fundamental shift in thinking on the economics of quality in TQM. Historically, companies viewed the relationship between quality and cost as being based on tradeoff between the two, where increasing levels of quality could only be attained at higher cost. Today, the overwhelming view is that there are latent, micro-level synergies between quality and cost and increasing quality is viewed as a driver of lower cost (4, 1979;5, 2004).

There was a similar shift in understanding of the relationship between lot sizes and total inventory-related costs with as dramatic consequences for management. Prior to the 1980s, the relationship was viewed as being based on tradeoff where smaller lot sizes would inexorably lead to higher total inventory-related costs. Currently, it is generally accepted that lot size compression not only drives inventory-related costs down, but also compresses non-inventory costs and, in particular, increases quality while simultaneously decreasing quality related-costs. The relationship between small lot sizes and total inventory-related and other costs is particularly instructive for our purposes, since it shows that relationships between cost and responsiveness that appear to be characterized by tradeoffs at the general level may have important synergies at the micro-level when responsiveness is disaggregated into its constituent dimensions, and the specific costs associated with each dimension are considered. In the case of JIT, the synergy derives from a specific activity, the compression of setup time, and the reduction

in lot sizes, total inventory costs, quality cost compression through defect reduction and the other favorable improvement interactions that are unleashed by small lot sizes.

The Cost-Efficiency Performance of Benchmark Responsive Supply Chains

But, there is ample evidence of a number of companies that have been acknowledged to be highly responsive, low cost competitors. Dell has been recognized as having created the most responsive supply chain system in its industry that is able to deliver highly competitive prices. Walmart is unquestionably the lowest cost competitor in its industry and it achieved that position while simultaneously increasing its responsiveness as measured by its very high inventory turns, the variety and breadth of its product line, the speed with which it can move products from local geographic markets where demand is sluggish to areas of high demand, the agility with which it can move products through the supply chain, from suppliers to its points-of-sale, to replenish inventory that has been depleted by higher-than-expected demand, and an incredibly favorable Net Conversion Cycle. The case of Walmart shows at least three things. First, it underscores the concept that supply chain responsiveness is multidimensional and multifaceted. Second, it shows that high inventory turns , that is, low inventory levels, are entirely compatible with high responsiveness and, as we shall argue subsequently and contrary to the popular thinking, high responsiveness is driven by high inventory turns. Inventory, we aver, does not necessarily increase overall supply chain responsiveness and, in fact, destroys many dimensions of it. Third, Walmart's supply chain strategy demonstrates categorically that there is no inherent trade-off between cost-efficiency and responsiveness where higher levels of responsiveness can only be achieved at higher cost. On the contrary, there is synergy between cost-efficiency and responsiveness where higher levels of responsiveness require low cost. Dell has found that by configuring the supply chain and positioning its manufacturing operations to be in direct contact with customers, focusing its core competencies on the final stage manufacturing process only, and using highly responsive suppliers at the upstream stages, it can create synergy between cost and responsiveness and become a low inventory, high responsiveness, low cost company. Toyota is accepted by most observers to be one of the most, if not the most, responsive automobile manufacturers in the world today. The company has set the world benchmark performance for the speed of designing, building and taking new car designs to market, extremely high inventory turns, a broad variety of products, unmatched quality for the classes of cars that it manufactures, delivery speed, production system flexibility that culminates in mixed-model processing and JIT/Pull supply chain systems. Yet, on the whole, the company developed, built and refined a network of lean production/supply chain system that, in terms of its efficiency, is a clear benchmark in its industry and the envy of its competitors. Toyota has shown that systematically compressing inventory out of the supply chain increases quality, lead time, variety, upward and downward demand change, innovation and product mix responsiveness, while simultaneously, almost inexorably, improving cost-efficiency. Toyota has recognized that the relationship between supply chain responsiveness and cost is substantially driven by synergy as opposed to tradeoff.

In the market niches in which it competes, Nike is, by all accounts, the most responsive company in terms of product variety, speed of design changes, speed of model introductions, speed of response to market demand, capability to shift production from one region to another in search of competitive advantage and inventory turns. If the

central tenets of the responsiveness-cost efficient frontier hold completely, then Nike should be an extremely high cost producer. Yet, that company makes and delivers shoes to market at very attractive cost and recoups margins of the order of 300% on its overall supply chain costs, including manufacturing and transportation costs. In point of fact, Nike could not successfully execute its competitive strategy which is promotion intensive and requires very high promotion costs that are designed to create and exploit an image of brand exclusivity if the company did not achieve an attractive total supply chain cost position. Nike has found that by astutely locating manufacturing facilities in areas where labor cost is low and the social, political and economic environment offer the potential for very high levels of manufacturing flexibility, it can create and exploit synergy between supply chain cost and responsiveness, thereby achieving extremely high levels of responsiveness at lower cost.

What the cases of Walmart, Toyota, Dell and Nike demonstrate is that the relationship between supply chain responsiveness and efficiency-cost is more complex than simple models based on tradeoffs between the two admit. We advance and argue the position that, not only is the idea of a mere tradeoff between responsiveness and cost-efficiency an inaccurate representation of the strategic relationship between the two, but that responsiveness necessarily requires lower cost. Stated differently, a company is not responsive at all if it must tradeoff responsiveness against cost. In addition, a company creates no competitive advantage and cannot improve its market position if its core competence is such that it must tradeoff greater levels of responsiveness against higher levels of cost. The ambiguity that exists in the literature as to the true nature of the relationship between responsiveness and efficiency-cost substantially derives from the absence of a systematic effort to identify a broad range of dimensions of responsiveness. The identification of a broad range of dimensions of supply chain responsiveness shows that some cost compressors are also drivers of responsiveness and that the relationship between the two is substantially based on synergy instead of tradeoff. By adduction, responsiveness strategies that are too costly are not, competitively speaking, responsiveness strategies at all. Just as high quality that is achieved at high cost usually destroys some of the value delivered to customers, high responsiveness strategies that are achieved at high cost invariably do not create value. These high responsiveness-high cost strategies simply confirm that a company is working harder to overcome weight, friction and inertia, which are hallmarks of an unresponsive system. Just like the economics of quality framework before it, the tradeoff relationship posited in the responsiveness-cost efficient frontier hides critical synergistic links that can be exploited to simultaneously propel continuous improvement in both responsiveness and cost. The TQM paradigm unleashed successive waves of simultaneous improvement in quality and cost when it recognized that the relationship between quality and cost is substantially characterized by synergy between the two and not by tradeoff alone and that higher quality is an important driver of low cost. Analogously, the evidence from benchmark supply chain responsiveness and/or cost companies examined here leads to the conclusion that companies can unleash significant improvement potential in responsiveness and cost when they recognize and manage synergy between the two, using one to drive the other.

The failure to consider cost/efficiency as an integral aspect of supply chain responsiveness has led to a very ambiguous understanding of the role that inventory plays in supply chain responsiveness. The nature of that ambiguity and the opposing conclusions that it leads to are clearly revealed from the following position taken by (3, 2004); “Inventory is a major source of cost in a supply chain and it has a huge impact on

responsiveness. If we think of the responsiveness spectrum discussed in Chapter 2, the location and quantity of inventory can move the supply chain from one end of the spectrum to the other. For example, an apparel supply chain with high inventory levels at the retail stage has a high level of responsiveness because a consumer can walk into a store and walk out with the shirt they were looking for. In contrast, an apparel supply chain with little inventory would be very unresponsive. A customer wanting a shirt would have to order it and wait several weeks or even months for it to be manufactured" (3,2004). The position we take here is that supplying an order when the customer wants it is responsiveness, but having to hold supplying high levels of inventory to do so is not.

On the other hand, they argue; "Inventory also has a significant impact on the material flow time in a supply chain. Material flow time is the time that elapses between the time materials enter the supply chain to the point at which it exists...The logical conclusion here is that inventory and flow time are synonymous in a supply chain. Managers should use actions that lower the amount of inventory needed without increasing cost or reducing responsiveness, because reduced flow time can be a significant advantage in a supply chain." (3,2004). It can be easily demonstrated that inventory increases flow time which is, unequivocally, a measure of decreased responsiveness. So, according to the standard position articulated in the supply chain management literature, (3, 2004; 13,1992;15,1998;25,1990) inventory is presented as both increasing and decreasing responsiveness. We are of the view that much of the current ambiguity as to the impact of inventory on supply chain responsiveness can be substantially reduced by an evaluation of the true nature of responsiveness and the relationship between it and cost-efficiency.

Synergy, Tradeoff and the Dimensions of Supply Chain Responsiveness

There are many more dimensions of supply chain responsiveness than are generally currently recognized in the literature (26,1998). Table 1 identifies a number of these dimensions and provides a succinct definition of each. The framework makes a distinction between upward and downward demand shift, and an increase in customer lead time as opposed to a decrease. Moreover, as far as supply chain responsiveness is concerned, the framework proposes that intra-product line demand shift is distinct from an overall increase or decrease in demand. These distinctions are important because each of these dimensions of responsiveness has different drivers and impose different costs and competitive consequences on a company. Inventory is a major driver of upward demand shift responsiveness and reduces the cost of responding to unexpected, upward shifts in demand. However, that same inventory destroys downward demand shift responsiveness and is costly when demand unexpectedly decreases. Holding excess capacity increases upward demand shift responsiveness but destroys downward demand shift responsiveness. In addition, because of legacy costs, adding capacity is usually less costly than reducing it. Low upward demand shift responsiveness invariably results in a lost sale, loss of customer goodwill, failure to build market share and reap the associated economies of scale and cost reduction. Finally, unexpected increases in customer lead times are rare, and much less problematic and costly than a decrease, usually resulting in a temporary increase in inventory as the supply chain adjusts to the new reality, while unexpected customer lead time compression could create shortages and lost sales.

Inventory increases unexpected lead time compression responsiveness but is costly when there is lead time extension. Furthermore, we identify the key drivers of each dimension of responsiveness and the nature of the relationship between each and supply chain efficiency-cost. An analysis of the table gives much support to the central proposition advanced here that supply chain responsiveness has a much larger number of dimensions than what is currently recognized in the literature and the relationship between cost and responsiveness is much more complex than the simple tradeoff relationship captured in

Table 1
Dimensions of Supply Chain Responsiveness and Key Characteristics Cost Relationships

Dimension	Definition/key characteristics	Key Drivers	Cost Relationships: Tradeoff vs Synergy
1. Unpredictable upward demand shift	Satisfy high fill rates when demand unexpectedly increases.	High cycle inventory; High safety stocks; or low inventories with capability to move goods quickly through pipeline with high responsive transportation; High capacity cushion and flexibility (overtime, multiple skills, worker rescheduling capability)	High tradeoff due to high inventory and excess capacity; Deployment of most of these drivers destroy efficiency; Partial synergy as multiple skills increase motivation/productivity
2. Intra-product line demand shift	Achieve high fill rates when demand for one product in the line increases at the expense of another; Overall demand does not change.	High inventory or low inventories with high capability to move goods from low to high demand areas or segments; Multiple skills and worker rescheduling flexibility	Moderate tradeoff due to high cost of holding inventory; Partial synergy due to motivational impact of multiple skills and better use of capacity
3. Downward demand shift Unpredictable: Individual product	Quickly adjust production rates and inventory levels to an unpredictably lower demand level	Structure of capacity, low fixed costs; Capacity lodged in multiple, small-scale production facilities; Relatively unskilled labor force; Low inventories	High tradeoff; low fixed cost, small-scale facilities tend to be high cost, low efficiency operations; Unskilled labor force tends to have low productivity
4. Lead time shift; decrease in customer lead time	Meet high fill rates when customers unexpectedly tighten their lead time requirements	Very low inventory driven by small lot sizes that give short flow time, low queue time	High synergy; Driving lot sizes down decreases queue time, increases variety and efficiency and also decreases cost
5. Market niche (Product	Dovetail product line to unique requirements of a	Flexible, cellular manufacturing systems for mixed model	Very high synergy; Cells give high motivation, productivity,

variety)	large number of market niches	processing; Low changeover (setup) times; Very high inventory turns	quality, quick time to market
6. Technological Change	Keep obsolescence costs low in the face of rapid technological changes	Very low levels of inventory; Time compression in product development and design through application of concurrent engineering and QFD	High synergy; Low inventories cause shortages; These costs are more than counterbalanced by greater market attractiveness, low obsolescence costs of low inventories
7. Time-to-market	Speed up market entry of new/improved product with minimal impact on existing products	Low levels of inventory; Flexible manufacturing systems and cell manufacturing	Very high synergy; Cells give high productivity, quality, quick time to market; low inventories drive costs down, quality up
8. Predictable demand shift (Increase)	Increase production and inventory in anticipation of demand increase	Capability to bring new capacity on stream quickly; Speed of aggregate production and supply chain planning and scheduling; High inventory	High tradeoff; High inventory increases obsolescence costs and decreases responsiveness when demand decreases
Dimension	Definition/key characteristics	Key Drivers	Cost Relationships: Tradeoff vs Synergy
9. Predictable demand shift (decrease)	Decrease inventory and production in anticipation of demand decrease.	Low fixed cost, low breakeven facilities; Multiple, small scale facilities; Low inventories	Moderate tradeoff; Low fixed, low breakeven, small scale facilities are high cost; Balanced by Inventory synergy; Low inventory increases this type of responsiveness
10. Supply uncertainty	Achieve acceptable fill rates when high probability of supply breakdown	High levels of parts inventory; Multiple suppliers	Neutral; Fewer suppliers give lower prices, although JIT holds the contrarian view
11. Quality: Feedback from market	Speed of quality improvement or causes of defects eradicated in response to customer actual experiences with product in market	New product: Ramp-up speed, steepness of learning curve All products: Strength of TQM system, customer relationship management, small production lot sizes(low	Very high synergy; Steep learning curve drives costs down; Strong TQM system drives defect cost down; Small lot sizes drive costs and flow times down

		inventories)	
12. Net Conversion Cycle (NCC)	Reduce NCC, generate enough cash from operations to sustain business without external financing	Low inventory; Deployment of Pull/JIT systems	High synergy; Low inventories reduce days-inventory-held, decreases NCC and drive interest costs down; Pull/JIT systems tend to high efficiency

the supply chain responsiveness-cost efficient frontier. Although when examined at the micro-level the tradeoff relationships are still present, the synergistic relationships are more prevalent and potentially more critical.

Moreover, the analysis based on Table 1 also clarifies the role of inventory in supply chain responsiveness. The role of inventory in supply chain responsiveness is unambiguous when one considers the specific dimension of responsiveness. Instead of being an unambiguous driver of supply chain responsiveness, inventory is a double-edged sword that enhances some specific dimensions of responsiveness while destroying others, and it appears that no matter where it is located, inventory is at best neutral and, at worst, is a net destroyer of overall supply chain responsiveness. This observation is in line with that made by Hau and Billington (13,1992;15,1998;16,1998). Specifically, inventory destroys market niche responsiveness (product variety), technological change, time-to-market, quality feedback to from market and Net Conversion Cycle responsiveness. This result may prove to be critical because the relative emphasis that customers place on the different dimensions of responsiveness varies from one market segment to another. A company that relies on high levels of inventory will be at a relative competitive disadvantage compared to those that do not if the dimension of responsiveness that is valued in its market segment is not enhanced, but instead, is destroyed by inventory. Just like quality, responsiveness performance must be market segment targeted and the drivers of responsiveness that are leveraged must be dictated by segment requirements (6,1997;7,1993) Broad-based responsiveness strategies are likely to fail in markets that are highly competitive and segmented, and companies that deploy responsiveness-focus strategies are likely to achieve dominant competitive advantage in their chosen segments. Hence, the relative emphasis that a company places on inventory as a driver of supply chain responsiveness is acutely dependent on the competitive responsiveness requirements of the market segment or segment in which it competes.

Current supply chain management literature does not recognize a responsiveness problem for unpredictable downward shifts in demand, but the problem exists, is as prevalent as that created by unpredictable, upward shifts in demand and, if not dealt with, is potentially devastating to a company's strategic and profitability performance. The costs imposed on a firm by downward shifts in demand are potentially very high. Downward demand shift responsiveness is the capability of the supply chain system to adjust production levels, supply or inventory downward to bring them in line with a lower demand rate. A decreasing demand places a squeeze on profits from three different directions. First, demand contraction usually derives from increased competition or cyclical decreases in demand which put a squeeze on prices and profit margins. Second, decreased demand means that the company has less volume over which to dilute fixed costs, which further decreases profits. Third, in the absence of high

responsiveness to drive inventory out of the supply chain faster than demand is contracting, decreased demand increases inventory levels at the very time that the product is less appealing to customers, and this exacerbates obsolescence costs, inventory financing costs, the net conversion cycle, and a wide array of other costs. In other words, downward shift in demand means that per units costs are increasing at the same time that the company is recouping less margins to cover these costs.

Downward demand shift responsiveness has a crucial impact on the capability of a company to maintain profitability levels in a tightening market situation because it creates the capability to drive costs down as fast as or faster than demand and prices. It is a reasonable conjecture that the long term capacity of a company to survive is critically dependent on its innate downward demand shift responsiveness of its supply chain, since all markets periodically or eventually contract, and a contracting market stresses a company's financial capacity to the very limit. Upward demand shift responsiveness, while a significant issue, is much less taxing of the company's survival capability. The immediate impact of upward shifts in demand can be assuaged with safety stocks, and upward pressure on demand means that the company's inflation flow-through rate is high, enabling the company to pass on the additional costs to customers. Intermediate-term, upward shifts in demand will require hiring or overtime while downward demand shifts require under-time and lay-offs. The former is usually much easier to implement and less costly than the latter.

Evidently then, inventory can significantly hamper the process of adjusting supply to demand. A company that already holds a high level of inventory and comes under severe downward demand pressure is faced with the dilemma of either making dramatic cutbacks in supply/production to quickly adjust supply to demand, or implementing a more normal, slower response and hold a much higher level of inventory for a longer period of time. The first response amplifies the fluctuations in the labor force and in raw materials and parts delivery from suppliers, which generate inefficiencies in labor and procurement costs. The second response exposes the company to very high obsolescence costs, particularly because the products that are left in inventory would most likely be the slower moving, less technologically attractive ones that are likely to be driven to obsolescence during the adjustment period. This is exactly what happened to Lucent when demand for its product plummeted at the beginning of the last economic downturn that started around 2000. The company already had very high levels of inventory of telecommunications gear that were already technological surpassed by superior competitive products. When the downturn came, Lucent's high level of inventory drastically slowed down its adjustment process and, by the time the economy had turned around, the company's product line had become largely obsolete and it was hit with massive inventory write-downs that, for a time, threatened its very existence. The point is that although it has not been fully recognized by supply chain management theory and practice, downward demand shift responsiveness is as crucial to a company's competitive advantage as upward demand shift responsiveness, and inventory, far from being a contributor to that dimension of supply chain responsiveness, exacerbates or destroys it.

Conclusion and Implications for Supply Chain Management Theory and Practice

The tradeoff relationships posited in the responsiveness-cost efficient frontier and widely accepted in theory and practice captures only a part, and not even the most significant one, of the rich interaction between cost and responsiveness in a supply chain system. There are some areas of tradeoff between cost and responsiveness, but there are also critically important areas of synergy that imply that aggressive supply chain management actions can drive supply chain costs down by driving responsiveness up, and vice-versa. The synergistic relationships and the critical drivers become visible when one disaggregates responsiveness into its constituent dimensions, of which there are no less than twelve. The disaggregation of responsiveness into its key dimensions shows that while some areas of tradeoff do exist, synergy is, by far and away, the dominant relationship between supply chain responsiveness and cost. The potential for synergy exists in all but two of the twelve dimensions of responsiveness identified here. This may prove to be a critical result for supply chain management since it implies two things.

First, because responsiveness is variegated, its disaggregation into its constituent dimensions will likely show that customers in distinct segments value different dimensions. Instead of formulating the company's sought-after position in terms of an overall responsiveness posture, supply chain management needs to understand the specific dimensions of responsiveness that are valued by the market segment in which their firms compete. This can help a company dovetail the dimensions of responsiveness to identifiable market segments, enabling it to sharpen its market-responsiveness focus. Second, dissecting responsiveness into its constituent dimensions may reveal new ways to segment the market and pinpoint underserved segments. Third, by identifying sources of synergy between cost and responsiveness, a company can accelerate supply chain performance improvement and build sustainable competitive advantage relative to competitors that are preoccupied with managing tradeoffs between the two and, as a result, fail to spot and exploit the potential synergies. What drivers to nurture and which to avoid because they destroy responsiveness are patently related to the responsiveness requirements specific to the company's market segments and made manifest by the framework presented here. This would enable a company to better leverage its resources and competencies and avoid efforts that, on the surface, are positive drivers of responsiveness, but when viewed at a more fundamental level, are destroyers of a company's responsiveness performance.

The fact that the impact of inventory on supply chain responsiveness is largely negative is both a rather critical and surprising result. Contrary to the view widely held in theory and practice, the analysis undertaken here reveals that inventory is an important net destroyer of supply chain responsiveness, negatively affecting all of the dimensions of supply chain responsiveness except predictable upward shift in demand and unpredictable upward shift in demand. Instead of increasing speed of supply chain response, inventory represents dead weight that slows down the response process. In consequence, a firm can only validly rely on inventory as a driver of supply chain responsiveness if that firm competes in market segments that are experiencing large predictable and unpredictable upward shifts in demand. These upward demand shifts can only exist on a sustained basis at the beginning of the growth cycle for unusually cyclical industries, or for industries that are starting the growth phase of the product life cycle. In both these cases, the reliance on inventory as a driver of supply chain

responsiveness is temporary and will, in fact, expose a company to severe cost and obsolescence penalties once the factors that are powering high increases in demand will have dissipated. A company that is using inventory as a means of increasing supply chain responsiveness must be very careful to monitor the pattern of demand growth to spot when the trend is changing and thereby deploy massive effort to reduce inventories quickly. Otherwise, inventory becomes a true double-edged sword that destroys responsiveness more than it adds to it and reduces rather than enhances competitive advantage.

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