Towards a Theory of Competitive Progression: Evidence from High-Tech Manufacturing

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This study replicates and extends Ferdows and De Meyers’ observed ‘sand cone’ model of cumulative competitive capabilities by means of Roth’s related competitive progression theory (CPT). Using path analysis, we model and test the relationships among the generic competitive capability constructs of conformance quality, delivery reliability, volume flexibility, and low cost as predicted by CPT. Our results, drawn from a sample of high-tech manufacturers, provide further evidence that on average, these four capabilities are acquired both cumulatively and in that sequence. We also find that each generic capability increases operational know-how and reduces non-value-added directly and/or indirectly through the enhancement of successive capabilities in the progression, which in turn improves profitability. The paper contributes a theoretical rationale for the observed sand cone effect, describes how the competitive progression acts to influence accelerated organizational learning over an innovation cycle, and offers evidence that combinative capabilities have strategic value for high-tech manufacturers.

Key words: manufacturing strategy; competitive progression theory; competitive capabilities; high-tech manufacturing; empirical research
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1. Introduction
A central theme of manufacturing strategy pertains to how competitive capabilities are acquired, and in particular, the nature of the relationships among the generic capabilities of quality, delivery, flexibility, and cost. Following the literature, we define competitive capabilities as the firm’s actual, or ‘realized,’ competitive strengths relative to primary competitors in its target markets, which differs from its competitive priorities, or planned, or ‘intended’ strengths (Boyer and Lewis 2002; Noble 1995; Roth and Jackson 1995; Stalk, Evans, and Shulman 1992; St. John and Young 1992). For more than a decade, there has been considerable debate in the extant literature regarding the consequences to business performance when manufacturers fail to follow the conventional wisdom of trading-off one capability for another, and instead attempt to develop multiple capabilities simultaneously (see e.g., Clark 1996; Ferdows and De Meyer 1990; Flynn and Flynn 2004; Flynn, Schroeder, and Flynn 1999; Hayes and Pisano 1996; Hayes, Pisano, Upton, and Wheelwright 2004; Hill 1989; Lapre and Scudder 2004; Miller and Roth 1994; Roth and Miller 1992; Roth 1996a,b; Safizadeh, Ritzman, and Mallick 2000; Schmenner and Swink 1998; Vickery, Droge, and Markland 1994; White 1996).

As an alternative to the conventional mandates, this paper focuses on the observed ‘sand cone’ model of cumulative capability development first noted by members of an international research team participating in Boston University’s International Manufacturing Futures Research Project (Ferdows and DeMeyer 1990; Miller and Roth 1988; Nakane 1986). We subject to empirical scrutiny a related competitive progres-
vision theory (CPT) proposed by Roth (1996a,b) that explains the observed sand cone effect. According to the CPT, in the process of acquiring combinative capabilities, manufacturers can simultaneously increase operational know-how and reduce process variation associated with waste and non-value-added over an innovation cycle, and in turn, influence business performance (see Figure 1).

Traditional manufacturing strategy, as advanced by Skinner (1969), holds that operational effectiveness is maximized when generic, operations-based capabilities of quality, delivery, flexibility, and cost are ‘traded off.’ Accordingly, achieving strength on one of these generic capabilities must come at the expense of the rest, such as cost for quality, unless there exists some level of operating inefficiencies (Boyer and Lewis 2002). During the 1980s, armed with high-quality and low-cost products, world-class Japanese manufacturers began to cast doubt on many sacrosanct Western manufacturing practices (Clark 1996; Flynn and Flynn 2004; Flynn et al. 1999; Giffi, Roth, and Seal 1990; Hayes and Pisano 1996; Hayes et al. 2004; Skinner 1996a,b; Vickery et al. 1994; Womack, Jones, and Roos 1990).

In their seminal article, Ferdows and De Meyer (1990, p. 169) provided some empirical evidence that “... different generic capabilities have been cumulative and not the result of compromises and tradeoffs.” Using the metaphor of a sand cone, these researchers suggested that the sequence of generic capability building is important, because manufacturing excellence is built on a common set of operating principles that are easier to put in place by starting with one particular type of activity, and then pursuing other activities that expand and enrich these operating principles.

Much of the ongoing debate concerning the observed sand cone model in the POM literature may be due to the lack of a grounded theory (Schmenner and Swink 1998). Without common definitions in measures and clarity in explaining the interrelationships among the constructs, different conclusions could be reached without advancing theory (Flynn and Flynn 2004; Roth 1996a). We address the following questions: (1) Is there empirical evidence of combinative capabilities in manufacturing when modeled as a nomological net of constructs and relationships as specified by the CPT? (2) Does the competitive progression matter to business performance? If so, what are its direct and indirect effects on organizational learning, and in turn, business performance? This is the first paper to our knowledge that subjects to rigorous empirical scrutiny the observed sand cone effect modeled as a nomological net of relationships. Our nomological net of relationships theoretically explains the competitive progression of conformance quality, delivery reliability, volume flexibility, and low cost and demonstrates its influence on organizational learning and an objective measure of profitability.

2. Competitive Progression Theory

2.1. Background

In the operations strategy literature, Nakane (1986) was the first to propose that tradeoffs among competitive capabilities were unnecessary in his study of Japanese manufacturers. Several years later, using a sample of European manufacturers, Ferdows and De Meyer (1990) illustrated that competitive capabilities seemed to accumulate in an orderly fashion, from quality to delivery to flexibility to cost. The so-called ‘sand cone’ effect was used to describe this ordering of capabilities. Variants of the sand cone model were described anecdotally by Womack et al. (1990) and theoretically by Wacker (1996). The sand cone effect was observed in aggregate cross-sectional samples of North American manufacturers (Miller and Roth 1988; Roth and Miller 1992) as well as within the high-tech industrial sector (Roth and Chapman 1993). Roth and Giffi’s (1995) longitudinal analysis of North American manufacturers provides some empirical evidence of causality between the proposed sequence of capabilities: manufacturers can improve along more than one competitive capability at the same time, but not all capabilities can be improved at the same rate, given assumptions of precedence. Specifically, Roth and Giffi (1995) reported that on average, between 1987 and 1995 North American manufacturers improved at the fastest rate on quality, followed by delivery reliability and delivery speed.

Research by Safizadeh et al. (2000), Flynn and Flynn (2004), and Noble (1995) suggests that contingencies, such as process choice (e.g., job shop, batch, line flow, and continuous flow), geographic region, and the industry studied may influence the observed sand cone effect. Building on research by Porter (1996), Skinner (1996a,b), Clark (1996), Hayes and Pisano (1996), and Schmenner (1997) among others and consistent with CPT (Roth 1996a,b), Schmenner and Swink (1998) conceptually integrate the tradeoff and sand cone models using the lens of performance frontiers, defined as the maximum performance that can be achieved by a
manufacturing unit, given a set of operating choices. Proponents of this integrative framework contend that where an organization is positioned relative to their performance frontier determines whether the tradeoff model or sand cone model holds (see e.g., Lapre and Scudder 2004).

In particular, tradeoffs among capabilities are more likely to occur when manufacturers are operating near their performance frontier, because further improvements are initially constrained by the limits of the organization’s technological assets. Note that in this case, reaching the performance frontier is similar to reaching the end of what Roth (1996a,b) calls an innovation cycle. After moving to another process innovation cycle, manufacturers have the potential to, in time, reach a position superior to competitors on multiple capabilities. Alternatively, when competing manufacturers are positioned further from the performance frontier, an organization can, at the outset, simultaneously provide higher levels of product quality, delivery, and flexibility at lower cost compared to competitors based upon its selected set of operational choices (Hayes et al. 2004).

2.2. Towards a Theory of Manufacturing Strategy

In theory building and testing, there is a need to first examine the “whats” in terms of precise construct definitions (Churchill 1995). Three of the four manufacturing capability constructs used in the CPT (conformance quality, delivery reliability, and low cost) have been clearly defined in prior related literature (see e.g., Dostaler 2001; Ferdows and De Meyer 1990); see Appendix for measures. The literature offers many variants of flexibility (Flynn and Flynn 2004; Gerwin 1993; Giffi et al. 1990). For example, Ferdows and De Meyer (1990) define flexibility as ‘speed of new product development’ while Noble (1995) uses a broad-based flexibility measure that includes items related to product customization and frequency of product mix and volume fluctuations. Flexibility in the CPT is specifically cast in terms of volume flexibility, which is consistent with traditional manufacturing strategy (see e.g., Hayes and Schmenner 1978; Hayes and Wheelwright 1979) where the “…volume base [is] so essential to efficient manufacturing” (Hill 1989, p. 61). Volume flexibility serves as a basic element of demand management and captures the manufacturer’s ability to effectively increase or decrease aggregate production levels (Gerwin 1993; Gupta and Somers 1996; Jack and Raturi 2003; Koste and Malhotra 1999).

Using these precise competitive capability construct definitions, we draw from Roth’s (1996a,b) CPT of knowledge-based competencies to deepen our understanding of “why” the tradeoff and sand cone models may coexist in different situations. Clearly, one way of explaining competitive advantage is through accelerated organizational learning, as expressed by the knowledge-based view (KBV) of the firm (Argote 1999; Grant 1996; Kogut and Zander 1992). Another explanatory factor pertains to the statistical variation inherent in all processes. Statistical variation is known to be associated with non-value-added costs due to unpredictability and waste in work processes (Anderson, Rungtusanatham, and Schroeder 1994; Blocher, Garrett, and Schmenner 1999; Giffi et al. 1990; Kerkhoff, Edgar, and Utterback 1998; Schmenner and Swink 1998; Wacker 1996).

The CPT offers a capability-based improvement path that is expected to create competitive advantage by accelerating organizational learning over an innovation cycle. The CPT holds that sustainable competitive capabilities are built cumulatively, from conformance quality to delivery reliability to volume flexibility to low cost, because (like in the sand cone metaphor) moving up each step in the model requires more learning than in the earlier steps. Operational know-how, reflected by the absorptive capacity to value, assimilate, and apply new knowledge, sheds light on the precedence constraints and sequencing observed among capabilities in the progression (Cohen and Levinthal 1990; Leonard-Barton 1992). Organizational learning is path dependent, for what a firm has done in the past tends to predict what it can do in the future (Clark 1996; Corbett and van Wassenhove 1993; Hayes 1992; Hayes and Pisano 1996; Hayes et al. 2004; Kogut and Zander 1992).

Extrapolating from this, Roth (1996a,b) argues in the CPT that the ability to evaluate and utilize knowledge is largely a function of the level of prior related process knowledge. Each stage of the progression calls for increasingly higher levels of process integration and coordination, beginning with the shop floor and expanding to the supply chain. In particular, the relative operational know-how derived from improved process capabilities at the plant/function level due to conformance quality efforts branches outward to the supplier and distribution system processes with the delivery reliability capability, to cross-functional and customer processes with volume flexibility improvements, and finally, to spanning entire supply chain processes with low ‘delivered’ cost. As manufacturers move through the proposed progression of competitive capabilities, operational know-how is expanded with the mastering of each stage of process complexity. At the end of an innovation cycle as manufacturing approaches the performance frontier, operating systems become technologically constrained. In turn, a manufacturer would typically face diminishing returns from investments in new knowledge on their existing processes.

Learning theories associated with statistical variation also come into play in explaining how manufacturers simultaneously achieve strength on multiple competitive capabilities, regardless of what capabili-
ties were ‘intended’ or prioritized as important. Statis-
tical variation in work processes is associated with heterogeneity in inputs, transformations, and/or out-
puts that may be related to differences in materials,
procedures and systems such as expediting and use of
buffer inventory, worker skills, changing customer
demands, etc. (Blocher et al. 1999; Kerkhoff et al. 1998;
Schmenner 1997; Schmenner and Swink 1998; Schroe-
der, Flynn, Flynn, and Hollingworth 1996; Wheel-
wright and Bowen 1996). Roth (1996a, p. 565) explains
the observed association among the generic capabili-
ties by what she calls the laws of operations physics:

“Operations physics offers a theoretical basis for the
observed simultaneity of benefits accruing in the pro-
gression. . . . From statistical theory on process control,
we know that process variance can be partitioned into
common and special cause variation. Each process has
natural tolerance limits, which specify its inherent ca-

capability to conform to external requirements (Deming
1987). Imagine now that generic capabilities [confor-
mance quality, delivery reliability, volume flexibility, and
low cost] tend to share overlapping work processes.
This property implies “physical” process co-variance.
By analogy, a basic tenet of competitive progression
theory is this: the work processes associated with cre-
ating any single generic capability can be partitioned
into one of two categories: (1) unique, or capability-
specific process properties . . . and (2) interdependent
properties, or process commonalities. Clearly, changing
one capability will automatically impact the others. The
cumulative magnitude of the impact will vary by the
degree of process commonality, or overlap; and the
direction is related to process synergy. . . . Each newly
acquired, or enhanced generic capability can act syner-
gistically to modify other capabilities with which it
shares common processes.”

To the extent that firms are constrained at the perfor-
mance frontier, more common variance is under ‘con-
trol’ and unique variance remains to be exploited.
Thus, initial tradeoffs can exist. The path dependen-
cies and simultaneity of benefits among the competi-
tive capabilities are explored in more detail below.

3. The CPT Model and Hypotheses

3.1. Accruing Combinatorial Capabilities
Roth (1996b, p. 38.15) concludes that the pursuit of
conformance quality comes first in the competitive pro-
gression because it “affords effective and efficient
approaches to process variance reduction [i.e., pro-
duces consistent output]. . . .” Quality management
(QM) is broadly defined as a set of tools, action plans
and principles aimed at reducing defects and impro-
ving processes (e.g., Deming-Shewhart Plan-Do-Check-
Act initiatives, kaizen or continuous improvement, ISO
9,000/14,000, and six sigma). QM serves as a primary
building block for gaining process knowledge to man-
ufacture products that consistently conform to specifi-
cations (Corbett and Kirsch 2001; Giffi et al. 1990;
Ittner, Nagar, and Rajan 2001; Wheelwright and Bo-
wen 1996). Through increased communication, dia-
logue, and the sharing of expertise, QM-related prac-
tices enable employees to gain new social skills along
with improved functional and technical expertise.

Achieving consistently high conformance quality
often requires a high degree of control over the pro-
cess, and is therefore a driver for subsequent capabil-
ity-based improvements (Corbett and van Wassenh-
suggest that successful firms concentrate their early
program targets first on achieving ‘fitness for use’
quality to control lead-time variances. Essentially, as
conformance quality increases, the number of items
requiring rework subsequently decreases, and materi-
als can then move more swiftly and consistently
through a process (Flynn and Flynn 2004; Flynn et al.
1997; Kerkhoff et al. 1998; Roth 1996a,b; Schmenner
and Swink 1998). These increasingly predictable cycle
times allow for more dependable production schedul-
ing, which in turn results in more reliable delivery
dates. Thus, more formally stated:

H1a. An enhanced conformance quality capability influ-
ences improvements in delivery reliability directly.

Yet dependable production scheduling is also contin-
gent upon reducing uncertainty with regards to cus-
tomer requirements and the timing of raw material
and component deliveries (Wacker 1996). Although
partially dependent on conformance quality, the
strengthening of the delivery reliability capability in
practice typically requires a broader degree of process
specificity (Roth 1996a,b). Relationship-building initi-
aves such as supplier certification, just-in-time (JIT)
mansuring, and customer integration, for exam-
ple, necessitate the sharing of technical information
and process knowledge cross-functionally and along
the supply chain with suppliers, distributors, and cus-
tomers (Flynn and Flynn 2004; Gupta and Lonial 1998;
Kogut and Zander 1992; Voss and Winch 1996). By
transferring and acquiring this information and
knowledge across organizational boundaries, manu-
facturers can subsequently reduce variance in their
delivery processes and improve the predictability of
the production and distribution systems.

The relationship-building activities initiated during
the second stage of the competitive progression facil-
itate not only delivery reliability, but also influence
improvements in volume flexibility (Corbett and van
Wassenhove 1993; Gupta and Somers 1996). Several
researchers have suggested that the development of a
volume flexibility capability may require close coordi-
nation between a manufacturer and its suppliers, par-

ticularly in the face of increasing demand (Jack and
Raturi 2002; Vickery, Calantone, and Droge 1999). Often due to the suppliers’ increased willingness to absorb demand fluctuations or to provide slack capacity, this close coordination allows manufacturers to more readily change production volumes without incurring high transition penalties or large changes in performance outcomes (Gerwin 1993; Gupta and Somers 1996; Jack and Raturi 2002; Koste and Malhotra 1999). More formally stated:

H1b. An enhanced delivery reliability capability influences improvements in volume flexibility directly.

If the organization is unable to meet due dates under normal circumstances, then it will almost certainly be unable to react flexibly to unforeseen volume fluctuations in demand (Corbett and van Wassenhove 1993). A volume flexibility capability efficiently breaks down many of the remaining barriers between manufacturers and their customers, as customer relationships deepen with the depth of information sharing and the degree of process integration across entities (Hill 1989). For example, we observed manufacturers like Frito-Lay, Inc. being more proactive and responsive to fluctuating demand by exchanging insights with customers regarding volume flexibility improvements and/or by scheduling overtime in advance. As a result, responsiveness to fluctuating and uncertain demand and, ultimately, market penetration can be improved further (Gupta and Somers 1996; Roth 1996b). A firm is said to be more volume-flexible if it can respond to both increases and decreases in aggregate demand at the same rate as its competitors, but at a lower cost (Gerwin 1993; Gupta and Somers 1996; Jack and Raturi 2003; Koste and Malhotra 1999). For example, the greater the ability of the firm to absorb volume fluctuations in demand, the lower the amount of safety stock required to meet the desired level of service, and consequently the lower the total cost (Jack and Raturi 2003). Similarly, Koste and Malhotra (1999) propose that an enhanced volume flexibility capability reduces production costs. Importantly, it is the variable cost of making the volume changes that determines volume flexibility rather than the fixed cost of providing the capability. This leads to the following hypothesis:

H1c. An enhanced volume flexibility capability influences cost improvements directly.

The potential for a sustained low manufacturing cost capability improves after moving through the prior three stages of the progression. Manufacturers who prioritize low cost must first understand the sources of product and process variation, establish deliberate strategies for accelerating organizational learning, and leverage enterprise processes (Corbett and van Wassenhove 1993; Gupta and Lonial 1998; Lapre and Scudder 2004; Roth 1996a,b; Voss and Winch 1996; Wheelwright and Bowen 1996). At this stage in the progression, the task becomes how to attain additional cost reductions, such as reduction of fixed manufacturing costs across the supply chain. As Ferdows and De Meyer (1990, p. 175) note, “A manufacturing capability developed in such a cumulative manner is likely to be more deeply ingrained in deep organizational abilities, [and] hence will be more lasting.” Otherwise, total cost reduction tactics may actually hollow out long-term competitiveness. For example, cost reduction strategies such as layoffs may produce quick bottom-line improvements, but they can also cripple an organization in the long run (White 1996). Note however, that short-term or initial tradeoffs, such as cost for quality are not necessarily inconsistent with the CPT because, in the long-term, the laws of operations physics will prevail.

The hypotheses specified above capture the direct effects of improving a given capability on the capability succeeding it in the progression. Yet the laws of operations physics suggest that reducing the statistical variation in one capability may automatically reduce the variation in the others due to shared (or common) process variance. This indicates that the form of these benefits may be indirect as well. More formally:

H2a. Conformance quality has an indirect, positive effect on volume flexibility through an enhanced delivery reliability capability.

H2b. Conformance quality has an indirect, positive effect on low cost through enhanced delivery reliability and volume flexibility capabilities.

H2c. Delivery reliability has an indirect, positive effect on low cost through an enhanced volume flexibility capability.

3.2. Linking Combinative Capabilities and Organizational Learning

The CPT posits that increases in both individual and organizational knowledge, or operational know-how, will coincide with enhanced generic competitive capabilities over an innovation cycle. In a learning environment, multifunctional experience is encouraged so that less-impeded flows of information can aid learning (Argote 1999; Kerkhoff et al. 1998; Kogut and Zander 1992; Leonard-Barton 1992). Likewise, employees with varied job experiences often bring to the table new ideas about how to make improvements or new ways to understand problems. While individual knowledge is an indispensable condition for organizational learning, it is not a sufficient condition-organizational learning results only when individual insights and skills are embedded in organizational routines, practices, and beliefs (Argyris 1977; Grant...
1996; Kerkhoff et al. 1998; Nonaka 1994). We offer the following hypotheses:

H3A. Increases in conformance quality have a positive influence on operational know-how.

H3b. Increases in delivery reliability have a positive influence on operational know-how.

H3c. Increases in volume flexibility have a positive influence on operational know-how.

H3d. Increases in the low cost capability have a positive influence on operational know-how.

The CPT also posits reductions in non-value-added related to inherent process unpredictability and anything that adds waste, such as moving, cataloguing, inspecting, counting, or reworking materials (Roth 1996a,b; Schmenner and Swink 1998). Essentially, the lower the random variability—either inherent in the process capability itself or in the items processed—the more efficient the process is (Blocher et al. 1999; Schmenner 1997). For example, overproduction, or producing more than market requirements, is often regarded as the most severe form of waste because it inhibits the smooth flow of goods and accompanying services (Kerkhoff et al. 1998; Schonberger 1986). Overproduction results in extra materials being consumed, extra paperwork, and more machine time used that “unnecessarily leads to extra inventory which in turn will require extra handling, extra space, and will require extra capital and increase opportunity costs” (Samaddar and Heiko 1993, p. 15). Moving through the proposed progression of competitive capabilities better equips manufacturers to produce defect-free products at the quantity desired by the customer at the time needed, which reduces the need for overproduction and ultimately decreases non-value added. More formally stated:

H4a. Increases in conformance quality reduce non-value-added.

H4b. Increases in delivery reliability reduce non-value-added.

H4c. Increases in volume flexibility reduce non-value-added.

H4d. Increases in the low cost capability reduce non-value-added.

Operational know-how itself is also expected to influence non-value-added, leading to what Argyris (1977) calls ‘double loop learning.’ Underlying process assumptions, norms and objectives are open to debate in double loop learning. In this case, the organization is not just concerned with learning how to do given tasks better, or single loop learning, but also with learning what tasks are even worth doing (Argyris 1977; Kerkhoff et al. 1998; Mukherjee, Lapre, and van Wassenhove 1998). Lapre, Mukherjee, and van Wassenhove (2000) highlight the need for creating new knowledge in dynamic production environments in order to adapt to new situations and to ultimately reduce waste. A strong knowledge base essentially enables manufacturers to remove obstacles in work processes and to yield new standard operating procedures, such that production can be simplified further (Leonard-Barton 1992; Lapre et al. 2000; Kerkhoff et al. 1998; Mukherjee et al. 1998; Schmenner and Swink 1998; Schonberger 1986). Therefore, as operational know-how increases, CPT posits an accelerated reduction of non-value-added. More formally:

H5. Enhanced operational know-how reduces non-value-added.

3.3. Linking the CPT to Business Performance
Manufacturers with superior operational know-how get more out of their inputs than peers because they have greater insight into managing particular activities or sets of activities and generally eliminate wasted efforts (Grant 1996; Leonard-Barton 1992; Porter 1996; Vickery et al. 1994). Hayes and Upton (1998, p. 8) assert, “Superior operations effectiveness not only serves to buttress a company’s competitive position, but, when based on capabilities that are embedded in the company’s people and operating processes, is inherently difficult to imitate. . . . it can provide the basis for a sustainable competitive advantage.” Hence, the following two hypotheses are added for model validation:

H6. Enhanced operational know-how positively influences profitability.


4. Research Design
4.1. Research Database
The database used in this research is part of a larger ongoing study, namely, the Vision in Manufacturing Project (VIM). VIM is an industry-academic research project that has been conducted biennially by Deloitte Consulting and researchers at the Kenan-Flagler Business School at the University of North Carolina since 1989 (see Roth, Gray, Singhal, and Singhal 1997 for details of the study). In addition to more traditional manufacturing strategy data, the 1997 survey used in this research gathered data on competitive capabilities and performance from manufacturing firms worldwide, and contained over 900 items with a mix of perceptual and objective data.

The data-gathering procedures were designed and executed by professional, independent survey research organizations, following general procedures
outlined in Dillman (1978). Gallup Organization, a renowned research organization, assisted with the overall study design, sample frame of databases of global public companies, and provision of contact names. The sampling frame was carefully checked and supplemented with individual country lists where gaps existed. The final sampling frame of business units was constructed from companies representing the top 25 percent in sales in 35 countries, covering both established and emerging markets. To ensure adequate representation, a probability sample stratified by broad industrial sectors (automotive, chemicals, pharmaceuticals, consumer products, high-tech, and aerospace) and geographic region was deployed. Professional translators first translated surveys in foreign languages followed by bilingual businesspeople in each country. Multilingual interviewers conducted telephone follow-ups to ensure adequate regional and industry coverage. The overall survey response rate was 10 percent, with a total sample size of 867 respondents.

The manufacturing business unit (MBU) represents the unit of analysis and is defined by the level in the organization at which the manufacturing strategy is formulated for the primary product (Ferdows and De Meyer 1990; Miller and Roth 1988, 1992, 1994). The corresponding respondents were senior manufacturing executives who typically held the title of Vice President or Director of Manufacturing. A prescreening of corresponding respondents generally followed the procedure outlined by Mitchell (1994) to ensure that corresponding respondents regularly participated in their MBU’s manufacturing strategy formulation processes. Corresponding respondents were asked to gather data from their management teams and present their teams’ collective views relative to their manufacturing and supply chain strategies for the MBU’s primary product in their target market.

4.2 High-Tech Subsample
This study focuses on manufacturers who compete in the global high-tech industrial sector, which comprised 13.7 percent \( n = 119 \) of the 867 survey respondents. Of the 119 high-tech firms involved in the study, 38 were removed from the data set due to missing data across the variables of interest. The remaining 81 firms were used in the analysis. We chose this particular industrial sector for testing the CPT for three reasons. First, unlike in most prior related research, a set of firms facing similar environmental conditions was chosen to reduce confounding of results (Cool and Schendel 1987; Ritzman and Safizadeh 1999). Sample SIC codes from the 1997 VIM study that describe the high-tech industrial sector include computers/office machines (3570) and electrical and electronic equipment (3600). Although these manufacturers share many commonalities, they do not necessarily compete for the same customers, nor do they employ the same manufacturing processes. We recognize, nonetheless, that the use of a single sector limits generalizability, which we leave for future research to investigate.

Second, fast clockspeed environments, such as the high-tech industrial sector, are frequently associated with shorter innovation cycles and environmental uncertainty (Dostaler 2001; Fine 2000; Pagell, Melynk, and Handfield 2000). Faced with such environmental dynamism, high tech firms have typically been exposed to TQM, JIT, and/or time-based competition, and have often installed advanced manufacturing technologies (AMT). According to Pagell et al. (2000, p. 69), “The introduction and acceptance of such developments as Just-in-Time production (JIT) and Total Quality Management (TQM) have resulted in situations in which the expected trade-offs [among multiple competitive capabilities] have not been observed.” Similarly, Lefebvre, Langley, Harvey, and Lefebvre (1992) assert that use of AMT generates a wide range of benefits, including higher quality, more reliable delivery, greater flexibility, and reduced costs.

Third, research by Pisano and Wheelwright (1995) and Chang, Lin, Wea and Sheu (2002) highlight the role of manufacturing as a source of competitive advantage in the high-tech industry, and in particular how conformance quality, delivery reliability, volume flexibility, and low cost capabilities link to profitability. Consequently, we felt that this industrial sector would provide a good test set for the CPT.

Profile statistics for our high-tech subsample are provided in Table 1. When compared with a North American sample of high-tech manufacturers from the 1996 Compustat database, the North American portion of our global high-tech subsample (46.9%) is generally representative of the research population on demographic-related items, such as number of employees (size) and sales volume. However, as with the total VIM sample, market leaders dominate the high-tech subsample. Almost 40 percent of the respondents were market leaders holding the number one or two position in their industry for primary products, while over 30 percent were one of the top three or four in the market.

4.3 Measures
With the exception of operational know-how, all measures were operationalized using single items that represent point estimates of each construct. We know of no multi-item scales relating to the theory-based CPT constructs (Roth and Schroeder, Forthcoming). For example, although the VIM database contains Garvin’s (1987) eight dimensions of product quality (conformance, reliability, durability, performance, aesthetics, customer perceived, service, and features), only conformance quality is theoretically consistent with the CPT. Note that Drolet and Morrison (2001) argue that single items can avoid many disadvantages...
of multiple-item scales, in which additional items can undermine respondent reliability and thereby inflate across-item error term correlations. Descriptive statistics, which include the mean, standard deviation and Pearson correlations, are provided in Table 2 (see Appendix for a summary of the VIM survey questions included in the analysis).

Because they are grounded in the operations strategy literature, we believe the CPT constructs to be content-valid. In terms of establishing criterion-related validity, the conformance quality measure correlated positively and significantly \( (p \leq 0.01) \) with Garvin’s (1987) seven other dimensions of quality. Similarly, the delivery reliability and volume flexibility measures correlated positively and significantly \( (p \leq 0.001) \) with the ability to achieve fast-response deliveries and short manufacturing and distribution lead-times. We also found volume flexibility to correlate positively and significantly \( (p \leq 0.01) \) with four of Gerwin’s (1993) dimensions of flexibility (mix, changeover, modification, and material) contained in the VIM survey. As expected, our measure for low cost correlated positively and significantly \( (p \leq 0.001) \) with the firm’s ability to offer lower-priced products than its competitors.

A two-item scale serves as a reasonable proxy for the operational know-how construct. In particular, the overall workforce flexibility variable represents individual knowledge, while the organization’s learning capabilities/knowledge base variable captures organizational knowledge (Grant 1996; Kogut and Zander 1992; Kerkhoff et al. 1998; Leonard-Barton 1992). For each MBU, the statistical average of these two items provides a composite index of operational know-how. The operational know-how scale correlated positively and significantly \( (p \leq 0.01) \) with superior worker technical skills and the ability to achieve fast decision-making and implementation, thereby establishing criterion-related validity.

The total manufacturing indirect costs relative to goals variable serves as a reasonable proxy for ‘reduced’ non-value-added (Kerkhoff et al. 1998; Schonberger 1998; Rosenzweig and Roth: Towards a Theory of Competitive Progression: Evidence from High-Tech Manufacturing Production and Operations Management 13(4), pp. 354–368, © 2004 Production and Operations Management Society 361

Table 1  High-Tech Subsample Profile

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<thead>
<tr>
<th>Geographic Region</th>
<th>N</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>North America</td>
<td>38</td>
<td>46.9%</td>
</tr>
<tr>
<td>Europe</td>
<td>24</td>
<td>29.6%</td>
</tr>
<tr>
<td>Asia-Pacific</td>
<td>17</td>
<td>21.0%</td>
</tr>
<tr>
<td>Latin America</td>
<td>2</td>
<td>2.5%</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of Employees</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 100</td>
<td>9</td>
<td>11.1%</td>
</tr>
<tr>
<td>Over 100 to 500</td>
<td>28</td>
<td>34.6%</td>
</tr>
<tr>
<td>Over 500 to 1000</td>
<td>15</td>
<td>18.5%</td>
</tr>
<tr>
<td>Over 1000 to 5000</td>
<td>20</td>
<td>24.7%</td>
</tr>
<tr>
<td>Over 5000 to 10,000</td>
<td>4</td>
<td>4.9%</td>
</tr>
<tr>
<td>Over 10,000</td>
<td>5</td>
<td>6.2%</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MBU Sales Volume</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Under $50 million</td>
<td>26</td>
<td>32.1%</td>
</tr>
<tr>
<td>Over $50 million to $100 million</td>
<td>11</td>
<td>13.6%</td>
</tr>
<tr>
<td>Over $100 million to $500 million</td>
<td>25</td>
<td>30.9%</td>
</tr>
<tr>
<td>Over $500 million to $1 billion</td>
<td>6</td>
<td>7.4%</td>
</tr>
<tr>
<td>Over $1 billion to $5 billion</td>
<td>7</td>
<td>8.6%</td>
</tr>
<tr>
<td>Over $5 billion</td>
<td>4</td>
<td>4.9%</td>
</tr>
<tr>
<td>No response</td>
<td>2</td>
<td>2.5%</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Market Position: Primary Product</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Market leader</td>
<td>29</td>
<td>35.8%</td>
</tr>
<tr>
<td>Top 3rd or 4th in market</td>
<td>26</td>
<td>32.1%</td>
</tr>
<tr>
<td>Second tier</td>
<td>18</td>
<td>22.2%</td>
</tr>
<tr>
<td>Minor player</td>
<td>8</td>
<td>9.9%</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Customization: Primary Product</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineered-to-order</td>
<td>10</td>
<td>12.3%</td>
</tr>
<tr>
<td>Assembled-to-order</td>
<td>29</td>
<td>35.8%</td>
</tr>
<tr>
<td>Made-to-stock</td>
<td>20</td>
<td>24.7%</td>
</tr>
<tr>
<td>Varies</td>
<td>19</td>
<td>23.5%</td>
</tr>
<tr>
<td>Don’t know</td>
<td>3</td>
<td>3.7%</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 2  Descriptive Statistics for Observed Variables \( (n = 81) \)

<table>
<thead>
<tr>
<th>Variable &amp; description</th>
<th>Mean &amp; std. dev.</th>
<th>( x_1 )</th>
<th>( y_1 )</th>
<th>( y_2 )</th>
<th>( y_3 )</th>
<th>( y_4 )</th>
<th>( y_5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x_1 ): Conformance quality</td>
<td>4.25 .84</td>
<td></td>
<td>.27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y_1 ): Delivery reliability</td>
<td>3.88 1.02 (.02)</td>
<td>.22 (.05)</td>
<td>.42 (.02)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y_2 ): Volume flexibility</td>
<td>3.67 .94 (.00)</td>
<td>.24 (.03)</td>
<td>.26 (.02)</td>
<td>.26 (.01)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y_3 ): Low cost</td>
<td>3.42 1.01 (.03)</td>
<td>.19 (.10)</td>
<td>.29 (.01)</td>
<td>.30 (.01)</td>
<td>.31 (.00)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( y_4 ): Non-value-added</td>
<td>3.17 .92 (.10)</td>
<td>.32 (.00)</td>
<td>.33 (.00)</td>
<td>.49 (.00)</td>
<td>.36 (.00)</td>
<td>.34 (.00)</td>
<td></td>
</tr>
<tr>
<td>( y_5 ): Operational know-how</td>
<td>3.66 .70 (.00)</td>
<td>.32 (.00)</td>
<td>.33 (.00)</td>
<td>.49 (.00)</td>
<td>.36 (.00)</td>
<td>.34 (.00)</td>
<td></td>
</tr>
<tr>
<td>( y_6 ): Profitability</td>
<td>4.26 1.56 (.46)</td>
<td>.08 (.31)</td>
<td>.12 (.11)</td>
<td>.18 (.06)</td>
<td>.21 (.00)</td>
<td>.35 (.00)</td>
<td>.20 (.07)</td>
</tr>
</tbody>
</table>

Notes: Significant Pearson correlation coefficients \( (p \leq .10) \) are in bold. The \( p \)-values are italicized and listed below each correlation.
1986; Schmenner and Swink 1998). This variable is inversely related to non-value-added costs because it is a perceptual measure of the MBU’s performance relative to internal goals over the last three years, measured on a five-point, self-anchoring scale. Total manufacturing indirect costs versus goals correlated significantly \( (p \leq 0.05) \) in the expected direction with a number of criterion-related measures, including percentage of product reworked, material yields, and scrap rates. Finally, the objective measure of profitability correlated positively and significantly \( (p \leq 0.05) \) with market share and sales growth.

4.4. Path Model
We used path analysis to investigate the hypotheses presented in Section 3 and depicted in Figure 2. Use of path analysis enables the researcher to test multiple equations simultaneously and to explore the indirect effects, leading to a truer assessment of the overall equations. Use of path analysis enables the researcher to test multiple equations simultaneously and to explore the indirect effects, leading to a truer assessment of the overall equations and to explore the indirect effects, leading to a truer assessment of the overall equations and to explore the indirect effects, leading to a truer assessment of the overall equations.

5. Results and Discussion
The model was evaluated using LISREL 8.30 software. The resulting CPT model chi-square statistic \( (\chi^2 = 6.78, 7 \text{ df}, p = 0.45) \) indicates excellent overall fit (see Table 3). The chi-square/df test also provides support for model fit, since it is well within the range of ‘good’ fit values, i.e., 0.97 < 3. Supplementary stand-alone fit indices (GFI, AGFI, 1-RMR, 1-RMSEA) as well as the incremental fit indices (IFI, NFI, CFI) shown in Table 3 further corroborate the null hypothesis of overall model fit, since they are generally well above the rule-of-thumb model fit value of 0.90. Finally, the squared multiple correlations \( (R^2) \) for operational know-how, non-value-added and profitability were 0.31, 0.18, and 0.13 respectively, indicating that a fair amount of variance is being explained by the CPT. Taken together, the results provide reasonable evidence that the hypothesized CPT model fits the data well.

Although these test statistics indicate excellent overall model fit, we evaluated two competing models that provided added support for the hypothesized CPT model depicted in Figure 2. The first competing model, which we refer to as the “Direct Effects” model (Bollen 1989), removes the following paths linking the competitive capabilities: (1) conformance quality and delivery reliability \( (\gamma_{11}) \); (2) delivery reliability and volume flexibility \( (\beta_{21}) \); and (3) volume flexibility and low cost \( (\beta_{32}) \). An examination of the Direct Effects Model allows us to more precisely determine whether the CPT model assumptions—positive direct and indirect effects among the competitive capabilities (Hypothesis 1A through 1C; Hypothesis 2A through 2C)—are consistent with the data. Because the CPT and competing model are nested within one another, the chi-square \( (\chi^2) \) difference test can be used to determine the statistical significance of the chi-square estimators of overall model fit (Bollen 1989). The observed \( \chi^2 \) difference test between the two models is highly significant \( (\chi^2 \text{ difference} = 33.37, 10 \text{ df}, p = 0.00) \). This empirical result indicates that the CPT model represents an improvement in fit over the Direct Effects model, as suggested from prior related research and the theoretical arguments of CPT.

Our second competing model, the “Sequencing” model, provides a test for an alternative sequence of competitive capability constructs in which the order of the delivery reliability and volume flexibility capabilities in the progression is switched. In this case, an enhanced volume flexibility capability is expected to improve delivery reliability through an increased adaptability to unforeseen volume-related demand changes (Koufteros, Vonderembse, and Doll 2002;
Table 5 CPT Model Direct, Indirect, and Total Effects of Exogenous and Prior Endogenous Variables—Standardized Maximum Likelihood Parameter Estimates

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Predictor</th>
<th>Parameter</th>
<th>Parameter estimates (C.R.)**</th>
<th>Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y_1$: Delivery reliability ($R^2 = .07$*)</td>
<td>$x_1$: Conformance quality</td>
<td>$\gamma_{11}$</td>
<td>.27 (.50)</td>
<td>H1A</td>
</tr>
<tr>
<td>$y_2$: Volume flexibility ($R^2 = .17$)</td>
<td>$y_1$: Delivery reliability</td>
<td>$\beta_{21}$</td>
<td>.42 (.09)</td>
<td>H1B</td>
</tr>
<tr>
<td>$y_3$: Low cost ($R^2 = .07$)</td>
<td>$y_2$: Volume flexibility</td>
<td>$\gamma_{32}$</td>
<td>.26 (.37)</td>
<td>H1C</td>
</tr>
<tr>
<td>$y_4$: Non-value-added ($R^2 = .18$)</td>
<td>$x_1$: Conformance quality</td>
<td>$\gamma_{41}$</td>
<td>.03 (.28)</td>
<td>H4A</td>
</tr>
<tr>
<td>$y_5$: Operational know-how ($R^2 = .31$)</td>
<td>$y_1$: Delivery reliability</td>
<td>$\beta_{51}$</td>
<td>.14 (1.18)</td>
<td>H4B</td>
</tr>
<tr>
<td>$y_6$: Profitability ($R^2 = .13$)</td>
<td>$y_2$: Volume flexibility</td>
<td>$\beta_{62}$</td>
<td>.11 (.91)</td>
<td>H4C</td>
</tr>
<tr>
<td></td>
<td>$y_3$: Low cost</td>
<td>$\beta_{63}$</td>
<td>.18 (1.70)</td>
<td>H4D</td>
</tr>
<tr>
<td></td>
<td>$y_4$: Operational know-how</td>
<td>$\beta_{65}$</td>
<td>.16 (1.34)</td>
<td>H5</td>
</tr>
<tr>
<td></td>
<td>$y_5$: Operational know-how</td>
<td>$\beta_{64}$</td>
<td>.32 (2.89)</td>
<td>H7</td>
</tr>
<tr>
<td></td>
<td>$y_6$: Non-value-added</td>
<td>$\beta_{64}$</td>
<td>.09 (.85)</td>
<td>H6</td>
</tr>
</tbody>
</table>

* Structural $R^2$ for Y equations for model represented in Figure 2.
** For one-tailed test of significance: C.R. = |1.28|, $p < .10$; C.R. = |1.65|, $p < .05$; C.R. = |2.33|, $p < .01$; C.R. = |3.10|, $p < .001$.

White 1996). Because the resulting stand-alone (e.g., AGFI = 0.89) and incremental (e.g., CFI = 0.97) fit statistics for this second competing model are generally lower than the CPT model, the Sequencing model represents no significant improvement in overall fit.

5.1. Evidence of Combinative Capabilities
Hypotheses 1A through 1C posit that competitive capability improvements are attained in a progression. In support of these three hypotheses, the $\gamma_{11}$, $\beta_{31}$ and $\beta_{32}$ parameter estimates are all positive and significant ($p \leq 0.01$) (see Table 4). As predicted, these multivariate results provide empirical evidence supporting the observed sequencing in CPT theory.

By considering the indirect effects posited in Hypotheses 2A through 2C, we can derive a more complete understanding of the underlying structure of hypothesized relationships among generic capabilities and their combined influence on accelerated learning, which has not been previously observed. Table 5 shows that conformance quality indirectly influences volume flexibility ($p = 0.05$) through enhanced delivery reliability capability, and it indirectly influences the low cost manufacturing capability ($p = 0.10$) through enhanced delivery reliability and volume flexibility capabilities. These results support H2A and H2B, respectively. In support of H2C, the results indicate that delivery reliability has an indirect, positive effect on low cost ($p = 0.05$) through enhanced volume flexibility capability. Taken together, the results supporting H1A through H2C provide some additional evidence for the prior observed sand cone model, demonstrating on average the path dependencies and observed simultaneity of capability benefits accruing in the progression.

Given the projected ordering of improvement efforts and the results from tests of H1A through H2C, one would expect the conformance quality capability mean

Table 5 CPT Model Direct, Indirect, and Total Effects of Exogenous and Prior Endogenous Variables—Standardized Maximum Likelihood Parameter Estimates

<table>
<thead>
<tr>
<th>EFFECT OF...</th>
<th>Delivery reliability ($y_1$)</th>
<th>Volume flexibility ($y_2$)</th>
<th>Low cost ($y_3$)</th>
<th>Non-value-added ($y_4$)</th>
<th>Operational know-how ($y_5$)</th>
<th>Profitability ($y_6$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct</td>
<td>Indirect</td>
<td>Total</td>
<td>Direct</td>
<td>Indirect</td>
<td>Total</td>
</tr>
<tr>
<td>Conformance quality ($x_1$)</td>
<td>.27***</td>
<td>.27***</td>
<td>.11**</td>
<td>.11**</td>
<td>.03*</td>
<td>.03*</td>
</tr>
<tr>
<td>Delivery reliability ($x_2$)</td>
<td>.42***</td>
<td>.42***</td>
<td>.11**</td>
<td>.11**</td>
<td>.14</td>
<td>.11**</td>
</tr>
<tr>
<td>Volume flexibility ($x_3$)</td>
<td>.26***</td>
<td>.26***</td>
<td>.11</td>
<td>.12**</td>
<td>.23**</td>
<td>.37***</td>
</tr>
<tr>
<td>Low cost ($x_4$)</td>
<td>.18**</td>
<td>.04</td>
<td>.22**</td>
<td>.21**</td>
<td>.21**</td>
<td>.09**</td>
</tr>
<tr>
<td>Non-value-added ($x_5$)</td>
<td>.32***</td>
<td>.32***</td>
<td>.16*</td>
<td>.16*</td>
<td>.09</td>
<td>.06</td>
</tr>
<tr>
<td>Operational know-how ($x_6$)</td>
<td>.16*</td>
<td>.16*</td>
<td>.09</td>
<td>.06</td>
<td>.15*</td>
<td></td>
</tr>
</tbody>
</table>

Note. One-tailed test of significance; *$p \leq .10$; **$p \leq .05$; ***$p \leq .01$; ****$p \leq .001$. 
score to be the highest, then delivery reliability, next volume flexibility, and finally low cost (Flynn et al. 1997). This, in fact, is the case, for the competitive capability mean scores are in sequence order (see Table 2) as previously observed in related prior sand cone model research. Note that the means within each pairwise comparison of the progression are statistically significantly different from one another, with conformance-quality-delivery reliability ($p \leq 0.01$), conformance quality-volume flexibility ($p \leq 0.01$), conformance quality-low cost ($p \leq 0.01$), delivery reliability-volume flexibility ($p \leq 0.05$), delivery reliability-low cost ($p \leq 0.01$), and volume flexibility-low cost ($p \leq 0.10$).

But are there contingencies with the CPT? Do these results hold across various primary geographic regions (Flynn and Flynn 2004; Noble 1995; Roth 1996b) and process choices (Safizadeh et al. 2000) as well? As noted by Safizadeh et al. (2000, p. 111), “Controlling for process choice or other measures of dependency goes a long way in uncovering consistency across different theories and empirical studies in operations management.” Given our relatively small sample size and subsequent lack of statistical power, we are unable to explore multi-group analyses indicating how primary region (North American, European, Asian-Pacific) and process choice (job shop, batch shop, production line, and continuous flow plants) might influence the path analyses or mean score statistical results.

Following Safizadeh et al. (2000), we explored the relative order, i.e., pattern of the capability means within each primary region and process choice type. As observed across multiple industries (Roth 1996b), the high-tech competitive capability mean scores are in the expected progression order for North American, European, and Asian-Pacific high-tech manufacturers, respectively, indicating that the progression holds on average across geographic regions. A similar pattern analysis of capability means was conducted for the four process choices. Note that all but one of the four process choices—jobs shops—followed the proposed sequence of competitive capability building. A binomial test provides some evidence of the predicted pattern of means across process types on average: the probability associated with “at least 3 successes out of 4 trials” is significant, albeit weak ($p = 0.065$). For job shops, however, we found a reversal in the expected order of the delivery reliability and volume flexibility means.

In job shops, greater managerial emphasis is often given to volume flexibility and “moving” bottleneck operations are commonplace. Drawing from the CPT, bottlenecks impose some technological constraints on resource deployment in a job shop, and may act like a performance frontier where initial trade-offs are theoretically possible. Furthermore, the knowledge acquisition processes and the degree and nature of shared variance among work processes could differ in job shops, as they are often comprised of independent work centers with multi-routing and sequencing capabilities. Differences in the patterns of knowledge creation, retention, and transfer may contribute to differences in the rates at which organizations learn (Argote 1999). The performance impact of job shops not following the expected competitive capability progression is intriguing and remains a subject for future research.

5.2. Influence of Combinative Capabilities on Organizational Learning
We found strong support for $H_3a$ through $H_3o$, as demonstrated by the direct and indirect effects of each competitive capability on operational know-how (see Table 5). As predicted by the CPT, conformance quality directly ($y_{51} = 0.17; p \leq 0.05$) and indirectly (IE $= 0.07; p \leq 0.05$) increases the stock of operational knowledge through enhanced delivery reliability, volume flexibility, and low cost capabilities. The effect of the delivery reliability capability on operational know-how is indirect (IE $= 0.18; p \leq 0.01$) through enhanced volume flexibility and low cost capabilities. Volume flexibility strength has a strong, direct effect ($\beta_{52} = 0.37; p \leq 0.001$) on operational know-how, as well as a weaker indirect effect (IE $= 0.05; p < 0.10$) through the low cost capability. Finally, the low cost manufacturing capability was found to have a direct, positive effect ($\beta_{53} = 0.21; p \leq 0.05$) on operational know-how.

Hypotheses 4a through 4d posit that enhanced competitive capabilities reduce non-value-added in the form of improved relative total manufacturing indirect costs to goals. Hypothesis 5 proposes a relationship between operational know-how and reduced non-value-added. As predicted by the CPT, low cost capabilities have a positive, direct effect on the proxy for non-value-added ($\beta_{43} = 0.18; p \leq 0.05$) (see Table 5). Interestingly, none of capabilities preceding low cost in the progression-conformance quality, delivery reliability, and volume flexibility-have a direct effect on the non-value-added proxy. Instead, the effects of each of these competitive capabilities on the proxy for non-value-added are indirect.

In particular, in support of the CPT, conformance quality has an indirect effect (IE $= 0.09; p \leq 0.05$) on the proxy for non-value-added through enhanced delivery reliability, volume flexibility, and low cost capabilities, and through operational know-how. The delivery reliability capability influences the non-value-added proxy indirectly (IE $= 0.11; p \leq 0.05$) through enhanced volume flexibility and low cost capabilities and increased operational know-how. Volume flexibility has an indirect effect (IE $= 0.12; p \leq 0.05$) on the proxy for non-value-added through enhanced low cost capability and operational know-how. Finally, operational know-how has a weak, direct effect ($\beta_{45} = 0.16; p \leq 0.10$) on the non-value-
added proxy, which provides some support for H5. Taken together, the results imply that the direct effects of the conformance quality, delivery reliability and volume flexibility capabilities, respectively, are perhaps not enough in themselves to reduce non-value-added directly. Rather, with the exception of low cost capability, their effects are indirect.

5.3. Impact of Organizational Learning on Profitability

We only found partial support for Hypothesis H6: the total effect of operational know-how on profitability is positive, but weak (TE = 0.15; p ≤ 0.10) (see Table 5). Nonetheless, while many exogenous factors influence profitability, these results imply that high-tech manufacturers possessing a strong knowledge base do seem to improve their odds at attaining superior profits because they reduced non-value-added. As expected from theory, we found strong support for Hypothesis H7. The proxy for reduced non-value-added-improved relative total manufacturing indirect costs to goals-has a strong, positive effect on profitability (β₆₄ = 0.32; p ≤ 0.01).

5.4. Limitations and Areas for Future Research

This research has several limitations. First, like many other empirical studies in operations management, the VIM data collection was based on a single coordinator due to the issues of time and cost (Ritzman and Safizadeh 1999). Data collected from multiple informants increases the reliability and validity of self-reports. However, it is unlikely that the VIM survey responses suffer from an individual’s unique perspective and/or limited access to information because the informants coordinated responses from the top management team (Miller and Roth 1994; Mitchell 1994). Likewise, the potential for common methods variance is minimized given the 1997 VIM survey design-items operationalizing the constructs were not in close proximity to one another on the 900-item survey. Follow-up field studies in prior years using the same format showed minimal measurement bias due to a common instrument. The inclusion of an objective measure of business performance-profitability—as a dependent variable in the CPT model further diminishes the potential for common methods variance. Although the VIM study design and our CPT model took prudent and adequate steps to minimize single informant bias, we nonetheless recognize it as a limitation to the study.

A second limitation is the relatively low response rate coupled with the sample size (n = 81), which may impact the validity and generalizability of the research findings. Yet we found no evidence for non-response bias, and the 1997 VIM study response rate is similar to other surveys of this length and nature (see e.g., Narasimhan, Jayaram, and Carter 2001). Moreover, the survey methods were consistent with Dillman (1978) and implemented under the aegis of Gallup, a professional research organization. Our findings, while valid, are primarily applicable to high-tech manufacturers holding the number one or two positions in their primary markets. However, in tests of the data for market-leader effects, none were found. It is possible that our results might differ for those high-tech manufacturers serving a small niche or modest share of the market: this remains a subject for future research. Future research should also replicate our analysis of the CPT model using a larger sample. Along these lines, future research should test the CPT model at the plant level—the proposed relationships among the capabilities are likely to be stronger if performance across individual plants within an organization varies significantly.

Third, the use of cross-sectional data limits the discussion of causality, which requires longitudinal research. Yet, we drew upon the literature, company visits, and our research objectives to predict the inter-relationships among the variables. Prior empirical results indicate that the path dependency of generic competitive capabilities generally holds over time (Roth and Giffi 1995). Thus, our use of cross-sectional data to test the hypothesized model, given plausible theoretical development, is consistent with conventional research practices (see e.g., Bollen 1989).

A fourth limitation is that item availability in the 1997 VIM database and the construct specificity required by the CPT caused us to operationalize the majority of our constructs using a single item. While multi-item scales also have limitations (see Drolet and Morrison 2001), our single items may suffer from measurement error. Future research should focus on developing reliable and valid multi-item scales for all constructs such that measurement error can be explicitly assessed. Moreover, future research should investigate how alternative operationalizations of each competitive capability dimension, such as ‘performance’ quality or ‘product mix’ flexibility, influence the results (Flynn and Flynn 2004; Gupta and Somers 1996). While clearly related to volume flexibility (Jack and Raturi 2003), mix flexibility, for example, may be more complex to manage and is often associated with multiple cost structures.

By addressing each of these opportunities for future research, we can continue to refine our understanding of the complex sequence of combinatorial capabilities first posed over fifteen years ago. Along these lines, future research might investigate how these generic capabilities translate into other capabilities such as new product development and supply chain integration (Skinner 1996a). Voss and Winch (1996), for example, identified quality, delivery, and price as the most common manufacturing-based, order-winning criteria in their sample of fifteen U.K. metal manufacturing organizations, while at the same, conclude that...
world class manufacturers emphasize new product development as a key competitive priority.

Finally, we suggest future research replicate the study across multiple industries to determine whether the CPT holds across fast clockspeed and ‘snail-speed’ business environments alike (Fine 2000; Flynn and Flynn 2004). The results from testing the CPT model using a sample of automotive manufacturers (n = 71) from the 1997 VIM study indicate that while the essential part of the model holds in terms of combative capabilities and organizational learning, the model breaks down in terms of how these competitive progression theory elements link to profitability—we found no significant direct, indirect, or total effects linking the elements of the competitive progression to profitability. Skinner (1996b) and Hayes (1992) conclude that a sole reliance on fundamentals-like the generic capabilities investigated in this research—achieves competitive advantage for only a short period of time. Accordingly, we suspect that the elements of CPT may have a more complex effect on business performance in more mature industrial sectors like the automotive sector because organizations in these sectors typically differentiate from one another on things like design, brand, image, etc., rather than on the core manufacturing-based capabilities of the competitive progression (Corbett and van Wassenhove 1993; Fine 2000; Flynn et al. 1999).

6. Conclusions
In this research, we replicate and extend the empirically observed sand cone model (Nakane 1986; Ferdows and De Meyer 1990) through the lens of Roth’s (1996ab) competitive progression theory. Using precisely defined constructs and an empirical model that specifies a nomological net of constructs and their interrelationships, we employ appropriate psychometric techniques to establish their tentative reliability and validity (Churchill 1995). Plausible explanations related to "why" firms can ultimately improve profitability are embodied in a series of hypotheses regarding the manner in which generic competitive capabilities are accumulated, and how improvements in each capability then relates to organizational learning theory and reductions in non-value-added. In contrast to prior research on the sand cone model, we use path analysis to test the hypothesized relationships simultaneously, allowing for the assessment of both the direct and indirect effects, and then empirically demonstrate the influence of the competitive progression on an objective measure of business performance.

The multivariate results reveal that manufacturers can, on average, increase strength on generic competitive capabilities simultaneously, when pursued in the specific progression as posited by the CPT: first conformance quality, followed by delivery reliability, volume flexibility, and finally, low cost. Our empirical findings generally support the paradigm that the development of one generic manufacturing capability need not necessarily be at the expense of another. One exception appears to be linked to job shops, which is generally consistent with the findings of Safizadeh et al. (2000). In future research, the exact form and structure of the CPT across process types should be investigated using multiple group analysis in structural equation modeling to test our speculation that constraints in a job shop environment may mimic a performance frontier. Beyond the job shop, further exploration of how a firm’s positioning from/along the performance frontier—where system-based and resource constraints may exist—might influence its learning processes and business performance is warranted as well. Note that the CPT proposes a specific path for moving to the performance frontier potentially faster than competitors. However, because it is based on average effects, CPT does not necessarily provide for positioning along the frontier, nor does it deal with the competitive capabilities of any individual firm at specific points in time. Longitudinal research on performance improvement paths, like that recently conducted by Lapre and Scudder (2004) using quality and cost data from the airline industry, is needed to gain a deeper understanding of the conditions by which manufacturers can simultaneously improve upon the full range of generic capabilities explored in this research. As noted by Lapre and Scudder (2004), however, lack of available, reliable data presents a major challenge in studying these performance improvement paths.

A final contribution of this paper is that it provides evidence that the CPT model (Figure 2) matters, at least for the relatively fast-paced, high-tech sector. Our CPT model offers a more parsimonious representation of the data when contrasted with two competing models that link competitive capabilities with performance. In particular, our results indicate that the form of the relationship between competitive capabilities and profitability is indirect through operational know-how and reduced non-value-added.

Acknowledgments
We thank the three anonymous referees, the Associate Editor, and the Editor-in-Chief for their valuable comments, which have considerably improved the paper. The authors are also grateful to Deloitte and Touche for their role in the data collection.
Appendix: Measures Used in the Path Analysis

Competitive capability measures:
Listed below are critical success factors for competing in an industry. Please indicate how strong you feel your business unit is for each capability relative to your primary competitors in the same markets.

<table>
<thead>
<tr>
<th>Capability</th>
<th>Lower</th>
<th>Average</th>
<th>Market Leader</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conformance quality</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Reliability of delivery times (on time)</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Ability to rapidly change production volumes</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Manufacture products at lower internal costs than competition</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Operational know-how measure:
Listed below are critical success factors for competing in an industry. Please indicate how strong you feel your business unit is for each capability relative to your primary competitors in the same markets.

<table>
<thead>
<tr>
<th>Capability</th>
<th>Lower</th>
<th>Average</th>
<th>Market Leader</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall workforce flexibility</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Organization’s learning capabilities/knowledge base</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Non-value-added measure:
About how has your business unit performed against internal performance measures over the past 3 years?

<table>
<thead>
<tr>
<th>Performance Level</th>
<th>Poor Performance</th>
<th>Okay/Met Goals</th>
<th>Exceptional Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total manufacturing indirect costs</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Profitability measure:
What was your business unit’s profit level (before taxes) for the most recent fiscal year?

<table>
<thead>
<tr>
<th>Profitability Level</th>
<th>Negative</th>
<th>Break even</th>
<th>Up to 5% profit</th>
<th>Over 5% to 10%</th>
<th>Over 10% to 15%</th>
<th>Over 15% to 25%</th>
<th>Over 25%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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