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Conducting Academic Research with an Industry Focus: Production and Operations Management in the High Tech Industry

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"The impact of high tech products on people's everyday lives is immeasurable. High tech products keep people safer and healthier, enable them to be more productive at home and on the job, and contribute to a better quality of life. Whether it's medicine or national security, education or agriculture, environment or entertainment, the high tech industry is omnipresent and is inextricably linked to the advancement of modern society."

(American Electronics Association 2003, p. 1)

1. Motivating Focus on a Specific Industry

Historically, knowledge in professional disciplines has developed through topically focused research grounded in the relevant discipline. The management discipline in general and the production and operations management discipline in particular are no exception. The field of production and operations management has evolved over the years through research focused in areas such as production and inventory control, facilities location and layout, operations strategy, quality management, new product development, technology management, service operations, supply chain management, international operations, and e-business. Hence, it is natural that this flagship journal of the Production and Operations Management Society is organized in departments predominantly centered on major topics in the production and operations management field. Further, we the scholars of production and operations management who publish in and review for *Production and Operations Management* and other sister journals of the field, when declaring our individual specialty and expertise, generally do so in terms of these topics or an even more refined version of them, in terms of methodological expertise, or in terms of some combination of both. Finally, our knowledge dissemination vehicles (i.e., production and operations management textbooks, courses, and executive education programs), too, are largely organized by such topics. In sum, the "supply side" of the field of production and operations management, consistently organizes and brands knowledge creation, reporting of scholarly expertise, and knowledge dissemination with a topical focus.

Patterns in the consumption and application of production and operations management knowledge on the "demand side" of the field are less obvious. If we are committed to advancing the production and operations management profession and practice (cf., Bennis and O'Toole 2005), it is imperative that we understand how production and operations management knowledge is being consumed and applied so as to effectively map the field's supply side to its demand side. To learn about how the consumption and application of production and operations management knowledge is organized, we looked outside the academic community at the community of management consultants and technology vendors and examined how they organize their specialties. Management consultants with production and operations management expertise (e.g., PRTM [http://www.prtm.com/], McKinsey [http://www.mckinsey.com/], Booz Allen and Hamilton [http://www.boozallen.com/]), and technology vendors of supply chain solutions (e.g., i2 [http://www.i2.com/], SAP [http://www.sap.com/], Oracle [http://www.oracle.com/]) share with production and operations management scholars a common interest in knowledge creation, dissemination, consumption, and application. While it is reasonable to assume that knowledge creation is the forte of scholars, knowledge synthesis, dissemination, consumption, and application are often the forte of management consultants and technology vendors. In fact, consumption and application of production and operations management knowledge is critical to the survival and sustained success of management consultants and technology vendors of supply chain solutions.

How do management consultants and technology vendors organize their specialties? They organize not only by function and disciplinary topic, but also by industry sector. Booz, Allen and Hamilton, for example, includes change management, innovation, operations, outsourcing advisory services, program management, supply chain management, and strategy among the topics on which it focuses, and aerospace and defense, healthcare, high tech, media and entertainment, pharmaceutical and medical, and telecom and networks among the industries it serves. Pittiglio, Rabin, Todd, and McGrath (PRTM), a firm focused more narrowly on operations in the high tech sector, includes strategy, product development, operations and supply chain management, customer service and support, marketing and sales, and strategic information technology management as its services and offers them to a variety of high tech industry sub-sectors including aerospace and defense, computers and peripherals, electronic equipment and distributors, medical devices and diagnostics, pharmaceutical and biotechnology, semiconductors and components, software, and telecommunications. Organizing by industry sector, in addition to organizing by function and disciplinary topic, provides management consultants and technology vendors an effective way to map how knowledge is created and disseminated (i.e., the supply side) to how knowledge is consumed and applied (i.e., the demand side).

Industry trade associations similarly show a focus on industry specific problems and solutions. In a short web search, one can find a wide range of industry-focused associations that provide information and services targeted to narrow populations of manufacturers. Examples include The Steel Manufacturers Association, Association of Home Appliance Manufacturers, Association of American Publishers, British Furniture Manufacturers Ltd., and Australian Mines and Metals Association. That such institutions not only exist, but thrive, provides additional evidence of the desire for industry based information.

The choice of industry focus on the "supply side," however, is not the only evidence of important differences among industry sectors. That there are systematic differences with respect to investigating issues or phenomenon pertaining to a particular management discipline becomes readily and intuitively visible in empirical studies where data are collected from organizational units across more than one industry. In these studies, for example, we observe the use and significance of indicator variables as proxies to capture aggregate industry effects in model specifications.

The Sloan Foundation's (http://www.industry.sloan.org/) significant investments in setting up industry centers in universities across the country also suggest that it is important for scholars to understand and investigate issues facing specific industry sectors. These industry centers have brought together faculty colleagues and graduate students from multiple disciplines and provided them with opportunities to collectively address problems of the industry. Many management scholars and, more specifically, production and operations management scholars have taken advantage of the Sloan Foundation industry centers and used specific industries as their empirical research settings to advance the frontiers of knowledge in their respective disciplines. Some of these colleagues include: Roger Bohn (University of California at San Diego) and associates studied the information storage industry; Charles Fine (Massachusetts Institute of Technology) and associates studied the motor vehicle industry; Marshall Fisher (University of Pennsylvania), Janice Hammond (Harvard University), Ananth Raman (Harvard University) and associates studied the textile/retail industry; Robert Leachman (University of California at Berkeley) and associates studied the semiconductor industry; K. K. Sinha (University of Minnesota) and associates studied the food industry.

Nonetheless, the outlets for knowledge dissemination (i.e., journals and conferences) in the field of production and operations management remain predominantly topically and sometimes methodologically focused. Notable exceptions include a special issue of *Manufacturing & Service Operations Management* (2004) on the food and agribusiness industry sector and a symposium sponsored by the National Science Foundation (2004) on supply chain management in process industries held at the University of Minnesota. While other industry-focused research has produced many publications usually in the form of individual papers or presentations, few are aggregated in focused special issues or symposia.

2. Focus on High Tech Industry

The AeA, formerly the American Electronics Association (2003), a well-known and well-established trade association representing the high tech industry defines high tech as including 45 different Standard Industrial Classification (SIC) codes in the following sub-sectors:

- High-tech manufacturing
  - Computers and office equipment
  - Consumer electronics
  - Communications equipment
  - Electronic components and accessories
  - Semiconductors and related devices
  - Industrial electronics
  - Photonics
  - Defense electronics
  - Electro-medical equipment
- Software and computer-related services, including:
  - Software services
  - Data processing and information services
  - Rental, maintenance, and other computer-related services
- Communications services including radiotelephone, telephone, and telegraph communications, as well as cable and other pay television services.

This list does not include the biotechnology, engineering services, and research and testing services sectors of the high tech industry, as they do not yet have established or meaningful SIC codes.

This special issue of *Production and Operations Management*, focused on the high tech industry, follows on the 2002 Annual Meeting of the Production Operations Management Society that we organized and chaired in San Francisco. The theme for the Annual Meeting, initiated by Robert H. Hayes and Aleda Roth, then President and President-elect, respectively, of the Production and Operations Management Society, was "High Tech Production and Operations Management." The meeting attracted not only scholars but also many high tech industry professionals, and highlighted the opportunities and challenges of conducting research in the context of high tech industry. The papers presented at the meeting by attendees from around the globe demonstrated that production and operations management in the high tech sector is a vibrant area of research that is not only theoretically grounded and methodologically rigorous, but also has significant practical relevance. Table 1 lists some session titles that illustrate our point. Our motivation for launching this special issue was to begin systematically showcasing and organizing advances in production and operations management research relevant to high tech manufacturing, service and supply chain operations. T1

What makes production and operations management research in the context of high tech industry both challenging and exciting is that the product and process technologies tend to be complex and cutting edge; product, process and production facility lifecycles tend to be short; the markets for high tech products tend to be global, dynamic and intensely competitive; and, as the quote that begins this article suggests, technology from this industry is likely to have a significant and long-term effect on our everyday lives. In many ways, high tech operations are prototypical of future operations (Jayanthi and Sinha 1998), as many of the issues and challenges high tech industry faces today are the same issues and challenges other industries will face tomorrow. History bears this out: High tech industry led the way in learning about and coping with fast-paced product development and introduction (Eisenhardt and Tabrizi 1995), outsourcing and procurement management (Amaral, Billington, and Tsay 2004), and adoption of environmental principles across globally distributed supply chains (Rosen, Bercovitz, and Beckman 2001). Finally, the sheer volume and variety of issues facing the high tech industry is so vast that this industry sector provides a large enough turf on which both current and would-be production and operations management scholars, regardless of their topical and methodological expertise and persuasion, can play and be productive.

Table 1 Examples of High Tech Industry Related Session Topics at the 2002 Annual Meeting of the Production and Operations Management Society

Paper sessions	Panels and plenary sessions
• Managing the High-Tech Supply Chain	• Supply Chain Management at Hewlett Packard
• e-Business and Supply Chain Management	• Global Software Outsourcing: The Case of India
• Technology and Strategy	• High Tech Services
• Implementing the Toyota Production System in Semiconductor Manufacturing	• Hewlett Packard's Portfolio Approach for Managing Procurement Risk
• SLIM—Short Cycle Time and Low Inventory in Manufacturing at Samsung Electronics Corporation	• Operations Strategy: Challenges of Intel's Move into Communications
	• Evolution of Electronics Manufacturing Services with Solectron

The Special Issue: Call for Papers and the Review Process

In the call for papers for the special issue, we defined the high tech industry sector to include semiconductor, computer hardware and software, electronics, biotechnology, and aerospace operations. We hoped that the special issue would be unique in eliciting papers that were at the intersection of one or more production and operations management topic areas and the high tech industry context. We also welcomed manuscripts based on any methodological approach—analytical, empirical, case and field studies, or some combination thereof—appropriate to the problem at hand.

The call for papers yielded 25 manuscripts. We reviewed and evaluated each manuscript for fit with the objectives of the special issue and for the theoretical and methodological rigor necessary for publication in *Production and Operations Management.* Based on this review, 9 of the 25 manuscripts were either returned to the author(s) with detailed comments or forwarded to the *Production and Operations Management* editor for consideration for a regular issue of the journal. The remaining 16 manuscripts were sent out for review. Each manuscript was evaluated by 2 to 3 reviewers who had the relevant topical and methodological expertise. Reviewers evaluated the manuscripts for theoretical and methodological rigor as well as relevance to the high tech industry. Nine of the 16 manuscripts went through 1 to 3 rounds of revision before they were finally accepted for publication. After the 9 papers were accepted, authors of the accepted papers were asked to cross-reference each others' work if and where it was appropriate. The authors readily agreed to this request and, as a result, we have a special issue which is as much of an integrated whole as it can be.

3. Special Issue Contents and Coverage

The papers in this special issue address a wide range of topics using a mix of analytical and empirical research methodologies. The broad topics covered include: new product development (e.g., clockspeed, new product development performance, and inter-functional collaboration); manufacturing operations (e.g., changeover flexibility, capacity planning, quality management, and set up time reduction); service operations; and supply chain operations (e.g., capacity reservation contracts and supplier selection). Each paper is either motivated by or based on analysis of data collected from a range of high tech industries. Table 2 summarizes the papers in the special issue showing the topics covered, research methods employed and the relevant industry context. We turn now to each of the general topics covered and a brief description of what the special issue contributes. T2

New Product Development

Among the defining characteristics of the high tech industry is its dynamic nature (Eisenhardt and Tabrizi 1995). The clockspeed of an industry is now a well-accepted measure of the evolutionary lifecycle that captures the dynamic nature of the industry (Fine 2000). Carrillo (2005), in "*Industry Clockspeed and the Pace of New Product Development,*" establishes the relevance of clockspeed to the new product development process (NPD). NPD clockspeed is defined as the rate of introduction of generations of new products into the marketplace and is treated as an aggregate measure of decisions made by the constituent firms in an industry. Via an analytical model, Carrillo explores the link between firm level decisions and industry

Table 2 Topical Coverage, Research Method, and Industry Context Relevant to the Papers in this Special Issue

Papers in the special issue by author name(s)	Topical coverage	Research method	Industry context
Carrillo	New product development: clockspeed	Analytical	Personal computer and aerospace
Mallick and Schroeder	New product development: performance and inter-functional collaboration	Empirical	Computer equipment, medical devices, communication equipment, and consumer electronics
Gaimon and Morton	Manufacturing operations: changeover flexibility	Analytical	Semiconductor, disk drive, and pharmaceutical
Karabuk and Wu	Manufacturing operations: capacity planning	Analytical	Semiconductor
Yeung, Cheng, and Lai	Manufacturing operations: quality management	Empirical	Electronics
Trovinger and Bohn	Manufacturing operations: set up time reduction	Empirical	Telecommunication
Chakaravarthy and Agnihothri	Service operations: after sales support service design, server flexibility	Analytical	Electronics
Erkoc and Wu	Supply chain operations: capacity reservation contract	Analytical	Semiconductor
Deng and Elmaghraby	Supply chain operations: supplier selection	Analytical	Electronics and aerospace

NPD clockspeed. Using illustrative examples of two high tech industries, she identifies the drivers of fast clockspeed (e.g., personal computer) and slow clockspeed (e.g., aerospace).

The dynamic nature of the high tech industry heightens the importance of being successful in NPD, and thus the appropriate and accurate measurement of NPD performance. NPD performance measurement is made particularly challenging by its largely cross-functional and multidimensional nature (e.g., Griffin and Page 1996), particularly in high tech firms. Mallick and Schroeder (2005), in "*An Integrated Framework for Measuring Product Development Performance in High Tech Industries,*" develop a three-stage model: The first stage focuses on R&D costs and time to market (i.e., budget and schedule); the second stage focuses on the product's technical performance and unit cost (i.e., value of the product to the customer); and the third stage focuses on market share and return on investment (i.e., commercial success). The framework is unique in that it integrates the different functional perspectives of research and development, manufacturing, marketing, and finance in a single model. Furthermore, the framework captures the temporal significance of the relevant metrics as the product development process advances from one stage to another. The empirical context in which the framework is verified is high tech assembled goods, including computer equipment, medical device, communication equipment, and consumer electronics.

Manufacturing Operations

Some high tech firms, notably those supplying semiconductors, telecommunications equipment, and disk drives, build short life cycle products in high volumes. For such firms, flexibility to reconfigure production facilities is fundamental to successfully launching new products in the marketplace on a sustainable basis. Lengthy changeover or start-up time to prepare a dedicated production facility for the manufacture of a high volume product can significantly delay a firm's market entry or new product introduction. Gaimon and Morton (2005), in "*Investment in Facility Changeover Flexibility for Early Entry into High Tech Markets,*" develop an analytical model to address the one-time strategic decision of a high tech manufacturing firm's investment in changeover flexibility of a single facility, establishing the link between market opportunities and manufacturing capabilities. The insights obtained from the model include: the value to a firm of developing more efficient process technology by, for example, working with its equipment suppliers; the effect of volume based learning capability on a firm's investment in facility flexibility and its pricing policy; and how a firm can realize long term competitive advantage with an early market entry strategy by operating a less efficient facility that affords its greater flexibility in responding to new market opportunities.

Capacity-allocation problems in semiconductor fabrication facilities are extremely challenging due to long production lead times, high demand uncertainty and decentralized demand management. Many custom semiconductor manufacturers market application specific integrated circuits (ASICs) to a wide variety of industries, such as telecommunications, consumer electronics, and computers, with drastically different demand characteristics. These firms often organize their business units according to industry sectors. Within each business unit, demand management authority is delegated to product managers (PMs) who are responsible for a certain line of products. PMs have the most accurate information on demand for the products they manage, as they interact with customers on a regular basis. Firms with such structures require incentive systems that motivate PMs to reveal true observed demand so that wafer fabrication facilities may reallocate capacity dynamically and accurately to meet changing market conditions in the tactical planning process. On the other hand, to meet corporate governance requirements for budgetary and fiduciary accountability, the firm must retain the strategic capacity planning structure, allocating capacity to each PM for planning purposes up front, knowing that the allocation may change later. Karabuk and Wu (2005), in "*Incentive Schemes for Semiconductor Capacity-Allocation,*" develop a game theoretic model to improve efficiency in overall capacity-allocation at the same time addressing the decision makers' (PMs') incentives. Specifically, they propose an incentive scheme that elicits private information from the PMs while implementing the optimal capacity-allocation to maximize the firm's expected profits. The incentive scheme can potentially be implemented through adjustments in the executive bonus system commonly used in semiconductor firms.

Germane to any production facility is the issue of managing quality. The issue assumes heightened significance for production facilities of high tech manufacturing firms located in developing nations that are becoming an integral part of global supply chains. Yeung, Cheng, and Lai (2005), in "*An Empirical Model for Managing Quality in the Electronics Industry,*" develop and empirically test an integrated framework for quality management for high tech manufacturing operations characterized by intense competition, high complexity, and strong volatility. The empirical context of this research is the production facilities of electronics manufacturing firms in the Pearl River Delta (PRD) region of Guangdong Province in China. The electronics industry in the PRD region is heavily export oriented and operates in a free and fiercely competitive global market. The electronics manufacturers in the PRD region are largely original equipment manufacturers (OEMs) or original design manufacturers (ODMs) with major customers (or parent firms) in the U.S., Japan, and Europe. The framework proposed has four modules: leadership, cultural elements, operational support systems, and process control and improvement. Key insights from the empirical analysis include: modules create a series of chain effects on organizational performance, rather than acting as parallel elements with an equal impact; and process management and customer focus dominate other factors in impacting business performance.

Finally, printed circuit board assemblies (PCBAs) are the basic building blocks of electronics products, and affect almost all sectors of the high technology industry. Even the biotech sector is integrating circuit technology with its products at such firms as Affymetrix (http://www.affymetrix.com). In many PCBA shops, up to 50% of effective capacity is lost to setups. This, in turn, has a detrimental effect on production downtime, capacity, quality, and costs. Hence, reduction of set up time is a key challenge in electronics manufacturing operations. Trovinger and Bohn (2005) address this challenge in "*Setup Time Reduction for Electronics Assembly: Combining Simple (SMED) and IT Based Methods*" using the "single minute exchange of dies" (SMED) methodology. SMED was originally developed by the legendary Shigeo Shingo (1985) and applied effectively to metal fabrication processes with documented evidence of reducing setups from hours to less than ten minutes. The empirical setting of this study is the PCBA operation of a major telecommunications firm. The paper demonstrates the application of SMED integrated with modern information technology (e.g., wireless terminals, barcodes, and relational databases) to reduce PCBA setup times by more than 80 percent, translating into direct savings of $1.8 million per year for the production facility.

Service Operations

High tech manufacturing firms now recognize that customers' purchase decisions are based not only on the value of the product, but on the services and support associated with the product as well. Profit margins on products are often lower than profit margins on services and support, heightening the importance of effective service and support for products of high tech manufacturing firms. Chakravarthy and Agnihothri (2005), in "*Optimal Workforce Mix in Service Systems with Two Types of Customers,*" develop an analytical model based on their observations of the after sales support operations of a leading supplier of high tech capital equipment to the electronics industry. The organization has sales, service, training, and parts distribution centers around the world. The model considers a service system with two types of customers and multiple servers who are either specialists or cross-trained, quantifies flexible capacity and shows that capacity can be gained by replacing dedicated servers by flexible ones. The net gain in capacity decreases, however, as the fraction of flexible servers increases, suggesting that total flexibility is not always the best choice once service and customer downtime costs are considered. From a practical standpoint, the paper provides guidelines that can be used by managers to determine the conditions under which full versus limited flexibility should be chosen.

Supply Chain Operations

In the semiconductor industry, aggressive capacity expansion to attain superior service or higher revenues and/or preempt competitors can expose a firm to significant financial risk. The cost of building a wafer fabrication plant can range from $500 million to $3 billion; planning, construction and ramp of a new facility can take 4 to 5 years; and during that time, demand can deviate as much as 80% from the original market forecast. As a result, semiconductor firms often adopt conservative capacity expansion policies that minimize downside risk at the expense of upside potential. This, in turn, can cause a shortfall in supply to those who buy and use semiconductors in their products (e.g., original equipment manufacturers (OEMs)). Capacity reservation contracts where the semiconductor manufacturer (supplier) shares the risk of capacity expansion with its OEM customer (the buyer) are a potential solution to this problem. Erkoc and Wu (2005), in "*Managing High-Tech Capacity Expansion via Reservation Contracts,*" use analytical modeling to propose reservation contracts for short life-cycle, make-to-order high tech products under stochastic demand. They establish conditions under which capacity reservation is beneficial to both the supplier and the buyer and establish the relevance of capacity reservation in the context of high tech manufacturing. They also identify situations in which capacity reservation contracts can be used as a means of channel coordination.

In high tech manufacturing industries, such as electronics and aerospace, a supplier can significantly influence the final quality of a buyer's product through its technological capabilities, skilled workforce, delivery performance, and product reliability. Supplier quality, willingness to invest in new technology, and flexibility in responding to the marketplace and buyer demands are critical for the ultimate success of the buyer-supplier relationship. To effectively identify high quality suppliers and provide them incentives to improve their quality, the United States Department of Defense initially parallel sources materials or components from a mix of new and incumbent suppliers, an approach used by many firms in the high tech industry as well. The buyer observes supplier quality and distributes its business among suppliers by increasing its reliance on observed high quality suppliers, and reducing or terminating its business with the low quality suppliers. In effect, by awarding greater portions of its business to high quality suppliers, the buyer creates a tournament in which the suppliers compete for the "prize"—i.e., a larger share of the buyer's business. Deng and Elmaghraby (2005), in "*Supplier Selection via Tournaments*," develop an analytical model to establish the optimal tournament duration under various market settings. The numerical experiments in the paper characterize the optimal length of the parallel sourcing period as a function of supplier characteristics and identify a variety of supplier settings where parallel sourcing dominates sole sourcing with a high quality supplier.

4. Future Directions

While the special issue covers a lot of ground with respect to a variety of production and operations management topics in the high tech industry context, it is at best a humble beginning. Below, we comment on topics that must be addressed in the future. These comments are based on what we did *not* see in this special issue as well as upon the thoughts of experts from academia and industry.

What We Did Not See

First, our call for papers did not elicit any studies focused on the biotech, pharmaceutical, or medical industry sectors. While research in these sectors has been published in related journals (e.g., Blau, Pekny, Varma, and Bunch 2004; Ding and Eliashberg 2002), and is represented in work by major contributors to our general field (e.g., Henderson 1994; Henderson and Cockburn 1996; Pisano, Bohmer, and Edmondson 2001), we found no publications in recent issues of *Production and Operations Management* and very few overall directly related to production and operations management. Given the growth and significance of the biotech, pharmaceutical, and medical industry sectors around the globe, it is imperative that we begin to identify and address the unique production and operations management challenges faced by these industry sectors.

Second, we did not see studies focused on issues pertaining to start-up and scale-up of high tech operations. That we did not see such research submitted to this special issue is ironic in that many firms in the global high tech industry sector are in start-up or scale-up stages of operations. However, the field of production and operations management has been focused mainly on issues relevant to larger, more established firms. Literature at the intersection of the fields of production and operations management and entrepreneurship is sparse and fragmented at best, and hence, presents a significant opportunity that is waiting to be exploited.

Finally, given that this was an industry focused special issue, we were surprised that very few practitioners submitted work either as sole authors or coauthors. This may be due to, first and foremost, a communication problem. In all likelihood, the call for papers for the special issue did not reach the relevant practitioner communities. Compared to other fields of the management discipline, production and operations management is at least as successful in promoting the kind of collaborative research between scholars and practitioners that Van de Ven and Johnson (2005) refer to as "engaged scholarship" (cf., Voss 2005). However, we can and must do significantly better. It is perhaps worthwhile exploring and considering opportunities to forge strategic partnerships between professional societies, such as the Production and Operations Management Society, and industry groups or trade associations to provide an overarching institutional framework for collaborative endeavors. Cooperation between academe and industry for the creation, dissemination, consumption, and application of industry-focused knowledge is perhaps the best means to rapidly advance the theory, profession, and practice of production and operations management.

Some Thoughts from the Experts

In addition to our observations on the conference and special issue, we also asked a number of leaders in high tech production and operations management research and practice to share their thoughts on critical issues facing the high tech industry sector today. A keynote speaker at the 2002 Annual Meeting of the Production and Operations Management Society on "High Tech Production and Operations Management," two academic leaders, and an industry representative responded. They describe the challenges of operating in a global environment, the struggles with structuring supply chains to operate in that environment and the increasing need to design and manage service operations, even in the manufacturing sector. Here is what they shared:

Robert H. Hayes (Harvard University) sets the stage: "Over the past decade, we have witnessed the collision of several forces: outsourcing, information technology/global communications, and the astonishing ability of countries that we used to think of as "developing" (and therefore unable to quickly master advanced product and process technologies) to participate fully in both implementation and development of high technology. As a result, we must pay a lot more attention to the management of distributed (i.e., multi-site) operations and technology development, and particularly those that take place in remote parts of the world." See Hayes, Pisano, Upton, and Wheelwright (2005) for more details.

Corey Billington, Vice President of Supply Chain Services at Hewlett-Packard Company at the time of his keynote address, thinks about the dynamics of the global economy as well and specifically addresses the management of global supply chains. His work today focuses on "procurement of services and outsourcing, how modularity creates real options in the supply chain, testing a hypothesis that modularity changes the technology life cycle and procurement's role in innovation." See Amaral, Billington, and Tsay (2004) for more details. Billington adds the important notion that many of the activities firms now manage are not within the bounds of the organization, but rather may be managed by many different firms.

Brian Cargille, Design for Supply Chain Program Manager at Hewlett-Packard concentrates his organization's work on developing and implementing programs that improve firm performance in the face of the many challenges set forth by dynamic and changing global networks. His concerns are: "product design for supply chain when done with original design manufacturer (ODM) partners, technical approaches for making tradeoffs in variety control, commonality, reuse, logistics enhancement, postponement, tax/duty, and take-back, as well as developing the incentive structures in contracts that lead ODMs to find and implement these improvements with limited or no oversight from the original equipment manufacturer (OEM)." See Cargille and Kakouros (1999) and Cargille and Bliss (2001) for more details. Cargille's comments take Billington's to an even more concrete level in asking how the decisions of an OEM affect the global operations of a supply chain, and how that OEM can best work with the ODMs in the supply chain to achieve efficient and effective results.

All three of these experts describe a highly dynamic and complex global environment in which high technology supply chains work. Further, they describe the difficulties of making decisions in this environment that can be followed by multiple players whose objectives may or may not coincide, and who reside in different cultures, regulatory environments and markets throughout the world. Although some of the papers in this issue touch upon topics that inform our understanding of this new global dynamic in the high tech industry, none take it on in a holistic way. Considerable research is still needed to understand and provide tools for assessing and managing the problems of this environment.

Aleda Roth (University of North Carolina at Chapel Hill) tackles the topic of service strategy and management. She identifies five critical areas of research for high tech firms who earn an increasing portion of their revenue from services.

- *Service strategy and positioning:* How can high tech firms keep pace with product and service innovation and simultaneously keep their service strategies and concepts aligned with dynamically changing product and markets?
- *Design for customer experience:* How do high tech customers experience the service component of their service bundle, and what is the right mix of tangible goods and intangible services to maximize customer's experience?
- *Customer support:* What is the role of technology mediation in customer support services and what is the appropriate context for captive versus outsourced offshoring of support that touches customers?
- *Service supply chains:* What are the extended customer points of contact (i.e., touch points) in a high tech service supply chain? How can business-to-business (B2B) services be shared among supply chain entities? How should domestic and global sourcing of services be managed?
- *Global service competence:* What are the critical success factors for transitioning a traditional high tech firm culture towards one that is more service oriented? How can globally dispersed high tech firms maintain high levels of service standards worldwide?

Clearly, there is a lot of room for new research on service management in the high tech industry. While Chakravarthy and Agnihothri (2005) touch upon a critical issue for service management—workforce mix—in this issue, there is still much to be done. See Roth and Menor (2003) for further description of the issues.

Putting it all Together

In sum, by focusing on the high tech industry, we find a number of issues that are not well addressed in the production and operations management literature. There needs to be more attention paid to the global and dynamic environment in which operations managers today are making decisions, and to providing models that are inclusive of the complexities of this environment. We need to pay particular attention to the role of start-up and small manufacturing firms in the global supply chains, wherever those firms are located in the world. We need to better understand the biotech, pharmaceutical, and medical sectors of the high tech industry, as they may well have new and different lessons for us to learn. We must acknowledge the critical role of services in providing customer with full solutions and experiences as well as to the revenues of high tech firms. To do all of these well, we must engage more practitioners in our knowledge creation activities.

The high tech industry is one of the most dynamic and exciting industries today. The complexity of its global operations can be overwhelming. To fully understand the industry, with a full sense of the issues it faces and the problems it manages on a day-to-day basis, we must escape our topically focused silos and take an industry-wide view. In doing so, we are likely to find a plethora of important and interesting research questions that remain unaddressed, and opportunities to work more closely with knowledgeable colleagues in industry. We must learn what consulting firms, technology vendors and trade associations have long known—that there are questions, and answers, that arise from comprehensive industry-centric examinations. We owe those to whom we are imparting our research knowledge the chance to learn specifically about the high tech industry in which they do or will work.

5. Acknowledgments

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References

Amaral, J., C. Billington, A. A. Tsay. 2004. Outsourcing production without losing control. *Supply Chain Management Review* November/December **8**(8) 44–52.

American Electronics Association (AeA). 2003. Defining the high-tech industry sector. February. (http://www.aeanet.org/Publications/idmk_naics_pdf.asp).

Bennis, W. G., J. O'Toole. 2005. How business schools lost their way. *Harvard Business Review* (Online version) May (http://harvardbusinessonline.hbsp.harvard.edu/b02/en/hbr/hbrsa/current/0505/article/R0505F.jhtml).

Blau, G. E., J. F. Pekny, V. A. Varma, P. R. Bunch. 2004. Managing a portfolio of interdependent new product candidates in the pharmaceutical industry. *Journal of Product Innovation Management* **21**(4) 227–245.

Cargille, B., R. Bliss. 2001. How supply chain analysis enhances product design. *Supply Chain Management Review.* September/October **5**(5) 64–74.

Cargille, B., S. Kakouros, R. Hall. 1999. Inventory optimization at Hewlett-Packard Company. *OR/MS Today* October **26**(5).

Carrillo, J. E. 2005. Industry clockspeed and the pace of new product development. *Production and Operations Management* **14**(2) 125–141.

Chakravarthy, S. R., S. R. Agnihothri. 2005. Optimal workforce mix in service systems with two types of customers. *Production and Operations Management* **14**(2) 218–231.

Deng, S., W. Elmaghraby. 2005. Supplier selection via tournaments. *Production and Operations Management* **14**(2) 252–267.

Ding, M., J. Eliashberg. 2002. Structuring the new product development pipeline. *Management Science* **48**(3) 343–363.

Eisenhardt, K. M., B. N. Tabrizi. 1995. Accelerating adaptive processes: Product innovation in the global computer industry. *Administrative Science Quarterly* **40** 84–110.

Erkoc, M., S. D. Wu. 2005. Managing high-tech capacity expansion via reservation contracts. *Production and Operations Management* **14**(2) 232–251.

Fine, C. H. 2000. Clockspeed based strategies for supply chain design. *Production and Operations Management* **9**(3) 213–221.

Gaimon, C., A. Morton. 2005. Investment in facility changeover flexibility for early entry into high-tech markets. *Production and Operations Management* **14**(2) 159–174.

Griffin, A., A. L. Page. 1996. PDMA success measurement project: Recommended measures for product development success and failure. *Journal of Product Innovation Management* **13**(6) 478–496.

Hayes, R., G. Pisano, D. Upton, S. Wheelwright. 2005. *Operations, Strategy, and Technology: Pursuing the Competitive Edge.* John Wiley and Sons, New York, New York.

Henderson, R., I. Cockburn. 1996. Scale, scope and spillovers: The determinants of research productivity in drug discovery. *Rand Journal of Economics* **27**(1) 32–59.

Henderson, R. 1994. The evolution of integrative capability: Innovation in cardiovascular drug discovery. *Industrial and Corporate Change* **3**(3) 607–630.

Jayanthi, S., K. K. Sinha. 1998. Innovation implementation in high tech manufacturing: A chaos theoretic empirical analysis. *Journal of Operations Management* **16** 471–494.

Karabuk, S., S. D. Wu. 2005. Incentive schemes for semiconductor capacity allocation. *Production and Operations Management* **14**(2) 175–188.

Mallick, D. N., R. G. Schroeder. 2005. An integrated framework for measuring product development performance in high tech industries. *Production and Operations Management* **14**(2) 142–158.

Manufacturing & Service Operations Management. Special Issue on Food and Agribusiness Sector **6**(3) 2004. Guest editors: Timothy J. Lowe and Paul V. Preckel.

National Science Foundation. 2004. Symposium on supply chain management in process industries. May 6–7. Center for Supply Chain Research, University of Minnesota. (http://www.ie.umn.edu/cscr/nsfmay04.htm/).

Pisano, G. P., R. Bohmer, A. C. Edmondson. 2001. Organizational differences in rates of learning: Evidence from the adoption of minimally invasive cardiac surgery. *Management Science* **47**(6) 752–768.

Rosen, C. M., J. Bercovitz, S. L. Beckman. 2001. Environmental supply chain management in the computer industry: A transaction costs economics perspective. *Journal of Industrial Ecology* **4**(4).

Roth, A. V., L. Menor. 2003. Insights into service operations management: A research agenda. *Production and Operations Management* Summer **12**(2) 145–164.

Shingo, S. 1985. *A Revolution in Manufacturing: The SMED System.* Productivity Press, Cambridge, Massachusetts.

Trovinger, S. C., R. E. Bohn. 2005. Setup time reduction for electronics assembly: Combining simple (SMED) and IT-based methods. *Production and Operations Management* **14**(2) 205–217.

Van de Ven, A. H., P. E. Johnson. 2005. Knowledge for theory and practice. *Academy of Management Review* (forthcoming) January. (http://webpages.csom.umn.edu/smo/avandeven/Vandeven&Johnson%20Know%201-25-05.pdf).

Voss, C. 2005. Engaging practitioners in theory development. Presented at the *Sixteenth Annual Conference of the Production and Operations Management Society*, Chicago, April 30. (http://www.london.edu/assets/documents/PDF/2.3.3.7.5_Chicago_panel.pdf).

Yeung, A. C. L., T. C. E. Cheng, K. Lai. 2005. An empirical model for managing quality in the electronics industry. *Production and Operations Management* **14**(2) 189–204.