Chapter 1

MYTHS AND REALITY OF SUPPLY CHAIN MANAGEMENT: IMPLICATIONS FOR INDUSTRY-UNIVERSITY RELATIONSHIPS *

André Kuper
Hewlett-Packard Company
Palo Alto, California
kuper@hp.com

Bublu Thakur-Weigold
Hewlett-Packard Company
Germany
sarbani.thakur-weigold@hp.com

Abstract

1. Introduction

The current business environment compels managers and researchers alike to focus on asset management. The manufacturing industry's ongoing reliance on supply chain partners to realize economic value has created a global network of dependencies, in which the overall performance is dictated by the weakest link. Moreover, the inexorable evolution of these networks has shifted attention from fixed assets (like manufacturing equipment and buildings), to variable assets (like inventory). It will come as no surprise that supply chain management-the science and prac-

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tice of end-to-end flows-has emerged as a determining factor in business success.

Successful adaptation begins when these shifts are recognized by all stakeholders. Here we address two particular constituencies, those who reflect upon the complex phenomena of supply chains, and those who must manage, and bear the brunt of their quirks. On the one hand, today's business schools and universities face the challenge of appropriately directing investment into the most promising research projects. Their intellectual output will eventually reach a wider audience, however, often with unintended consequences. Seized upon by an insatiable industry of consulting methodologies and management literature, this intellectual property often arrives at the "user" in unrecognizable form. The solutions observed in one particular success story are rapidly packaged into repeatable initiatives or programs, regardless of the business case at hand [1]. On the other hand, managers in industry face mounting pressure to validate the theories and slogans upon which they base fateful operational decisions. The volume of both scholarly and publications and their often distorted popular reductions is daunting: how to translate all these ideas into operational success?

The reality of supply chain management contradicts one of the oldest beliefs shared by both of these parties: with proper management, companies can control their own growth. This assumption seems self-evident and is so fundamental to the raison *d'etre* of MBA training, that it no longer merits discussion. However, a recent interview with the chip company LSI Logic shows that even this apparently unshakeable assumption requires revision: their management states that they cannot afford to build a new production facility on their own[2]. Imagine training a future

[1] In a recent article, the authors come to the conclusion that "In truth, SCM remains more of a pipe dream than a reality." In the article, unfortunately, implementing SCM is stated to be the equivalent of [launching] "a number of initiatives, including efficient consumer response (ECR); vendor-managed inventory (VMI); and collaborative planning, forecasting, and replenishment (CPFR)." The authors proceed to detail some of the barriers and propose actions to overcome the obstacles, some which will require longer time horizons than the business cycle will permit (like "Develop a new breed of manager"). The list of barriers is made without analysis of the ("best") practices which construct them, i.e. no comment is made on the risks of blind faith in one-size-fits all approaches. Although no sick person would mindlessly swallow a pill that once cured a distant relative, common-sense habits of diagnosis and measuring dosage are often lost in the business rush. To their credit, the authors' concluding enjoinder is to "Engage in More Practical and Applied Research!" Moberg, C., Speh, T., and Freese, T. (2003). "SCM: Making the Vision a Reality", *Supply Chain Management Review*, September/October, p34–39.

[2] Decock,B., Page, M., and Flebut, J. (2002), "How to generate a business advantage in a fiercely competitive manufacturing environment," *HP Webcast Series*, August 22, `http://www.on24.com/clients/hp/index.asp?sessionid=14`: The factory will in fact be built by a consortium of suppliers. The role of the manufacturing company in the "center"

executive to deal with dependency, volatility, and lack of knowledge. Contemporary cases like this one abound, mounting evidence that both the practice and theory of operations management could benefit from critical self-examination.

What follows is a symptomatic listing of the most common assumptions that we, at HP, have observed in academic (and subsequently), popular thinking. For those who must face reality daily, the persistence of misrepresentations and myths in supply chain management is striking, not least because there can be no doubt that each of the topics we sketch here is the subject of sustained and serious reflection. This leads us to suggest that something is dysfunctional in the dissemination of academic research into the business world-insights upon which real managers can successfully act[3].

The rupture in this feedback loop is an absurd irony. When asked, scholars will unabashedly confess that the validation of their knowledge in practice is not even an objective; profound and rigorous thought leadership is the "real" goal. When reading an article on management science, one must ask which audience the author implicitly addresses. Can universities be moved to seek more than the self-referential approval of their erudite peers? Is the quality of an innovative MBA course in operations management to be judged by other professors-or might operations managers have input on how to reach the ideal operational state? Can the sometimes-tedious labor of applying knowledge to organizational situations become the subject of intellectual passion? We firmly believe that the answer is yes. The consequences of the contemporary, mutually dismissive estrangement are costly and avoidable: mistaking the theoretical model for reality remains a too-frequent pitfall in a world where expertise is available in overwhelming abundance.

Our objective is to share the what we at Hewlett Packard's "Innovation Diffusion" team have learned in dozens of business-transforming Supply Chain Management projects. This chapter will discuss how to validate theory with business reality and how, in turn, to deploy aca-

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of the supply chain as a determining agent of its structure and flows has been transformed by this innovation of collaborative ownership.

[3]Moberg, C., Speh, T., and Freese, T. (2003). "SCM: Making the Vision a Reality", *Supply Chain Management Review*, September/October, p34-39. The article gave a checklist of factors (many of which require sweeping change with years of costly implementation), for successful implementations, while perpetuating uncritical trust in turnkey initiatives i.e. suggesting that Supply Chain Management will produce measurable business results if only all these actions were exhaustively carried out. The sometimes banal habits of successful supply chain management (identifying your industry's characteristics, network mapping, locating bullwhip triggers, prioritizing business-critical metrics, identifying key stakeholders, then communicating diagnostic results to get buy-in, etc.), do not seem worth mentioning.

demic research[4] to better interpret-and thereby survive-the complexities of business change. It will conclude with a vision of profitable collaboration between the doers and thinkers in management science, drawn from the positive experiences HP has had over the years.

Today's supply chain challenges

Cost is the incessant concern of many managers today, especially in high-tech manufacturing. Following euphoric decades of double-digit growth, we find ourselves in a period of reset revenue expectations. In this industry, the combined factors of stalled growth, high debt load, and the pressure to transform existing business models, demand that cost be eliminated wherever possible. There is an inherent paradox in the challenges that arise, since cost-cutting alone will not necessarily have any meaningful impact, and, simultaneously, the trough is usually the right time for strategic investment. For management, shrewd and swift investment can become agonizingly complex, since the assumptions upon which existing business models were built, are increasingly out of date. Suddenly, business as usual may not be an option[5]. The paradox that our high-tech industry must wrestle with is that if we just cut costs without changing the business fundamentals, we may ignore the realities that made cost an issue in the first place. In the medium- to long-term, cost-cutting, which tends to short-sighted and motivated by immediate returns, must be associated with risk. What we jettison, outsource, sell, and lay-off may well inhibit revenue and profit growth when the market picks up.

For supply chain managers, we face specific risks, with potentially devastating consequences. Ignoring the fact that increased volatility in demand will actually require more inventory-not less[6]-means that cutting stock in the hopes of freeing up capital will ultimately impede sales. In commodity markets like for consumer computers, availability is as critical as low price: a lost sale is a lost customer and bundled with peripheral products, can mean missing years of follow-up revenue. Considering a manufacturer's inherent dependency upon up- and downstream

[4]We do not recommend a surge in professorial consulting start-ups (although some experience of the consequences of academic analysis will benefit research, without doubt).

[5]This is clearly one of the reasons why formulaic, checklist, one-size-fits-all SCM initiatives like VMI, CRM, BTO, etc. cannot reliably work unless they have been identified as the "pill" which should cure the diagnosed illness, within the known boundary conditions.

[6]That inventory is always a liability because it is nothing more than superfluously locked capital is an alarming myth that we battle constantly. It is the rare manager who declares a strategy "to push back the efficiency frontier", rather than simplistically "reduce inventory" on her P & L.

partners, the self-centered habit of passing on costs (in the form of inventory), also weakens our end-to-end supply chains. Typically, these short-term actions will increase the total costs for every party involved, while reducing flexibility. Both outcomes will negatively impact revenue and profitability. Even worse, it might drive partners out of business, and ultimately, destroy a market.

Such can be the consequences of the well-meaning, but poorly-informed, intuitive response. It should demonstrate the urgency of research and business investment into one of our high-tech industry's most pressing topics, the phenomenon of commoditization. Two trends contribute to the commoditization of goods: customer education, and specialization. When customers do not honor the value of a higher quality or better-engineered product by paying more, they render it a commodity. As a consequence, competition for revenue will be based on supply chain attributes like availability and price. Similarly, increased industry specialization has driven the use of commodity platforms like storage, data processing, input devices, displays, and software. This eliminated the possibility of leapfrogging the competition on innovative features, and left players competing on time-to-revenue by pushing generic products with few distinguishing features. In this scenario, in order to compete in commodity markets the supply chains need to be agile, responsive, and create velocity. At the same time, traditional competitive aspects like capacity utilization and economies of scale will, in turn, diminish. In this context, capacity utilization and economies of scale actually reflect a dangerously obsolete assumption: that effective management of fixed assets is a driver for business success. If not critically reappraised, our favorite levers may become constraints to profitability in markets that grant players no second chance[7].

Let us proceed to another subtlety that must be managed in the commodity space. A vendor's ability to meet demand is determined by its cash constraints and by dependencies in the supply chain. In commodity environments, the ramp rates and flexibility of volume are critical to a successful response to demand volatility, and thus the prerequisites to profitability at HP. Our research[8] has shown that product ramp rates are

[7]Lost market share in the high-tech industry when the market shifts is rarely recouped. Who remembers for example the first "portable" computer manufacturer Osborne (See for example Billington, C., Lee, H., and Tang, C. (1998). "Successful strategies for product rollovers" *Sloan Management Review*, Spring, 39(3):23–30.).

[8]See for example A.C. Marquez and C. Blanchar's presentation at INFORMS, Salt Lake City, 2000 entitled "Evaluating Marketing Strategies using System Dynamics Models." Four subsequent HP projects using improved modeling techniques illustrated this phenomenon, in different supply chains, operating in different channels.

constrained by how effectively upstream suppliers obtain access to cash. These financial positions are fairly static, requiring vendors to nurture the health of their own suppliers[9]. An example, the strategic silicon market, whose players are critical suppliers to high-tech manufacturers, demonstrates that industry consolidation is another threat to assurance of supply. In this extremely capital-intensive industry, once, in the zeal of cost reduction, capacity has been cut back, it takes a year or more to install new fabs[10]. Similar trends are discernible in packaging, logistics, plastics, and contract manufacturing.

The common element in all the complex phenomena discussed here is relentless pace of change, and more anti-intuitive dependencies than one might expect. If the boundary conditions of our operations are constantly being revised, any reliance upon benchmarks and successful behavior from the past becomes infeasible. Since the intuitively sound approaches that worked in the past suddenly fail, even experienced managers find themselves at risk. The lack of reliable learning that can be applied to current conditions is also a wake-up call for operations research: an attention to cross-functional, dynamic environments has become critical to economic growth.

Inter-disciplinary research spanning more than two fields is, however, untypical to university projects (whose internal metrics reward specialization and eschew the apparent dilution of disciplines)[11]. To illustrate this let's turn to the topic of capacity utilization. A recent study from Arizona State University[12] claimed that maximum capacity utilization is the right approach for profitable automotive manufacturing. Not only did this theoretical position not raise an academic eyebrow, it is appar-

[9] 1999, HP internal paper

[10] currently a similar capital issue is hampering investment and capacity allocation in the shipping industry where a "pigs cycle" and the "bullwhip effect" are creating delays, distortion, and amplification of responses to demand dynamics: Matthews, R.G. (2003). "A surge in ocean-shipping rates could increase consumer prices", *The Wall Street Journal*, November 4.

[11] Metrics often create undesired behavior. In successive collaborative projects with retailers HP encountered again and again that aligning trucking activities with dock capacity yielded significant costs savings in inventory while improving availability. This is a direct result of the performance metrics of truckers, who are measured on miles driven, not time. This decreases trucking capacity utilization and drives up supply chain costs. Interestingly, industry sees changes to these metrics as threatening, clearly lacking a holistic view of supply chain costs. Machalaba, D. (2003)."Cost of trucking seen rising under new safety rules", *The Wall Street Journal*, November 12.

[12] "Strategic Cost Management in the Supply Chain: A Purchasing and Supply Management Perspective," written by Lisa M. Ellram, a professor of supply management, Bebbling professor of business, Arizona State University, available through CAPS research. See also Ellram, L.M. (2003). "A Prescriptive Model for Cost Management in the Supply Chain," *ASCET*, v5, July 7, `http://www.ascet.com/documents.asp?d_ID=1985`.

ently reflected in current U.S. automotive manufacturing. Carmakers use steep discounts to sell off the mountains of unsold finished goods that will inevitably result from continuous factory output[13]. This strategy is the diametric opposite to those of innovative factories from VW, Porsche, and Mercedes[14]. Virtual, or "solution" factories[15] do more than focusing on flexible response to volatile demand. They go so far as to adapt entire manufacturing processes and associated employee behavior to mobilize the manufacturing function into a customer-centric team. Porsche, for example, dedicates a single worker to the entire production process of a car. HP's server (dubbed Solution) factory differentiates tasks by competence level and uses annualized labor contracts that permit flexibility as precise as one hour, and this in labor markets as intransigent as Germany's.

Myths and realities

Arguably, the most important task of the Innovation Diffusion group at HP is to question the assumptions of managers who ask us to support new programs and projects. In the course of our work, reviewing plans to launch anything from the latest IT solution, to a new logistics or process improvement program, it becomes apparent that a number of myths drive management practice. For all its self-imposed analytical rigor and relentless publication, academic research has done little to make ideas a foundation for feasible action for the very community that is their laboratory. Here is a less-than-exhaustive list of influential, thus dangerous myths that we continue to encounter.

Real-time information. There has been an ongoing craze for real-time information, partly driven by the deployment of powerful information systems and as well as availability of Internet-based information technologies. The reality of most supply chains is, however, that supplier lead times far exceed the cycle times of assembly and test, as well as the typical delivery lead times. These disparate time scales can lead

[13]White, G.L. and Lundegaard, K. (2002). "U.S. auto sales accelerated 13%, Driven by Deals," *The Wall Street Journal*, September 5, pA1.

[14]See for example Anonymous (1999). "Porsche to make new sports utility vehicle in Leipzig," *Automotive Intelligence News*, November 16, p2; Mudd, T. (2000). "Back In High Gear", *Industry Week*, February 21; Smith, T. (2001). "VW factories in Brazil look for export markets", *The New York Times* September 3, pC1.

[15]Kupér, A., Kahn, D., Schmid, H., and Thakur-Weigold, B. (2002) "Delivering solutions to customers: high-velocity manufacturing," *ASCET*, v4, May 16, `http://www.ascet.com/documents.asp?d_ID=998`.

to distorted views on business performance; even worse, they can drive uncoordinated decision-making[16].

As anyone will recall from their Physics 101 lab, sample rates and signal frequency can predetermine or impair our perspective on what is happening. Therefore, when the data entry frequency is erratic (causing us to miss signals), or if the samples are based upon different units of measure, or if they come to view discrete and arbitrary time windows (while we expect them to be continuous and systematic), the data sampling will distort the analysis of actual system behavior[17].

In daily business operations, the data points are typically sparse, and selectively consolidated to reflect quarterly and annual financial performance-hardly the normed laboratory for sound statistical analysis. This illustrates that the striving for real-time information, (presumably in the hope of zooming in on reality faster), in order to improve business results is often misguided. It also begs the question: "How can we exploit this elusive reality to guide business decisions?"

The tool of choice for many businesses eager for real-time insight, uncritically implemented, then baffled by the disappointed return on investment (ROI)[18] is the data warehouse[19]. Well-designed systems or analytic projects fail to bring the expected returns (and the expecta-

[16]Forrester, J.W. (1958). "Industrial dynamics–a major breakthrough for decision makers," *Harvard Business Review*, v36, n4, p37–66. Forrester, J.W. (1971); *Principles of systems*, Wright-Allen Press. See also `http://sysdyn.clexchange.org/sdep/papers/D-4224-4.pdf`; Lee, H. Padmanabhan, V., and S. Whang, (1997), (1997). "The Bullwhip Effect in supply chains," *Sloan Management Review*, Spring, p93–102; Kupér, A. (2000). "Managing supply chains while moving at internet speed,"
emphCutter IT Journal, March, v13, n3, p17–22.

[17]See for example Shearer, Murphy, Richardson, *Introduction to system dynamics*, Addison-Wesley, 1971; chapter 9: Interference, of Hecht, E. and Zajac, A., Optics, Addison-Wesley, 1979; Wilson, J., Hawkes, J.F.B., Optoelectronics: an introduction, p 297, van der Meulen, S.F., Fysische Meettechniek 1 and 2, Technische Hogeschool Twente (University of Twente), 1981, first-year applied physics university course reader; Bendat, J.S., Piersol, A.G., random data analysis and measurement procedures, New York, 1971; F.R. Connor, Modulation, E. Arnold, London, 1973; K. Küpfmüller, Einfüring in die theoretischer Elektrotechnik, Springer, Berlin, 10. Aufl, 1973, chapter 5; Elgerd, O.I., Control systems theory, Mc Graw-Hill, New York (1967); an understanding of Fourier or Laplace transforms provides a mathematical basis.

[18]Although half of all organizations rate their data mining efforts as moderately successful, just 6% believe their data mining efforts have been a"major success." Probably the most startling finding is that 44% of organizations believe that their data mining efforts either have "not contributed much in the way of success," or have "not contributed any real value to their organization's business efforts." In other words, for 44% of organizations, it appears that there has been little or no business advantage gained from their data mining efforts to date."

[19]Hall, C. (2002). "How companies rate the success of their data mining efforts," *Cutter Consortium*, May 8. As Curt Hall concludes "A data warehouse is only one part of a decision support solution."

tions upon technology remain astonishingly high, emotional, and lacking qualification in functionality) because of the most banal of reasons. The operator is a minimum-wage worker. Information that must be shared is parked because collaboration between workers is not rewarded and employees benefit more from keeping knowledge to themselves. Information quality depends not upon whether it is in "real-time" or not, but how appropriately it has been structured for search and query. Are the key fields that the system developers anticipated relevant to the question? Did the system designers account for the possibility of commercial airlines flying into high-rises[20]? The training, quality awareness, and availability of data entry operators, all of which will cost money, have another profound impact, which is rarely factored into academic correlations (or project budgets for that matter.) As Curt Hall regretfully concludes "Many corporate data warehouses fail, not because they do not have the correct information, or "enough" information, but because their end users simply do not know how to use the warehouse or how to apply their findings[21]."

Successful examples of balancing supply chain dynamics with decision-making horizons can, however, be found at HP. For example, the Automated Inventory Replenishment (AIR) program, which replenishes channel inventory, uses a weekly review period. IT systems at HP's server or "solution" factory in Gueltstein align inventory allocation with the subsequent manufacturing process, with the final shipments, and most critically, with the delivery times expected by the customer.

Vertical integration. With the advent of the PC, and IBM's decision to "outsource" the microprocessor, operating system, and firmware, vertical integration is a passed station in the developmental journey of the high-tech industry. Most products include a host of third party hardware and software, creating a network of companies contributing to the customer value. This approach has spread to other industries that are often perceived to be "vertically integrated". An example is steel, where so called mini-mills process steel sourced from global suppliers, rather than create steel from scratch[22]. When analysts or researchers call for vertical integration they ignore the realities of value collaboration networks. Even if the information flow were to be successfully integrated, the met-

[20]Hall, C. (2002). "The terrorist information and prevention system" *Cutter IT Consortium*, July 23.
[21]Hall, C. (2002). "The terrorist information and prevention system" *Cutter IT Consortium*, July 23.
[22]See for example King, Jr. N. and Guy, R. (2002). "So far, steel tariffs do little of what President Bush envisioned", *The Wall Street Journal*, September 13, pA1.

rics driving the performance and behavior of the individual companies would deter operations as a vertically-integrated supply chain. Moreover, increased specialization in both competencies and assets, makes it virtually impossible to integrate from a return-on-investment perspective. As the LSI Logic example (embedded within a consortium to build capacity), illustrates, the interdependencies of the players, their disparate objectives, and diverging metrics make vertical integration a myth. Once you have lost the financial and human capital base for a vertical integration, it is very difficult to rebuild that foundation, let alone become a competitive player. Moreover, the trends of shedding fixed assets and managing brands have created an economic landscape that favors risk mitigation through specialization. Finally, because so many players in the high-tech industry act as suppliers or partners of their own competitors, real incentives exist to maintain sub-optimized processes and perpetuate self-interested behavior.

Outsourcing reduces cost and creates flexibility It is striking how, contrary to the known trade-offs, outsourcing is being decreed as a blanket supply chain management strategy in the high-tech industry. Any cost reductions from outsourcing are typically the result of a myopic focus, abbreviated time horizons, or a zooming-in on one isolated driver of supply chain costs (like cost-per-part). Reviewing the whole picture, however will likely arrive at entirely different conclusions about real benefits. Neglecting the impact of logistics, escalation, rework, warranty, support, and cash-flow is typical of a hasty and myopic view of supply chain costs. Another obscuring element is control and visibility[23]. The net result of outsourcing is an accumulation of hand-offs in a supply chain, which inevitably increases delays, and opens up the abyss of misalignment. Reduced visibility decreases overall flexibility and responsiveness. It can also offset the flexible use of capacity enabled by the sharing a supplier with other customers. Furthermore, how do you incent an autonomous supplier to meet your particular business needs? The OEM will be confronted with increases in component prices in close to real-time, whereas drops in cost will understandably be kept well-concealed from the OEM. HP's former chief procurement officer Corey Billington concludes in a recent interview "It is a characteristic of outsourcing. ... Companies outsource functions that previously were not

[23]See Sullivan, L. (2003). "Outsourcing's Hidden Costs," *Electronic Buyers' News*, `www.ebnonline.com`, May 10. Laurie Sullivan summarizes "Electronic manufacturers embracing the outsourcing trend are incurring hidden costs because of sloppily written contracts and a lack of resources to audit component prices and services."

well-priced to begin with. Outsourcing creates an advantage, but then you have hidden costs and inflation in loopholes that company employees can't negotiate away[24]. The intrinsic dependency of an in-house operation allowed control over metrics and information, but this visibility becomes elusive in the outsourced configuration. An industry of auditors, contract and systems designers may well mushroom to address the multimillion dollar loopholes which open up in poorly-regulated divisions of labor. The charges of their professional services will have to be tallied against any savings made by contracting away the specialized function[25].

If we take the lesson of component pricing to heart, we will realize that the drive to remove assets from the books does not automatically yield sound business results, but can actually aggravate a weakness. A worst-case scenario could involve transferring ownership of a manufacturing operation without taking on additional users of this capacity load. This half-hearted move cancels out the main objective for outsourcing i.e. risk-pooling of capacity, actually increasing the cost of overtime, or destroying the viability of the assets. Finally, once outsourced, it is expensive and difficult to reestablish a competency. In some European countries like Great Britain it is even illegal to rehire comparable job positions after shedding the headcount[26]. Tax and duty advantages could also be lost in the bargain, creating anything but the hoped-for increase in flexibility and reduction of cost.

Build-to-order means velocity and flexibility. Building to customer order (BTO) is typically in conflict with reducing costs. It is also an over simplification: while it takes minutes to assemble a PC (and additional time to burn-in and test), the longest supplier lead times are in the order of months. This time discrepancy requires sophisticated forecasting and planning to ensure that all parts are available. This is complicated by the fact that, in the high-tech industry, the longest lead times may be longer than the product lifecycle! The inability to accurately forecast is often offset by using supplier hubs, where OEMs do not have liabilities for the parts until they are pulled from pre-delivered

[24] See also, Billington, C. and Kuper, A. (2003). "Trends In Procurement: A Perspective," *ASCET V*, Montgomery Research, San Francisco, p102–105.

[25] "... OEMs approach these services like it will solve all their problems ... Companies think they can turn over the function to a consulting firm that will find all these holes, and that is not always the case. If as a company, you are not keeping track of what the market is doing and auditing the audit company, you will still lose millions." Ibid.

[26] See for example Atkinson, A. (2001). "Outsourcing manufacturing: creating a value collaboration network", *HP Webcast Series*, February 15, `http://www.on24.com/clients/hp/index.asp?sessionid=40`.

inventory. For generic parts with diversified demand patterns, suppliers can probably afford this. However, unique or custom-made parts which cannot easily be sold on the remaining market will drive up costs for the supplier, which when written-off will either negatively impact their business health and viability, or else be passed on as generally increased prices to the manufacturer. Thus, although the vendor delivering to pooled hubs may be apparently responsive and flexible, the end-to-end supply chain, typically, is not. Only deliberate holistic decisions about where to hold inventory, how to share both risk and benefit can truly increase velocity and flexibility. Disregarding overall supply chain performance by punishing suppliers does not. If the supply chain cash flow is taken into account this picture becomes more bleak. That is, payment terms reduce the cash available to the upstream players, diminishing their ability to invest in flexible capacity, or in the inventory required to meet end-user demand. Therefore, in markets where time-to-revenue is critical to business success, production ramp rates might be artificially constrained by the cash position of suppliers. Without assurance of component supply for the BTO operation, it is an illusion to expect that your operation can instantly meet volatile customer demand. Furthermore, increased demand volatility requires larger inventories of parts, making inventory management a game of survival. In high-tech manufacturing, products devalue incessantly over their lifecycles, therefore pulling component inventory on-demand is advantageous, because it lets you exploit market prices to either increase margins, or lower price in order to drive demand. When part prices are increasing (recall the skyrocketing DRAM market of 2000), this may not be as beneficial. These factors also determine the effectiveness of auctions as a sourcing tool for any business case, since locking-in a price can induce a runaway competitive disadvantage, capped only by the volume of your spend.

Modeling reduces costs. Modeling can be an instigator for adopting better processes or organizations, but in itself does not change behavior. Involvement of all stakeholders-the people that can make or break a project -is the prerequisite to successful implementation. Otherwise, experience has shown that the lone modeler exposes herself to challenges from all sides to the legitimacy of the proposed model and its conclusions: the data, the assumptions, the approximations, the results, and how to apply its outcome. Ironically, these battles of authority typically drive up cost, rather than saving anything. Furthermore, models rarely take into account the return-on-investments, or any business practices that could thwart the projected return. A famous example is the application of postponement to the manufacturing process of HP's DeskJet

printers[27]. Although the theoretical model initially predicted savings in FG inventory, the actual savings were significantly higher when the less conspicuous packaging function discovered its opportunity to reduce cost[28]. This reiterates the need for cross-functional involvement, and the positioning of models as an enabler of decision-making, not its driver.

"Best in class" creates competitive advantage. History suggests otherwise, most successes in technology adoption can be linked to the commercial exploitation of technologically mediocre products (like video, PCs, combustion engines, or filament light bulbs). Marketing, timing, and distribution networks seem, instead, to be critical to success. Moreover, dependent upon your industry, any competitive advantage of "best-in-class" may have a very limited longevity compared to development costs, disappointing expectations of a good return-on-investment. Settling for "good-enough" product developments and focusing on agility in your supply chain are more typical characteristics of success. HP's home PCs, for example, became successful in the retail market when they focused on processes. Information technology was adopted pragmatically to fit the needs of these processes, and geared up to support a volatile, customer-driven commodity marketplace. Its success can be attributed to a can-do attitude of the team, rather than adoption of best-in-class technology. Revering benchmarks can create a copycat (necessarily a follower) attitude to business management. As the example of unforgiving consumer markets demonstrates, competitive advantage will require courage to try the untested, and bold innovation.

Killer application. Media and companies alike uphold the myth that the success or failure of a technology is linked to a killer application. In fact, technology adoption is much more an outcome of customer attitudes[29] or legislative force (for example for seatbelts and airbags). Furthermore, if the application lacks standards, customers may be wary or become frustrated. A case in point is the of cell phone technology infrastructure in the US, whose multiple standards have deterred widespread adoption of the short messaging services that are popular in Europe

[27]See H. Lee, C. Billington, and Carter (1993). "Hewlett-Packard gains control of inventory and service through design for localization", *Interfaces*, v23, n4, p1-11.
[28]Howard, K. (2001). "Beyond postponement: regional logistics effectiveness," *HP Webcast Series*, March 21, `http://www.on24.com/clients/hp/index.asp?sessionid=43` or a more recent perspective see `www.hp.com/go/manufacturing`
[29]See for example Piszczalski, M. (2002). "Five myths of telematics." In *Automotive design and production*, `http://www.autofieldguide.com/columns/martin/0702it.html`, July, as well as Zetie, C. (2003). "The myth of messaging," *Information Week*, February 17, and Jasper, J. (2002). "The Quest for the Killer App", *supportindustry.com*, February.

or Asia[30]. Similarly, the adoption of broadband Internet connectivity seems to be much more related to the perceived trade-off between price and performance than to any lack of content, or the capabilities of web browsers.

The same mechanism also drives transforming software applications innovation. Software companies use industry leaders as testing ground for "best practices". In the current economic landscape few companies are willing to invest in software where the survival likelihood of the supplier is perceived questionable. This decreases the likelihood of innovation or adoption of break-through technology, both from a testing and a purchase perspective.

What does this mean for Operations Research?

The field of operations research continues to refine its methods of modeling and programming, oblivious to the fact that the problems they presume to address may be inappropriately captured and set up. Mathematically indisputable, the outcome of these computations may not only be irrelevant, in the worst case, it may be dangerously misleading. The impact of false assumptions on our ever-changing environment makes the need to (re-)validate well-established operations research practices (like economic order quantities) all the more urgent. An often-used approximation, large numbers, must be challenged in the face of contemporary industry trends. Solutions with low recurrence rates (because they have unique configurations), make it very hard to use large product volume approximations. This will come as no surprise for those working on processes like store-level replenishment. In retail operations, decisions on one, two, or three inventory units can have profound implications on cost, sales, and credit.

Similarly, since partial shipments tend to be unacceptable to customers, the relevance of typical fill rate optimizations become questionable. The cost of missing a shipment, resulting in rework cost, penalties, and missed sales, might well exceed any benefits derived from conventional replenishment policies.

Finally, even with apparently pervasive information systems, research must face up to the paradox of inadequate data in real business environments. The data that exists in most organizations is often incomplete, sampling rates are low, or data entry by minimum-wage, temporary staff

[30]See for example Labarge, R. (2002). "Can your clients play your DVDs," *Digital Video*, July, p20-32

has occurred at irregular frequencies. These characteristics may well violate the input requirements of algorithms.

For the field of operations research, incessant change and inescapable dependencies imply that certain widespread models and algorithms must be revised. The models, which rely upon single node approximations, assumptions of independent demand, and the review of material, information, and finance flows irrespective of their relative impact on each other, do not necessarily reflect current business realities. Most importantly, if applied in the wrong context, these models might end up actually increasing inventory cost, or diminishing availability.

Conclusion: Cases of successful collaboration

Operations Research is the historical foundation of Supply Chain Management and has lost neither its impact nor its relevance, in spite of the dramatic shift in what we claim to be problem definition. Single-node approximations have accompanied single-criterion decision-making in the shop floors and offices of our industry. Both interested parties-effectively building a dichotomy of the researcher and the researched, subject and object-would benefit from an explicit definition of what they do not know. We can imagine a day on which a GM will intuitively speak of "pushing down the efficient frontier" instead of "reducing inventories", or the OR professor will enjoin a class to "build a model, then pilot, then revise your model in a continuous feedback loop,..." instead of simply "build a model". Changing the attitude that models "should yield an answer", would surely help to, as it iterates that models are based on assumptions and reality may not reflect those. Moreover, this attitude percolates in industry applications where the black box provides an answer instead of highlighting the underlying uncertainties that would assist the operator to evaluate a suggestion.

Clearly, the metrics and life-cycle of innovation in both environments differ. Several months or even years is affordable (and respectable) for the in-depth pursuit of an idea at a university, whereas a single quarter in industry can decide the fate of an inventory management strategy. The sample rates of academic case studies would profit from velocity, i.e., more frequent and continuous interaction with the managers in industry. At present, however, as long as internal standards of rigor are met, validating the assumptions and delineating the operative scope of a model do not even make it onto the list of academic priorities. As our cases illustrate, the isolation that results from addressing a narrowly-defined audience can produce false confidence in the readers who were

implicitly excluded, with fateful consequences in any subsequent on-site implementation.

With a culture rooted in Bill and Dave's ties to Stanford University, HP has been fortunate enough to look back upon a history of fruitful exchange with academic institutions. In our observations, the success of HP's collaboration with research institutions depends upon simple mechanisms, and can take on a variety of forms. Prof. Eric Johnson from Dartmouth's Tuck School works every summer upon projects within the company, removed from his university's constraints and scholarly detachment. Johnson also co-teaches our team's basic supply chain management course to HP staff and managers around the globe, receiving immediate feedback on the feasibility of theory, as well as what is developing at the industry's cutting edge. Members of our Innovation Diffusion team regularly run the beer game for Prof. Warren Hausmann's students at Stanford university, affording them direct insight into how current corporate operations are enacted by the game.

No one company can afford to reflect and analyze a phenomenon with the breadth and sustained concentration of a scholar. Not only is time a factor, but market conditions prohibit the objective distance that serious analysis demands. Therefore, one of the most valuable forms of partnership is the benchmarking process, in which the academic institution plays the neutral moderator, assessor, and filter. Prof. Arnd Huchzermeier of the Wissenschaftliche Hochschule fr Unternehmensfhrung in Vallendar in Germany, and Prof. Ludo Van der Heyden of INSEAD collaborate with popular European business magazines to annually honor what they call the "Best Factory"[31]. This university-sponsored "contest" overcomes barriers of trust and communication to provide value to all the parties involved.

The scholars gain access to a wealth of cutting-edge manufacturing innovations by directly polling and interviewing a sample[32] of companies. At the ensuing plant tours, they encounter an otherwise uncharacteristic willingness of their (delighted) subjects-including key executives-to share details. The business press publishes a compelling story, legitimated by a prestigious academic institute, complete with interviews of top exec-

[31]For full details of the Best Factory Award along with case studies of past laureates, see Loch, C.H., Van der Heyden, L. Van Wassenhove, L. Huchzermeier, A. and Escalle, C. (2003). *Industrial Excellence: Management Quality in Manufacturing.* Springer-Verlag, Berlin.

[32]Due to the voluntary application process, the sample is self-selected and cannot be exhaustive. The magazines invite companies to download a questionnaire and submit it to the selection committee. In spite of the questionable statistical significance of the judgment of who is "best", it provides enormous value to both industry and scholarship.

utives and exclusive photos. The laureates of the Best Factory benefit from the free and glowing marketing in the magazine's cover story. The competition concludes with a conference-cum-awards ceremony, at which each laureate presents the specifics of their plant, followed by commentary and contextualization by the panel of professors and journalists. Not only do the practitioners from industry gain valuable benchmarking and market insight, the neutral ground inevitably becomes a forum for networking and informal exchange.

The TECTEM (Transferzentrum für Technologiemanagement) benchmarking institute at the University of St. Gallen puts the same principles into practice to select and honor best practices in many other areas of operations management. A dedicated research team from TECTEM interviews and visits European companies[33] on an ongoing basis. Moderated by the university, benchmarking participants are invited to present themselves to one another on-site, and are provided with detailed reports of each event. Prof. Daniel Corsten's recommendation at a European Supply Chain Management conference[34] reflects what HP has successfully practiced for years: If Manufacturing companies maintain R&D teams to develop products, why not create R&D initiatives around internal processes? HP's supply chain think tanks, and innovation diffusion teams to carry out internal research and development of their process environment[35]. As the preceding catalogue of myths make abundantly clear, questioning the assumptions of project managers and program sponsors is one of our most critical tasks-and has deterred many a doomed investment.

Overall, HP's successful encounters with academic research can be traced to individual passion, uncompromising ethics, and heroism. Interestingly enough, we are aware of no instance of profound and sustained collaboration that was the outcome of an institutional program. Creating a partnership cannot be decreed: trust is neither goodwill nor even feeling good, but built upon a balance of power, and the implementation of a win-win charter. The publications that defined Supply Chain Management for a generation of managers and scholars estab-

[33]The sample is selected by the university. The response rate to the invitation results in a form of self-selection.

[34]Prof. Daniel Corsten's concluding remarks at the "Supply Chain Management" conference organized by the University of St. Gallen's Institute for Technology Management, January 29-30, 2002 in Zürich, Switzerland.

[35]See Branvold, D., and Kuper, A. (2002). "Innovation Diffusion at Hewlett-Packard," In Johnson, M.E., Pyke, D.F., editors, *Supply chain management: innovations for education, Production and Operations Management Society (POMS) series in technology and operations management* v2, p205–315

lished both Prof. Hau Lee and Dr. Corey Billington as experts[36]. Both sides benefited from telling the story: HP consolidated its brand as a manufacturing innovator[37] and Prof. Lee's academic reputation was anchored. Their mutual esteem and prodigious personal energy were key to fruition.

The details of ethical behavior are banal: sharing the credit for a successful innovation in industry makes the pie you are dividing up bigger, whereby a scrupulous respect for intellectual property does not hurt. Let us articulate another truism: authorship implies authority, as both the source and owner of invention, a sensitive issue for many project managers (who may not qualify academically through a list of publications per se), who understandably expect recognition in any article based upon their labor and courage. Need we say that the prospect of being reduced to scientific material by a publishing scholar, divested of the active (thought) leadership that led to business success in the first place, will become a barrier to communication and trust in the future.

When HP looks back upon its history of collaboration with universities, it has been these fine details that enabled (or sabotaged), success. Let us continue to combine forces with professional maturity. It is not at a safe distance, but at an unaccustomed proximity, that universities and businesses will more effectively address the burning platforms which can threaten the existence of whole industries.

[36]Lee, H. and Billington, C. (1992). "Managing supply chain inventory: pitfalls and opportunities," *Sloan Management Review*, v33, p65–73; Lee, H. and Billington, C. (1995). "The evolution of supply chain management: models and practice at Hewlett-Packard," *Interfaces*, v25, n5, p42–63.

[37]Turned into a successful marketing program by its Manufacturing Industries team, which sells thought leadership to external customers as a differentiator from those consulting firms which will never have to implement their designs themselves.