Proceedings of the Supply Chain 2020 Project's Industry Advisory Council Q4 2004 Meeting

MIT Supply Chain 2020

Held by the MIT Center for Transportation & Logistics

At the Dell Topfer Manufacturing Center

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Background

The Supply Chain 2020 (SC2020) Project is a multiyear research effort to identify and analyze the factors that are critical to the success of future supply chains. This pioneering project will map out the innovations that underpin successful supply chains out to the year 2020.

Initiated by the MIT-Zaragoza International Logistics Program, the global research project involves dozens of faculty, research staff, and students at MIT and other institutions around the world. Two advisory councils, the Industry Advisory Council (IAC) and the European Advisory Council (EAC), made up of supply chain executives from leading companies, are playing a crucial role in helping to shape the work and generate new ideas.

By looking further into the future than most business research initiatives, the SC2020 project hopes to deliver practical breakthroughs on the design and management of future supply chains. The project also aims to help companies understand the forces that are changing supply chains so that they can be better prepared for the future. This work can create value in society through improvements in transportation, logistics and Supply Chain Management (SCM) practices.

SC2020 research is broad and far-reaching, and is designed to meet a series of objectives in two phases. The objective of Phase I is to understand excellent supply chains and the underlying strategies, practices, and macro forces that drive them. Leveraging what is learned during the first phase, Phase II of the research will project the future using scenario generation and planning methodologies.

As well as leading to a better understanding of future successes in supply chain management, the work will highlight what actions organizations should take to help ensure supply chain excellence. The work will also identify "sensors in the ground" -- approaches to recognizing which of the many possible futures is becoming reality. By thinking about the future companies can position themselves for the long-term and avoid ill-conceived emotional responses to change.

The Q4 2004 quarterly meeting of the IAC was hosted by Dell on December 9, 2004 at its Topfer Manufacturing Center in Austin, TX to solicit insights from the corporate supply chain executives. Also participating were faculty and staff representing the MIT Center for Transportation & Logistics (MIT-CTL).

Participants heard a brief update on the SC2020 project and then provided research input on a variety of topics according to the following agenda:

- Supply chain drivers & challenges of various industries

- Balancing operational performance metrics

- Trends and future scenarios on globalization and RFID

- Dell plant tour and discussion with founder, Michael Dell

1. Industry Context

As part of the SC2020 research, MIT and Zaragoza students are exploring the supply chains of various industries. In each industry, the students are studying the supply chain context and strategies of companies in the supply chains. From there they will dive deeper into the supply chain of a portion of those companies to help elucidate the key factors that have shaped their current supply chain design. After hearing a short high-level summary of the students' interim findings, IAC members shared their knowledge of the supply chains of those industries. By understanding how and why supply chains of today are structured the way they are, researchers will be able to model future supply chains.

1.1. Aerospace

Commercial aerospace is a slow clock-speed industry with a penchant for big risks. The industry is characterized by three factors: year-long or more manufacturing lead times, six-to-eight-year design cycles, and a 40-year aftermarket product lifespan. These factors mean long-term commitments and long-term consequences for supply chain decisions. Activities such as designing a new aircraft and purchasing a fleet are all financial gambles involving hundreds of millions or even billions of dollars. Fluctuating fuel costs and economic cycles in business and leisure air travel make these bets very risky.   The industry's current condition is fairly grim because some major airlines are near or in bankruptcy.

Council members noted additional factors that affect aerospace supply chains. Different aerospace companies are taking different paths. Boeing is betting on an increase in point-to-point air travel and the need for better efficiencies in designing its latest mid-sized 7E7. Airbus sees a future for more hub-and-spoke consolidation of passenger flows in betting on the massive double-decker A380. Brazil's Embraer is shortening its aircraft design cycles to two years, a strategy that may help it reduce risks by being more able to match the supply of aircraft types to suit shifting air travel patterns. Participants did note that both Boeing and Airbus are moving to a supply chain model that places more of the design and build responsibilities in the hands of suppliers.

Although Boeing is optimistic that air travel will only increase, some participants criticized this conclusion on three levels. First, many airlines around the world are in desperate financial trouble. Boeing's response to this criticism is that the logo emblazoned on the tail does not matter because the number of passengers will only increase. Second, critics said that the number of air travelers may not increase if poor economic conditions or global insecurities impact tourism.

Third, critics suggested that the Internet has commoditized air travel and harmed airlines' abilities to manage revenues. If business travelers refuse to pay ticket prices that are several times the price of a leisure fare seat, the then lack of high-fare revenues will damage the financial underpinnings of the airline industry. If the price per seat drops, (even if more people fly), then airlines may not have the funds needed to buy new aircraft.

1.2. Apparel

Currently, apparel manufacturing is highly labor intensive. This fact has driven many companies toward off-shoring. For example, Coach, a maker of handbags and leather fashion accessories, has shifted from 80% domestic production to 80% overseas production. This shift to cheaper -- but distant -- sources of labor has lengthened the lead time.

Even as apparel makers have moved to overseas production, the retail world has seen accelerating cycle times in fashions. Fickle consumers worldwide and the rise of a fashion-conscious middle class in China and India place increasing pressure on apparel purveyors. This is affecting all stages of the apparel supply chain, even back to the initial steps of petrochemical production for synthetic fibers. Polyester production is moving to either the Middle East (close to oil supplies) or Asia (close to apparel makers) to help cut costs and speed the chain. Boutiques such as Zara have even flaunted the trend toward overseas production. Zara locates its factories in Europe to be more responsive to its European customers. To satisfy the need for speed, apparel companies are benchmarking high-tech companies.

To balance the contradictory goals of cheap labor but responsive supply chains, companies have deployed various strategies for postponement, vendor managed inventory (VMI), distribution center bypass, and direct-to-consumer. Some companies also pursue split strategies in using low-cost labor for low-risk goods during certain times of the year while using fast-response supply sources for timely replenishment of time-sensitive fashion items. Retailers are also using more aggressive markdown processes to clear shelves of old merchandise but are finding that this strategy has limits -- if the price drops too fast, consumers assume the worst about the discounted merchandise.

1.3. Automotive

Automobile manufacturing is truly global. Global brands with global factories sell cars to a global customer base. Even though car-making and car-buying has spread around the world, it will see continuing changes. The rise of a middle class in China and India brings the promise of massive volumes of new sales in those regions.

Automobiles are changing, both in terms of product design and in terms of supply chain design. First, modern cars have increasing amounts of high technology in the form of sensors, actuators, and microprocessors. Second, automakers are placing greater and greater responsibilities on suppliers. The ongoing move away from vertical integration means that suppliers now have design and build responsibility for increasingly larger subassemblies.

Auto-making does face some special challenges. Current automobiles have a relatively low level of standardization that hurts economies of scale and supply chain efficiencies. Although companies such as GM would seem to have massive economies of scale, fragmentation of the brands, platforms, designs, and components make for less-than-ideal economies of scale. For example, lower gasoline prices translate into Americans wanting larger cars than their

counterparts around the world coping with higher gas prices. A challenge is in standardizing the non-customer-facing parts without hampering the creativity of designers.

Council members openly wondered why auto-making has not followed Dell's model in building cars to order, especially if car-making continues its trend to modularization. Michael Dell suggested that one reason may be that automotive parts don't follow the same price-performance curve as tech parts do. Rapid shifts in price-performance give an innate advantage to a company, such as Dell, that can sell direct to the customer. Moreover, franchise laws prevent automakers from going direct to the customers and disintermediating car dealers in the way that Dell disintermediates computer resellers. Nonetheless, several members noted that some automakers, including Toyota and DaimlerChrysler, are moving closer to build-to-order business models.

1.4. Communications

Much of the communications industry is moving to a one-stop-shopping model. Large equipment providers, such as Cisco Systems, are offering expansive ranges of equipment. Service providers are trying to become a single point of contact of service for consumers. At the same time, some players see a variety of threats.

In many ways, the communications industry supply chain is strongly split into consumer devices and commercial products. Members noted how consumer devices, such as cell-phone handsets, have become a fashion item with the attendant problems of cycle time issues.

The industry faces a battle between the equipment providers and the service providers on more than one front. First, the handset makers and wireless providers are battling for control of the consumer in terms of whose name is on the handset. If service providers get their name on the handset, they might source from lower-cost OEMs that are offering an increasingly sophisticated level of white-box product.

Second, hardware manufacturers such as Cisco may become competitors to service providers. When consumers get VOIP (Voice Over Internet Protocol) from Vonage, they receive a Linksys interface box that is made and supported by Cisco.

As with the issue of declining per-seat revenues for commercial air travel, cellular service providers are seeing declining per-call-minute revenues. Competition with ever-declining subscription rates and ever-increasing "free minutes" threatens subscriber revenues. At the same time, some service providers are crafting new and lucrative sources of revenue. For example, ring-tone sales to wireless consumers offer a high-margin adjunct to make up for declining revenues for calling-minutes.

The case of the ring-tones illustrates how the communications industry is changing from a hardware-dominated world to a software-dominated world. Companies are adding value through software. This suggests the need for a proper software supply chain to help deliver new value. Fortunately, the low cost and speed of replicating or downloading software means less threat of

the bullwhip effect. Companies might move to flexible manufacturing of largely undifferentiated boxes that are customized by the latest software.

1.5. Computers

Moore's Law and killer software applications drive the computer industry. Moore's Law means an ever-improving price-performance ratio. This enables new applications and new digital devices with ever-better features at ever-lower prices.   For example, one can now buy a full-featured Dell computer for as little as $349. Michael Dell noted that the ongoing rate of price deflation is a major reason for the competitive advantage of the Dell direct model. When component technology prices drop 1% per week, the company with one less week in the supply chain has a 1% advantage on price or margin.

The supply of new, killer-app or "gotta-have" technology at ever-lower price points then drives demand. In the long-term, the supply of technology has driven the demand for technology. Spreadsheets drove demand for PCs, ERP drove demand for servers, and the latest Windows software and compliant applications drive upgrades of PCs.

As with other industries, the computer industry has internal divisions with different supply chain dynamics. On the consumer side, computers and digital devices are proliferating in many homes. Just as TVs went from one per household to one (or more) per room, computers also seem to be multiplying in homes. Music and photos have become the killer apps that drive the proliferation of computers in the home. Extremely high price elasticity means that each drop in price drives ever-higher unit demand.

In the enterprise market, the refresh cycle seems to be slowing. Current businesses replace PCs once every 2 to 3 years, where as they formerly replaced them once every 18 months. The high cost of migration to a new PC (it takes 6-8 weeks) and the adequacy of recent computers to handle the full range of office applications reduce the incentive to upgrade business machines. At the high end, companies keep looking for new ways to use ever-greater concentrations of computing power for pharmaceutical drug discovery, financial services, and data mining applications. The enterprise market comes with a massive opportunity to provide support and maintenance for both hardware and software.

Council members emphasized the demand-driven elements of computer supply chains. This demand-side could be viewed in different ways. On the one hand, a demand-driven supply chain brings with it elements of risk management and maximizing the profits across a portfolio of risks. On the other hand, companies can manage demand and reduce risk, especially if they move closer to the customer. Current-day computers, especially PCs, are also highly modularized and highly standardized, a fact that has enabled Dell's build-to-order model of satisfying demand.

1.6. Consumer Personal Care

Needs creation is a major part of the personal care industry. Some companies spend more on marketing than on manufacturing. Companies, such as Gillette, try to create dominant brands in categories such as razors and shaving products.

Council members noted changes in the business. First are demographic trends, with both an aging population that is trying to stay young and a rising youth segment that is trying to be mature or different, so place greater focus on how they look. The aging population offers an opportunity to push toward the high-end in selling to people in their peak earning years. On the youth end of the demographic trend, personal care product makers try to get young adults to form life-long brand bonds.

Second, personal care is becoming more fashion-driven, with 25% of the product portfolio being less than one year old. New flavors, new fragrances, and new packaging help companies keep brands fresh. Newer, fresher products command higher price points, create buzz, and drive demand. The industry is also segmenting, with some companies pursuing upscale customers and avoiding the low-end with its undifferentiated me-too products.

The industry blends elements of B2C and B2B commerce. On the one hand, the end customer is the consumer. On the other hand, the immediate customers are massive retailers like Wal-Mart. These relationships may be shifting, too. Retailers are fielding more private-label brands, making them competitors to the brand-name personal care product makers. Some personal care product makers are trying direct-to-consumer strategies that may disintermediate the retailer.

Consumer goods companies have found that brand loyalty varies by product subcategories. Products associated with the face, such as makeup and facial cleansers, enjoy higher loyalties than products devoted other parts of the body. Yet these brand loyalties may vary by region.

China poses both opportunities and some challenges for branding, according to participants. On the one hand, China is a massive whitespace. When watching Chinese consumers, observers noted that shampoo buyers simply grab the first bottle on the shelf without regard to brand. Moreover, retailers restock these shelves with no regard for shelf position.

1.7. Oil

Oil, especially on the supply side, is dominated by geopolitical issues. Many current and forthcoming sources of oil lie in politically unstable regions of the world. Oil also faces an inevitable separation of the sources of supply from points of demand. Many major oil consumers in highly-developed countries lack adequate local supplies of fossil fuel.

Oil is a commodity that is subject to extreme price volatility based on perceptions of supply and demand. Moreover, many oil products, such as gasoline, are commodities. In a mature industry with commodity products, operations are managed for efficiency. The quest for efficiency drives companies toward scale as they ride the experience curve toward lower costs.

One council member noted that oil actually has two supply chains. The obvious supply chain involves the extraction, shipment, and refining of crude oil to provide a range of fuels and petrochemicals. But a second supply chain feeds the massive projects undertaken by oil companies. For example, one global oil company currently has 20-25 major projects with budgets higher than a billion dollars each. Oil exploration, drilling, pipelines, and refinery projects are massive logistical undertakings involving the movement of millions or billions of dollars in materials. Although 80% of the big projects are on-time and within budget, 20% become financial boondoggles. Oil companies are wrestling with the balance of centralized and local management and sourcing for these projects.

1.8. Pharmaceuticals

The high and growing cost of new drug development, combined with the limited life-span of patents, drives drug makers to seek blockbuster medicines -- new drugs that tackle significant ailments in a large population. Although the marginal cost of manufacturing pills is often modest, drug companies need billion-dollar operating profits to fund massive R&D programs. The issue of profits -- and drug makers are quite profitable -- creates challenging downstream supply chain issues with managed care, global drug sales, and the appearance of generic drugs.

Drug makers also face health and safety issues, which mean that they must ensure traceability of their products across the supply chain. The high value of drugs makes them prone to criminal activities such as theft and counterfeiting. For retail pharmacy chains, such as CVS, the cost of RFID is small compared to the value of the drugs.

The high cost of pharmaceuticals, limited shelf-life of medicine, and the large number of drugs for a broad range of ailments creates a massive inventory challenge for the downstream side of the supply chain. Hospitals cannot afford to stock every drug for every possible disease or condition that might arise in its patients. Limited inventories of pharmaceuticals mean worse than stock-outs and lost sales; they could mean death for the patient.

One future scenario, described by Prof. Fine, is a move to a different type of blockbuster business model -- the business model pioneered by Blockbuster Video. Before this video rental outlet changed its model, video stores paid a high price to buy rentable copies of new movies. As with drugs, the development costs of new movies are high but the manufacturing costs of VCR tapes or pills are low. Under the old model for video rentals and the current model for pharmaceutical sales, the downstream partner bears all the inventory costs and risks based on the margin-loaded price to the consumer. Blockbuster Video changed the model by crafting a revenue-sharing agreement that gave the studio a cut of the rental revenues in exchange for a reduced price per tape. Blockbuster could then afford to buy more tapes and have less stockouts of hit movies. Although the studio had to forego an up-front ultra-high margin sale, it received greater total revenues and profits under the new model.

Similarly, distributors, pharmacies, and hospitals could enter analogous agreements with pharmaceutical makers. The downstream outlets would pay a nominal price to carry inventories

of the drug and share revenues at the full price when the sale was made or the drug was used. Although the drug maker would then bear the risk of unused and expired inventory, that risk would be scaled to the low marginal cost of pill production, not the high development-burdened price of the drug. In return, all parties would see higher service levels, higher revenues, and higher profits.

Long-term, the pharmaceutical industry may see even larger changes, according to Prof. Fine. Opportunities for blockbuster drugs -- new drugs that help everyone with some malady -- are dwindling as each new drug carves out a chunk of the remaining whitespace. The next phase will be personalized medicine in which specific medications help specific people based on the genetic fingerprint of the patient. This will increase the complexity of the supply chain by further increasing the number of drug SKUs and possibly add customizations, and it will add a new layer of SKUs for diagnostic tests.

2. Balancing Operational Performance Metrics

Council members discussed the major executive-level operational objectives and metrics they or their clients use to evaluate supply chain performance. Each council member listed and ranked up to five of their top metrics. With representatives that ranged from commodities to computers, products and services, consumer goods and enterprise infrastructure, the group offered insights that spanned the realm of supply chain management.

The metrics discussed were grouped into three categories. The first category is *customer-focused* metrics which emphasize external-facing performance such as quality, service, and order cycle-time. The second internal-facing category emphasizes *efficiency*, with metrics related to costs and margin. The third category, also internal-facing, emphasizes *assets* and their utilization, especially metrics associated with inventory levels and other working capital components.

2.1. Customer-Focused Metrics

All of the council members use metrics that reflect the importance of customers and the customer experience. In fact 100% of them include some customer-facing metric among their top 3. Quality, customer service, on-time delivery, and order cycle time were commonly-mentioned metrics. Several members also watch new revenues or use revenue targets to ensure that they are garnering their customers' business.

Two of the council members mentioned perfect order as a key metric. Perfect order can be a brutal measure. One company uses a measure of perfect order that is the product of 10 different terms, 4 external measures of perfect order and 6 internal measures. A foul-up on any of the 10 measures means an imperfect order, that the company's current perfect order rate is only 10% (up from 6%) with a goal of reaching 75%.

2.2. Efficiency-Focused Metrics

Most of the companies -- over 85% -- had metrics derived from costs or margins. These companies seek to minimize the cost of the supply chain, the cost of touches, and the cost of materials. Because many of the executives on the council have supply chain responsibility, their metrics focus on what they can control such as costs and other efficiencies. For example, R&D costs might be excluded from their efficiency metric.

2.3. Asset-Focused Metrics

Many of the companies also watch the assets required by the business. In the realm of supply chains, two-thirds of the council members use some measure of inventory as a key asset-focused metric. One member cautioned that a company's obsessions with minimizing inventory turns is leading that company to push inventory onto supply chain partners without actually reducing the total inventory in the chain. Working capital and cash-to-cash are other metrics derived from the balance sheets of companies.

2.4. Balancing

Few of the companies restricted their metrics to a single category. Great customer service is irrelevant if the company loses money or squanders assets. As one member noted, Wall Street watches the bottom line, and all of the council members at the meeting were from publicly-traded companies. Thus, over 85% of members reported using at least one non-customer-focused metric in addition to customer-focused ones. Almost three-quarters of the members use metrics that include a combination of both customer- and efficiency-focused metrics.

Yet not every company emphasizes customer-focused metrics over the other types. One third of the companies placed greater weight on metrics in one of the other two categories. One member also reported a survey of companies in *Supply Chain Management* magazine in which most of the metrics focused on non-customer-related, bottom-line-driven performance measures.

Some more-innovative metrics, such as "efficient perfect order", can blend customer and cost issues. Efficient perfect order measures not only the quality of service to the customer -- did the company delivery the right goods at the right time to the right place -- it also assesses the cost of that perfection. It's not an efficient perfect order if the company must pay extra to expedite the shipment.

3. Future Global Supply Chains

A significant factor in the supply chains of 2020 is the shifting global footprint of supply, manufacturing, and customers, For example, the global distribution of polyester plants has shifted from the U.S. to either oil-source countries in the Middle East or to apparel-manufacturing countries in Asia.

3.1. Footprint Scenarios

Prof Fine conducted a session soliciting thoughts on this important SC2020 topic.   He first asked Council members to think about the distinction between the footprints of the computer and automotive industries. Whereas cars are made all around the world, computer manufacturing is highly concentrated in Asia. In each industry, company, or product, supply chain footprints depend on the global disposition of supply, manufacturing, and customers. Supply and manufacturing might be concentrated (e.g., computers) or regionalized (e.g., cars). The council was divided into small groups to discuss cross-cutting issues related to global footprints of their respective industries. This also included issues such as exchange rates, natural resources, labor competencies, and government policy that affect what gets made where and for which customers.

Intra-Country Footprint

One participant noted that countries are the wrong granularity for discussing future global footprints. The intra-country footprint also matters, on two levels. First, countries such as China have highly non-uniform labor rates. Whereas labor rates in the Pearl River delta are rising, China still has deep pools of labor inland. Even today, manufacturers are shifting production from low-cost factories on the coast to lower cost factories inland.

Second, companies may create multiple points of presence inside a country for cost or cycle time reasons. For example, Dell serves the Americas from factories in both the Austin area and in Nashville. Originally, these factories were planned for economies of scale and specialization -- one site would focus on the Dell Dimension line and the other would specialize in the Dell Optiplex line.

Dell soon changed this strategy toward having both factories produce both product lines and split the production geographically. Today, Austin serves the West Coast and Nashville serves the East Coast. The central states can be served by either factory depending on the patterns of the demand and supply. Creating a footprint that divides the country lets Dell cut more than a day off its transportation cycle time and save on the order of $40 a shipment. In a world where either cycle time or transportation costs play a major role in footprint decisions, companies may create a mesh of intra-country locations to serve different parts of the country.

3.2. Chasing Cheap Workers vs. Good Workers

Many participants suggested a continuation of the current tendency for manufacturers to seek out suppliers and factory locations with the lowest possible cost of labor. A decades-long follow-the-cost-leader mentality has been seen in the manufacturing move from America to Japan to Korea, Taiwan, Mexico, etc. and on to China. For instance, Dell noted that the Mexican economy has been severely hurt by the move to Chinese suppliers. Low-cost suppliers in Mexico lost business to lower-cost suppliers in China. Thus, the footprint of the supply base might float around the world looking for the lowest total costs.

Productivity: Part of the Real Cost of Labor

Low-cost labor means more than a low wage rate. Dell suggested the US may become a low-cost source of labor. The combination of rising labor rates around the world, the falling dollar, and the very high productivity of U.S. workers mean that the U.S. is not as unattractive as the raw dollar-per-hour figures would indicate. Dell may pay U.S. workers an hourly wage that is 16 times more than they pay Chinese workers, but other factors reduce the gap.

Automation: Can Change the Offshoring Equation

Some industries rely on increasing automation to reduce the labor content of products. Robotic systems build cars, chips, and many other categories of goods. For example, a modern semiconductor fab has no operators on the production lines. Robotic systems shuffle wafers and chips through the complex choreography of steps needed to make the microchips. This high-tech approach to manufacturing lets companies maintain a global footprint of factories in high-wage countries. It also changes the balance of factors toward capital costs -- making the factory more capital intensive as it makes the facility less labor intensive.

Yet Dell noted that automation has its limits. Although Dell's U.S factories do use more automation than Dell's Asian plants, the company has not moved to fully robotic systems. In considering capital investment projects, such as automation, Dell looks for a 12-month ROI. This hurdle is not due to shortsightedness or the impatience of capital in the U.S.; rather, it is due to the fluidity of the industry. Too many long-term investments would create constraints and rigidity for Dell. That is why Dell relies on people for many potentially automated tasks such as part picking, PC assembly, and boxing.

In addition, one council member noted that in Apparel, while China's current low-wages are the enticement for foreign businesses today, the Chinese are building plants as automated as anywhere else in the world. The reason is to help keep its industry state-of-the-art enough to keep businesses there in the future as well, as incomes and wages rise.

3.3. Capital Goes where it is Appreciated

A second factor discussed by council members that underpins supply chain design and global footprint issues is the role of capital to build factories. A number of industries, from petrochemicals to semiconductor fabrication, currently require large quantities of capital investment. Thus, financial issues such as cost-of-capital, tax rates, and exchange rates can affect the global footprint of these companies. Although some petrochemical projects are constrained by the location of the oil, other projects such as refineries can be located either at the source or at the destination of the oil.   Large and expensive factories with multi-decade depreciation periods make companies cautious about where they locate these projects. Regions that are noted for their "patient capital" may attract more capital-intensive industries.

Non-Financial Appreciation

More than just financial factors affect the footprint for capital-intensive industries. Capital can be appreciated in more ways that just financial. Local and national governments may offer incentives to entice foreign investment. For example, Dell's newest factory will be in North Carolina, in part due to local government incentives to help bring jobs to the region. Similarly, refinery and chemical processing plants are going to African oil-producing countries as part of efforts to create more jobs for the local populace. National development priorities and national pride can also impact these decisions -- every country seems to need its own airline, its own automakers, its own semiconductor makers, and so on.

The Future of Capital

Looking toward 2020, council members described two scenarios. On the one hand, capital-intensive industries could follow a current trend and become increasingly capital-intensive. For example, as semiconductors have grown smaller and more complex, the price of a new "fab" has grown to $2-3 billion dollars. Similarly, companies such as British Petroleum find themselves managing ever-larger numbers of ever more expensive projects. Ten years ago, BP might have only had a single ongoing billion-dollar project. These days, the global giant has more than two dozen ongoing projects valued at greater than a billion dollars.

On the other hand, innovations in either technology or business processes could lead to smaller versions of these large factories. This would parallel the development of so-called minimills in the steel industry. Microfactories would let companies spread the factories around the globe, tying into local market outlets or supplies of materials.

3.4. Cost of Energy

The recent rise in the price of oil has highlighted the role of energy prices in supply chains. The rising consumption of oil in China and India is pushing prices higher. With the exception of raw materials industries, the cost of energy is primarily a factor because of its effect on the cost of transportation. High fuel prices drive up the cost of trucking and airfreight. In fact, one participant noted that this year is the first year in a long time when the cost of transportation has increased. Dell already divides US production between the eastern and western sides of the U.S., thereby saving about $40 an order in transportation costs.

But fuel isn't the only driver for the current trend toward higher transportation costs. Increasing supply chain security concerns also impact transportation, especially global transportation. On the flipside, RFID and related technologies might ameliorate the cost of security by automating the monitoring of SC flows and aiding the detection of tampering or diversions.

3.5. Cycle Time

Most computer makers and apparel manufacturers have located their factories where labor is cheapest. Yet participants cited two companies that run counter to this trend. Both Zara and Dell use local, seemingly high-cost labor, to make their respective goods. Their rationale for going against the off-shoring trend is cycle time.

For Zara, factories in Europe making clothes for European shops, which means Zara has a jump on fashion. While other apparel retailers wait for shipments from Asia, Zara can design, manufacture, and stock items to suit the hottest fashion trends. For Dell, local factories mean fast lead times on customized computers. Creating a direct relationship with customers and serving them locally has given Dell an advantage.

3.6. China and India

Many of the comments and discussions raised the issue of China and India. Currently, China is seen as a rising provider of manufactured goods, and the Dell factory tour confirmed China's rise in the world. Throughout the factory, one saw many component boxes stamped "Made in China." More than only low-value components come from Asia. Six days week, a China Airlines 747 delivers fully-assembled Dell laptops to Nashville. Michael Dell noted that Dell's status as a major buyer of PC components from China gave it a unique strength in selling PCs in that country. China is currently the fourth-largest market for Dell, and Dell is the largest non-Chinese seller of PCs in that country.

China, The Consumer

One of the more surprising phenomena has been the rapid rise of a middle class in China and India. Demand for consumer goods and cars is growing exponentially. This offers the opportunity to introduce new brands to these freshly-minted consumers. Coach, an upscale maker of leather goods, sells 50% of their product in Asia. At the same time, the surge in demand is having an adverse effect on some supply chains. Tight steel supplies forced Nissan to shut down production for three days. Demand from China and India were also cited as a cause for rising oil prices that have created rising transportation costs.

Expanding Pool of Engineers in Developing Countries

China and India will eventually become much more than just a source of cheap unskilled labor. India is graduating 500,000 engineers per year and China is graduating 2 million engineers per year. In comparison, the U.S only graduates 66,000 engineers. Foreign students, who formerly stayed in the U.S after graduation, are now returning to their home countries. These trends suggest a rapid rise in the skill base of these countries. Although some suggested that it will take much more than 15 years for these countries to reach the aggregate education level of the U.S. or Western Europe, the burgeoning number of engineers in China and India suggests a greater role for design and sophisticated supply chain activities by foreign suppliers in the future.

3.7. Supply vs. Demand

The balance of supply and demand affects many aspects of supply chains. Companies differ in their ability to influence upstream and downstream supply chain partners.

Managing Supply

Companies have varying degrees of control over supply. On the one hand, supply constraints can severely degrade performance. For example, the recent three-day shutdown of Nissan was driven by rising steel consumption in China. Other types of supply disruptions can also affect companies. During the West Coast Port Lockout, many companies suffered interruptions in the supply of goods from Asia. In response to the event, Dell chartered fourteen 747 cargo jets to quickly ensure a flow of parts. Although Dell's just-in-time model would seem to make it more prone to these types of disruptions, the company's just-in-time model of business meant it solved its supply blockage much faster than its rivals and did not delay any customer orders.

Companies may also hold some level of power over suppliers. For example, Wal-Mart's ability to drive adoption of RFID reflects the power of this retailer over its supply base. In another example, Dell changed its component inventory policies in 1992, calling on suppliers to hold and manage inventory up until the moment when Dell needs the parts. Dell called the concept a "revolver warehouse," but suppliers said that it was called "revolver" because Dell was putting a gun to their head. Although some suppliers complained when Dell moved to vendor-held component inventories, the computer maker's growing size motivated suppliers to accede to Dell's wishes. One factor that helped was that holding inventory for Dell was not as risky as holding component inventory for other computer makers. Dell's direct model made it less prone to both forecast error and the bullwhip effect. In contrast, computer makers with long distribution and retail channels faced problems of channel stuffing and less transparent demand signals.

Managing Demand

Although many business models see demand as an exogenous force that "pulls" from them and their suppliers, several companies and industries see demand as something that can be created and shaped.

For example, Dell shapes demand on a daily basis to help to sway customer's choices. At first glance, the Dell direct model would seem to be the ultimate in a demand-driven system -- customers can ask for a PC configured any way they want. In reality, the company actually guides customers' decisions in three ways to help the company match demand to supply. First, because many customers pick the default configuration, Dell changes that default choice on the website interface to match supply or to discourage selection of scarce components. Pricing also lets Dell sway customer choice -- placing higher prices on scarce items or offering inexpensive upgrades to more plentiful components. Finally, Dell uses promotions such as free shipping or free extra memory to shape demand.

Demand-shaping at Dell is a real-time process. Every day, Dell makes decisions to shape demand, and it can change its website very quickly to help tailor demand to match supply. Demand shaping is even regionalized. For instance, demand from the East Coast, which is fulfilled from Dell's Nashville factory, is shaped according to supply levels in Nashville. Dell encouraged Council participants to try buying the same computer configuration on each of several days to see demand shaping at work.

Zara, the European fashion retailer, was also cited for its ability to create demand. The boutique chain intentionally understocks the shops to go out of stock on fashion items. Whereas out-of-stocks are the bane of most retailers, at Zara customers know that if they don't buy immediately, they won't get the item. This artificial scarcity drives demand and helps Zara avoid the discounter's spiral of stale stock and poor margins.

Other companies and industries spend large amounts of money on marketing -- effectively manufacturing demand. Needs creation activities in the consumer packaged goods industry help convince customers of the merits of products and product categories that they have never bought before. Personal care product companies are said to "sell hope in a bottle."

Other industries are increasing the use of marketing to create demand. The rise in consumer-direct advertising in pharmaceuticals is driving adoption and consumption of new drugs. Getting consumers to ask if some new drug is "right for them" is an important step to driving volume sales that help recoup massive investments in new drug development.

4. Cross-Cutting Industry Trends

The council's discussions of the industries surfaced a number of cross-cutting current and future trends that drive supply chain design.

4.1. More Products Becoming Fashion-Driven

Council members noted that more industries, such as cell phones and technology, are now becoming more fashion-driven. High technology products are driven by so-called killer-apps and "gotta-have" features. In CPG, for example, products require more frequent refreshing with new flavors, formats, and packaging. This means faster turnover of designs, more new product introductions, and faster price declines on obsolete goods. It also increases risks as each new product comes with a high degree of uncertainty about customer acceptance and demand. Demographic fragmentation adds to the challenge -- both young people and older people want products tailored to their specific needs.

The Rise of Velocity

The demand for fashion begets a move to velocity -- the rapid flow of the latest goods through the supply chain. This pulls companies toward the Zara or Dell model of local manufacturing and very short cycle time replenishment or fulfillment processes. Dell, for example, schedules

factory production on a two-hour cycle. At the beginning of the day, Dell does not know how many PCs it will make because it does not know how many orders it will get. A shift to velocity will benefit companies that can co-locate their manufacturing footprint with the customer footprint. The trend will also benefit air freight companies that can help shorten supply chains by accelerating transportation.

The Continuation of Stable Goods

At the same time, fashion is not an all-consuming goal. Some goods are less prone to this shift toward fashion. The supply chains of these goods will continue to be driven by low costs, high efficiencies, and large, ongoing volumes of production. One council member noted that nobody has introduced a markedly new grade of gasoline in years. Similarly, Wal-Mart does quite well selling large quantities of basic consumer goods with stable sales patterns. Even some personal care products may be less fashion-oriented than they first appear to be. Consumers may stay loyal to a brand for years or even for life.

Mixed Strategies

The result, for some companies, may be to split supply chain strategy into a division between high-velocity fashion goods and stable-volume staples. Companies could make this split according to product category or according to different times of the year.

4.2. The Increasing Role of Technology

Council members noted the increasing importance of electronic and digital technology in a wider array of products.

Software Adds More Value

Not only is electronic hardware rising in importance, but so is software. Manufacturers in the automobile, communications, and computer industries use software to help differentiate their products from competitors'. This trend gives rise to a software supply chain that includes providers of the needed software as well as a support infrastructure.

This shift from mechanical systems to digital electronic systems poses challenges into some industries, such as the automobile industry. First, it means new suppliers and new supplier competencies. Currently, cars lack the same level of technology standardization that the PC industry enjoys. The rise in technology also impacts the downstream end of the supply chain. For example, car dealers to gain skills in servicing the technology that is now embedded in modern automobiles.

Differentiation through software may affect the global footprint to the extent that hardware and software are coupled and customized to meet regional needs. The supply of Indian software engineers or Chinese edicts for home-grown technology could affect the regional footprint for hardware manufacturing.

Build-To-Order Software

Dell exemplifies this trend both in its application and in the competitive advantage of differentiation through software. When Dell builds a computer, the last stage is to "burn an image" of the required software on the new computer's disk drive. Dell can customize and download the software and data into each PC to meet the needs of each customer. Dell stores over 100,000 of these customized "images" so that when a corporate customer orders another Dell, the computer arrives with all of that company's applications preloaded and ready to use. Dell uses this capability as a competitive differentiator to become the exclusive provider of PCs to companies by delivering machines customized at the software level.

Moore's Law

Moore's Law is a major reason for Dell's success. Dell's direct model lets it provide the latest and fastest technology weeks before its competitors could. Yet one council member noted that Moore's Law is facing limitations in two areas. First, modern processors are becoming too power hungry -- laptops are becoming too hot to hold. Second, modern processors are becoming fast enough for most consumer and mainstream business applications.

4.3. The Increasing Reliance on Suppliers

Several participants noted that other industries are moving toward greater reliance on suppliers. For example, car makers now subcontract major subassemblies of cars to their network of suppliers. Ball-bearing makers are being asked to take a greater role in designing and making wheel assemblies. OEMs in electronics are taking a greater design role for consumer electronics companies. Even Boeing and Airbus are evolving to consortia of suppliers. In this shift, the front-facing company (such as Dell, GM, or Boeing) becomes the prime coordinator, marketing front-end, and service provider for systems that are quickly assembled from pre-built major subsystems. The rising populations of engineers in China and India may support this shift.

Modularity and Design by Suppliers

The modular nature of computers permits Dell to be a world-class assembly operation that relies on whatever better world-class technology suppliers can create. Dell relies on others to do the R&D needed to create the next microprocessor, disk drive, or display. Dell's build-to-order model works especially well in a fast-paced ecosystem of supplier-created new technologies. With a very short supply chain between component makers and computer-buyers, Dell can offer the latest high-performance technology and the latest low costs before its competitors can fill long distribution channels.

The Threat of Supplier Power

At the same time, other companies are worrying about the increasing power of first-tier suppliers. As suppliers take on more and more responsibilities, they come to provide more and more value. Thus, they rise in power in the eyes of the customer. For example, Cisco is worried

that their first-tier suppliers are becoming too powerful as the suppliers grow in size and capability.

4.4. Government: The Wild Card

Another cross-cutting issue is the often capricious, reactionary behavior of government bodies. Import quotas, tariffs, tax laws, environmental laws, and government incentives impact business decisions. For example, Dell chose North Carolina for its new factory, in part, because of local government incentives.

Products that have public safety implications, such as automobiles or pharmaceuticals, can be subject to shifts in regulatory mood. One member noted that the recent problems with Vioxx, a prescription pain reliever, have made the U.S. Federal Drug Administration more cautious. This contributed to the rejection of a new drug application for Intrisa, a drug targeting female sexual dysfunction.

The effects may go beyond simple footprint or safety issues. In the PC industry, for example, the Chinese government's intentions to move away from Microsoft and toward a home-grown operating system will affect the development of the industry in that country. Similarly, China wants to create its own DVD standard to avoid paying royalties to non-Chinese companies. On the one hand, this may splinter production of computers into Chinese and non-Chinese fractions. On the other hand, one council member suggested that China's massive consumer base and product volumes may drive the world to adopt the Chinese standards and products.

4.5. Curse of Complexity

One member referred to the recent series of articles in the *Economist* concerning the need for simplicity -- that many elements of life, products, services, and technology are just too complicated. In moving toward more ubiquitous penetration of technology, these products must become both more robust and easier to use. As one participant pointed out, "when was the last time you rebooted your washing machine?"

The desire for simplicity is seen in the move to one-stop shopping in industries such as communications. Customers don't want to deal with multiple service providers or hardware vendors. Instead, they want a single point of contact and easy interoperability.

Cost of Complexity

Migrating to a new PC takes six to eight weeks, according to one council member. The complexity of the upgrade process means lost productivity and makes buyers more reluctant to upgrade. One study suggested that computer owners have changed from refreshing their computer every 18 months to buying a new computer only once every 2-3 years.

A Post-PC Era?

Some of the participants noted the rise of non-PC-based digital lifestyle products. Some consumers are buying digital cameras and cell phones but not buying a PC. Printers and high definition TVs can print and display images from digital cameras without the need for a PC. For consumers that don't want the complexity of a full-featured home computer, these single-function devices offer a digital lifestyle without the complexity.   One member suggested that Microsoft is caught in a complexity trap -- they cannot remove complexity without breaking their current systems and alienating their current customers.

Pruning Complexity

Despite the wealth of choices Dell offers, the company is very selective about what it offers to customers. For example, disk drives might come in nine different models that could potentially satisfy 100% of customer needs. But Dell knows that it might only need three models of drives to accommodate 98% of its customer base. Given the high cost of stocking additional variants of each computer component, the company carefully chooses the subset of the range that can cost-effectively serve the widest range of customers.

Even at Dell, this quest for simplicity is an ongoing battle. Michael Dell admitted that the company constantly works to prune its array of models and offerings to maintain simplicity, but complexity creeps upward after every pruning.

5. RFID: Disruptive or Not?

The shape of supply chains in 2020 will be affected by the advent and adoption of new product and process technologies. Disruptive technologies, especially, have the potential to remake the competitive landscape and promote radical shifts in supply chain design. Council members discussed whether RFID is one such technology.

5.1. Sustaining vs. Disruptive Innovation

At issue is whether RFID is a sustaining innovation or a disruptive innovation. Sustaining innovations create quantitative performance improvements. These might include incremental improvements in well-established performance metrics such as lower stock-out rates, lower costs, or lower shrinkage. In general, sustaining innovations help already successful companies become even more successful.

In contrast, disruptive innovations create a step change in performance and often change the basis of competition in qualitative ways. For example, by all traditional performance metrics, wireless phones are inferior to wireline phones. Cell phones have poorer reliability, lower sound quality, and higher cost. But they create a new basis for competition -- mobility. Disruptive innovations can permit small upstarts or industry outsiders to supplant entrenched competitors.

5.2. The Path to Disruption

Innovations become disruptive in one of three ways, according to Prof. Fine. The first one is that they may offer an overwhelming advantage compared to prior practices. Penicillin was unquestionably better than prior practices (e.g., amputation of infected limbs) and soon supplanted the old methods.

Second, new customers or a subset of the customer base may pull an innovation into a disruptive position. When small hard disks first appeared, the prevailing mainframe computer companies had no interest in the small disks. Big iron needed big drives, and physical space was no concern. The arrival of the PC created a small, but growing, customer base for smaller disks. As PC production grew to critical mass, demand for small disks outstripped demand for big disks and the nexus of new disk technology development, competition, and profits shifted to small disks and their makers.

Third, relative competencies may drive disruption. Mainstream airlines knew of Southwest Airlines low-cost air travel model for decades, but they could not emulate it. Entrenched labor practices and fleet investments made it hard for other carriers to copy Southwest's simple model. Similarly, Compaq and IBM could not copy Dell's model. Relationships with downstream channel partners prevented these other PC makers from going direct.

5.3. Adoption: Costs vs. Benefits

Companies that supply to RFID-mandating retailers such as Wal-Mart complained about the lack of a business case for their use of RFID. Although Wal-Mart will certainly enjoy a multi-billion dollar benefit, suppliers to Wal-Mart fear that they will only see the costs of tagging the goods. If the benefits of RFID are truly asymmetric, the only disruption may be financial. As one participant joked, Wal-Mart is the disruption, not RFID.

Cost is a key issue for the adoption of RFID. Currently, the tags are too expensive to be put on every retail product, and the readers are too expensive to go into every location where tags might be read. Yet the price-points are changing. For example, Nokia is putting an RFID reader into a cell-phone handset. Because the handset already contains the radio transmitter and receiver, the incremental cost of the reader function is very low.

5.4. Council Inputs on RFID

The council then organized into small discussion groups to assess RFID's potential as a disruptive innovation. Different groups and members summarized their views of the impact of the technology.

Goliaths Foresee No Disruption

Many of the council members saw RFID as non-disruptive technology, even a temporary nuisance. At best, they saw RFID as bar codes on steroids -- quantitatively, not qualitatively, more powerful than bar codes. Prof. Fine suggested that some of this commentary reflects well-established companies' response to new technology.

Is Goliath Supplying the Stones?

RFID could disrupt retailing if it provides new insights into consumer behavior or provides a radically different approach to retailing processes. If RFID does disrupt retailing, it might be highly ironic: Wal-Mart's RFID mandate could create the infrastructure and technology penetration that gives some small retailing innovator the tools to outflank Wal-Mart.

Disruption for Other Goliaths

One option is that RFID will disrupt those industries that have not leveraged existing ID and tagging technologies. For example, construction requires the management of large quantities of equipment and materiel in an outdoor environment that is not suitable for optical bar codes. One member described the huge problems with lost materials and mis-coordination at a massive construction project at Heathrow airport. Similarly, the petrochemical industry oversees large numbers of massive industrial projects, 20% of which have trouble. RFID could revolutionize the construction industry, and the construction firms that leverage RFID could well displace larger rivals who don't adopt the new technology.

Discussions of RFID surfaced other uses for the increasing data flows associated with physical products. For example, some equipment makers now use on-board monitoring systems and wireless datalinks to interrogate the equipment and proactively spot impending failures or maintenance issues. The technology helps maintain high utilization on capital-intensive, mission-critical products such as aircraft engines and heavy construction equipment. These types of enhanced RFID functions could revolutionize the equipment service business by making it more proactive and less reactive.

The Nimble Goliath

One council member suggested that RFID could even disrupt the normal innovation process in which small, nimble entrepreneurs defeat large, aging competitors. RFID and the real-time processes that it enables could make big companies as nimble as small ones.