OPTIMISING DISRUPTIVE TECHNOLOGIES: APPLICATIONS TO TRANSPORTATION

Julian Liew, Scott Moore, Mony Ung, Hanna Skyttä and Norma Harrison
Macquarie Graduate School of Management, Macquarie University
Norma.Harrison@mgsm.edu.au

ABSTRACT

Disruptive technologies shake the status quo of the industry by changing the prevailing value proposition. Drawing upon strategic management, our study of the transportation industry suggests a new strategy to manage disruptive technology, which may, according to our preliminary results, improve on the approaches previously discussed in the literature.

KEYWORDS: disruptive technologies, technology management, new product development and design, transportation

INTRODUCTION

Technological, political and social domains of the society have experienced many significant changes over time (Miller et al., 1998). Most of these changes that were unforeseeable a decade ago, are now part of everyday life, mostly due to the technological change (Dierkes et al., 1998), which has been considered as the driving force of innovation, productivity, growth and development of the economy (McKelvey and Texier, 2000, Evans, 2003, Harrison and Samson, 2002, Cornelius, 2003, Charpie, 1970). At the macroeconomic level, technological development ensures international competitiveness, continued economic growth and wealth creation of a country, region, cluster or other operational unit, whereas at the microeconomic level, it ensures the continued leadership of a company in the marketplace, through the introduction of innovative products or services that meet the customer needs (Harrison and Samson, 2002, Tidd et al., 2001, Paija, 2001). Hence, a firm‘s business strategy should have a strong emphasis on issues associated with technological change.

Predicting the path of the technology evolution is a very challenging and, in most cases, an impossible task. The difficulty is not necessarily in anticipating the future technological changes per se, but rather the choices that society makes about which technologies to invest in and what to accept, adopt and reject (Gallaire, 1998, Christensen, 2000). Thus, even if the technical specifications of DTs are available and understood at the time of introducing the technology, the time required for it to become fully performance-competitive with the established technologies, and the uses that it may get once accepted by mainstream market, are usually unforeseeable. Furthermore, as the history of DTs demonstrates, the availability of an advanced and radical technology does not assure that its potential will be extended into useful applications, nor that its diffusion reaches those who might use it most productively (Abetti, 2000), thereby increasing the risk associated with such advancements (and adoptions).

If the assessment above is true, then organizations introducing or confronting DT must be prepared for a lengthy period of turbulence, which may challenge their very raison d‘être. Consequently the unpredictable nature of DT increases ambiguity and insecurity both at the business sector as well as at the consumer level. What follows then, is vigorous discussion about how desirable it is to encourage the technological change process and introduction of DTs given the dangers associated

with them (Miller et al., 1998). The concerns are not only technical in nature, but they emerge also at social level, including social injustice and its extreme form of social exclusion (Castells and Himanen, 2002).

Despite these debates about preservation of status quo versus dynamism, and incrementalism versus radicalism, the widely held view favors pursuing socio-technical dynamism rather than preservationism (Miller et al., 1998). From the corporate point of view this means that the threats and opportunities brought about by the continuous need for change and innovation, and the recent world events requiring increased focus on security and resilience (Evans, 2003), makes it imperative for firms to revisit their strategies and increasingly focus on efficient introduction, management and exploitation of emerging and disruptive technologies.

Based on exploratory case studies of two companies in transportation industry with different strategies to manage and introduce DTs, this paper aims at challenging earlier recommendations for the best practice strategies to manage DTs. Furthermore, it attempts to show how DT can become, if properly managed, a capability-enhancing strategic asset and a medium to improve the business model.

The paper is structured as follows. In the following section, a brief, systematic review of focused literature and theoretical framework underpinning the motivating research question is presented. In this review, a perspective of evolutionary economics is adopted. Drawing upon the literature review, the research hypothesis is formulated, followed by a discussion of analytical problems associated with DTs. After brief review of DT in transportation industry, we present and analyse the case study companies using our assessment framework. The paper concludes with conclusions and implications for further research.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

The fundamental question in the field of strategic management is how firms achieve and sustain competitive advantage. To respond to this question, Joseph Schumpeter was the first scholar to conceptualise the general idea of "creative destruction" (Schumpeter, 1934).

Since the pioneering work of Schumpeter, numerous contributions have been made to refine and further develop his theories. The ones most referred to in the recent literature include the ′five-forces′ (also referred to as competitive forces) model by Porter (1980), the strategic conflict approach by Shapiro (1989), resource-based approach (e.g. Penrose, 1959, Rumelt, 1984), and ′dynamic capabilities′ approach by Teece et al. (1997). Building upon the idea of creative destruction, Schumpeter was also the first scholar to capture the problem of finding the right equilibrium between exploration and exploitation strategies.

Exploitation and exploration strategies are frequently associated with radical and incremental innovations in the literature. The mainstream of the previous contributions have recognised that technological innovation frequently falls into one of these categories (Afuah, 2001, Day and Schoemaker, 2000, Tushman and Anderson, 1986, Abetti, 1989). Despite the vagueness of the definition criteria (Abetti, 1989), the underlying difference between these two categories is that whereas incremental innovations are developed with modest advancements to the old technology following the logic of exploitation strategy and preserving the status quo of industry, radical innovations mainly result from utilisation of exploration strategy and have an industry equilibrium-disturbing character (Afuah, 2001, Perrons and Platts, 2003, Tushman and Anderson, 1986).

The very essence of DT, as it is defined in the literature, is that it changes the prevailing value proposition (Christensen, 2000), thereby shaking up the status quo of the industry to which it is introduced. For organisations this shake-up can be felt at three different, but increasingly interrelated levels – changes in their external environment, changes in their organisational settings, and changes in the skill sets required from the members of the organisation to adjust to the new situations (Dierkes et al., 1998). Furthermore, in this change process, leadership changes hands (Utterback, 1994, Christensen, 2000) suggesting that efficient management of technological discontinuities – and DTs in particular – ought to have a profound impact on any firm's strategy (Perrons and Platts, 2003). Failing to understand the role that technology can take as a key strategic resource of a corporation can impede its becoming a strategic asset if improperly managed (Abetti, 1989). Hence it follows that business strategies of firms can be said to be very sensitive to technological novelties and should be revisited and redesigned according to the changes in their internal and external circumstances. Indeed, a successful strategy to manage DT involves not only deciding the modi operandi of the technological development within the boundaries of the firm's capabilities, as portrayed in the resource-based theory, but also requires constant surveillance of markets and how entirely new uses and new needs in their external environment might emerge (Miller et al., 1998), as well as what kind of an approach should be used to identify and respond to these challenges.

Hypothesis: Given that the success of a disruptive technology is largely determined by the market, finding the right equilibrium between market penetration and market creation has a potential to improve the overall business performance and result in the generation of the ideal business model.

Definition of Disruptive Technology

The vagueness of the definition criteria is reflected in the definition of DT. DT, as it is portrayed in the mainstream literature, seems to have been given the characteristics of, and sometimes even seen as a synonym to, radical innovation. However, according to Christensen (2000), a distinction should be made between radical-incremental and disruptive-sustaining antagonisms. His proposition is that both disruptive and sustaining technologies can be developed either by incremental improvements or as a radical innovation. In another words, DT can be developed by following either exploitation or exploration trajectories. Hence, a distinction should be made between radical-incremental and disruptive-sustaining antagonisms.

Another misleading issue is related to the 'technology' part of DT, which gives the impression that DT refers only to products. However the term has a much wider meaning. "[Disruptive technology is] a method, a procedure, or superior knowledge or skill in application" (Lievano, 1999). In other words, DTs are new technologies, concepts or methodologies that revolutionise the way things are done. What is common to all DTs is the potential for them to act as the genesis for brand new industries.

ANALYTICAL PROBLEMS CONCERNING DISRUPTIVE TECHNOLOGY

As the definition of DT implies, all such advancements are novel and unique. Christensen (2000) illustrated this by exploring the limits of the technology S-curve, and concluded that "DTs emerge and progress on their own, uniquely defined trajectories" (ibid. p.46). What follows is that this uniqueness creates an analytical problem of ex-ante and ex-post comparisons of success and failure factors of DT in relation to established technologies. Despite this difficulty, many attempts have been made to address such factors (Marquis, 1969, Levi, 1998, Roberts, 1991, Hippel, 1988, Kelly and Kranzberg, 1978, Abetti, 2000). Abetti (2000), for instance, concluded that the overall success

of a radical innovation is not only determined by its ability to meet technical specifications (technical success), but also how well it is accepted by the market (commercial success) and whether it provides an adequate return on investment (financial success).

DISRUPTIVE TECHNOLOGIES IN THE TRANSPORTATION INDUSTRY

History is rich of great examples of advances, each occurring through a single discovery which quickly replaced the old products and techniques. The examples include metalworking, gunpowder, printing and cash money, all of which have had a profound impact on the economy and society through industry shake-ups (Cooper and Schendel, 1976), and changes in market and industry leadership (Utterback, 1994).

It is often said that society has advanced further in the last 50 years than it did in the previous 2000 years. This is reflected in the number of scientific, engineering and medical advances that have occurred in this period. The transportation industry has been a beneficiary of many of these developments suggesting that the transportation industry is largely built on technological innovation. By its nature, it is very capital intensive, encouraging the introduction of new technologies, many of which have had the characteristics of DT. This makes the transportation industry an interesting sector for examining the impact of introduction of DT on firm performance and to test our hypothesis. The two case studies that follow illustrate the revolutionary and evolutionary effects that DT can have on different aspects of the transportation industry.

EFFECTS OF DISRUPTIVE TECHNOLOGIES ON TWO FIRMS IN THE TRANSPORTATION INDUSTRY

In this section we examine in more detail the effects that DTs have had on two firms in the transportation industry. The first one, United Parcel Service, is an almost 100-year-old company with vast global operations centred on the transport of goods. By contrast, the second company, Octopus Card, is a small 10 year-old Hong Kong company whose service facilitates the transport of people.

United Parcel Service Inc.

United Parcel Service Inc. (UPS) was founded in 1907 in Seattle, Washington, as a private messenger company. Today, UPS is the world's largest delivery company. In 2002, its revenues and shippings totalled US$31 billion and 4.8 billion packages and documents (equal to 13.3 million items everyday), respectively. It has a fleet of 88,000 delivery cars, vans, tractors and motorcycles, 581 company-owned and chartered aircraft and 1,748 facilities worldwide with a workforce of 357,000. In short, it is a global leader in supply chain services managing the flow of funds, goods, and information to 200 countries (UPS 2002 Annual Report).

Management of Disruptive Technology

UPS did not reach its current position by accident. From its earliest days it quickly adopted new technology to maintain its competitive market position. In fact, in its first few years it was the beneficiary as well as a victim of DT. As telephone technology became more widespread, its original business of delivering messages was almost destroyed. However, the automobile allowed it to greatly expand the geographic scope of its package delivery business.

Today, with 13.3 million packages to track and 7.9 million requests to process daily, UPS needs both to supply accurate information for their delivery services and have a reliable network infrastructure to transfer this information quickly and effectively. Hence, UPS' latest information

technology project is the development of an end-to-end wireless network. This project, with a budget of $127 million, will take 5 years to complete. By the end of the project, each driver's handheld DIAD, a device that records and uploads delivery information to the UPS network, allowing customers to track in real-time the status of their shipments, will be able to connect to six different wireless networks - infrared, WiFi, Bluetooth, the satellite-based Global Positioning System (GPS), and two cellular networks, CDMA1x and GSM/GPRS enabling drivers to connect to UPS' worldwide network from the customer's site.

Even though UPS spends about $1.5 billion dollars per year on technology, its innovative technologies mainly represent "qualifiers" that allow it to compete in this industry (see appendix 2, table 2). For example, the U.S. Postal Service has also adopted its own automated tracking package technology. UPS' main private sector competitor, Federal Express Corp., has developed a similar handheld device called FedEx PowerPad. Therefore, UPS' order winners still remain price and a timely delivery service.

Impacts of DT

UPS is an example of how DTs can help a company to improve its operating performance. The company still basically provides the same service it did in 1907 – delivering packages for customers. However it is using advanced technology to improve the way it operates its primary business and to leverage those skills and infrastructure to move into other related lines of business. UPS has developed software applications and mobile devices with the support of wireless networks for shipping and tracking services. Its software applications work on a common platform with a single database, enabling it to optimise the route and load plans faster in order to surpass its competitors.

UPS' software applications generate reports for managers that allow them to better plan and control the delivery routes. Better planning and route control result in time saving and more efficient use of resources.

<u>Octopus Card</u>

In the mid-1990s, the two passenger rail companies in Hong Kong – the Mass Transit Railway Corporation (MTRC) and Kowloon-Canton Railway Corporation (KCRC), wanted to adopt a modern 'smartcard' system. To maximise the potential of the new system and reduce the development costs each company faced, they asked the other three major public transport operators in Hong Kong at the time - Kowloon Motor Bus, Citybus and the Hong Kong and Yaumati Ferry - to join their venture.

A company called Creative Star Limited was established in 1993 to manage the development and implementation of the smartcard. It is a private, non-profit organisation that settles accounts between the Octopus system and the member operators and merchants. The Octopus system was launched in September 1997.

Octopus Card has a unique marketing position, as it is both a product and process technology. As a product, there was no standard technology platform at the time of its introduction and hence the technology behind Octopus Card consists of a proprietary system of radio frequencies. Having begun as a replacement of magnetic cards, the Octopus Card created a new method of payment and evolved into a process by which transport services and goods are purchased and transacted.

Defeat of Mondex

The Mondex smartcard system was launched in Hong Kong in 1997. It had the backing of two large and powerful organisations – Mastercard and the Hong Kong and Shanghai Banking Corporation (HSBC). It promised a revolution in the way consumers paid for ordinary goods and services. Over 100,000 people applied for a card in its first two months on the market. The number of merchants accepting Mondex reached into the thousands. It appeared to be on the way to great success.

However, on 31 March 2002, HSBC announced to its Mondex cardholders that the Mondex card program had been discontinued, only five years after it was launched. The reason was that the Octopus card was introduced which provided an innovative electronic payment service, reducing the need to handle cash. Compared to Octopus, the Mondex card was cumbersome and slow to use. The more sophisticated technology required for the Mondex platform was no match for the simplicity and ease of use of the Octopus, the latter system therefore achieving market acceptance and eventual commercial success. A similar situation was reported in the telecommunication industry by Abetti (2000).

Impacts of DT

At UPS, it is seen that the adoption of advanced technology is an enabler for a better business model. With Octopus Card, the technology used to operate the system is itself a DT. From a narrow view, given its origin as a transport payment system it could be said that Octopus has largely displaced the magnetized paper and plastic ticket system. However the full value of the technology is only now becoming apparent.

The Octopus system is not particularly advanced compared to some of the technologies available today, but it is one of the most successful smartcard systems in the world. It has impacted on the whole national socio-economical system through its co-operation with the main public transport operators in Hong Kong by developing a single smartcard system. In many countries, different public transport operators develop their own smartcard technologies but these are often incompatible with each other, thereby restricting their adoption (Abetti, 1989). This inhibits the generation of dominant design and its spread into different contexts, thereby decreasing the likelihood of other follow-on innovations (Nooteboom, 2000). In contrast, every major public transport system in Hong Kong now uses the Octopus Card. Thus the Octopus Card has created a systems disruption, and is anticipated to give rise to many other innovations in different sectors.

Following the life cycle of technological innovation described by Nooteboom (2000), the use of the Octopus Card has spread far beyond its initial purpose. In addition to the uses in public transportation system, it is slowly becoming a standard payment method as well. Other businesses using it include car parks, photograph booths and other vending machines. Some residential estates are now using Octopus as the respective complexes' security access card, as each card has a unique identification (ID) number. In line with Nooteboom's model (ibid.), the Octopus Card technology seems to exhibit more of the exploitation characteristics. This differentiation and fragmentation of the original technology can then lead to the "cleaning-up stage" where new innovations are created through reconfiguration of the established technology. Thus, the challenge for Octopus is to find the balance between market penetration and market creation.

ASSESSMENT FRAMEWORK

To understand and assess the impact that DTs can have on companies, we put forward an 'Assessment Framework', based on contributions by Lievano (1999) and Christensen (2000). Whereas the 'Prototype Markets and Strategies' model (Lievano, 1999) suggested that the formulation of the appropriate business and technology strategies should be based on matching

technologies to market characteristics, our Assessment Framework is a reverse of such a process, incorporating Christensen's ideas of the product life cycle and product-process matrixes.[1]

The first step in the Assessment Framework is to position the DT of the firm in an appropriate market or industry. The second step is to assess the 'fit' and success of the firm's business strategies in the market and the operating performance objectives that must be met, using the Assessment Framework as a guide. Based on the information presented on Octopus and UPS, and using this Assessment Framework, we can measure the success of companies in terms of their introduction of DT.

Octopus

In terms of market positioning, we placed Octopus at the 'High-End' as it possessed the characteristics of a product at the introductory stage of a typical product life cycle. Firms operating in this category would have order winners similar to Octopus - uniqueness and speed of introduction (to all mass rapid transport commuters). Whether by design or not, Octopus' ability to expand out of its transport fare market demonstrates its ability to create new product/market combinations. The attainment of the operational performance objectives of this category of DTs like speed, quality and flexibility have been experienced by Octopus.

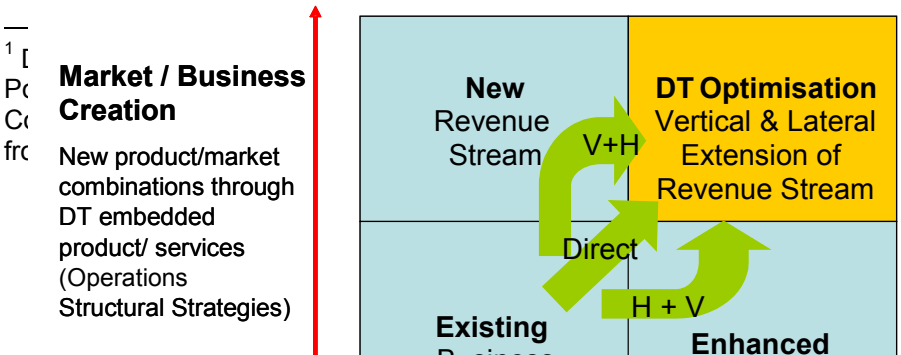
The Assessment Framework emphasises Octopus' strengths. In addition, it highlights the DT's potential in encouraging the creation of new markets or businesses beyond those originally planned or expected. This element of surprise will be discussed and incorporated in our DT optimisation model below.

UPS

While Octopus is in the high-end market, UPS competes in a mature market. In order to surpass its competitors, UPS relies on advanced technology to integrate its operating processes to provide faster and more accurate delivery services. This technology provides a new method to serve its customers. The return on investment from adopting new technology is not just the higher productivity that results (and hence lower costs), but also the incremental sales revenue that this superior performance attracts. It also opens up opportunities to penetrate into new geographical markets and lines of business. It is this business philosophy that has turned UPS into one of the world's largest delivery service and global supply chain solution providers.

DT OPTIMISATION MODEL

Octopus Card's example of breeding a new business model from a DT, thereby creating a new revenue model entirely different from its original intent, suggests that it has created a systems disruption through its multiple uses. A major surge of innovation is now expected from these uses beyond the transport industry. Combined this with UPS' progressive introduction of technologies that strengthens its market position, allow us to plot a new direction of interaction between market creation and market penetration, where the benefits of both can materialise. As depicted in the Figure 1, by tracking and merging the separate paths taken by both companies, it is possible to generate a scenario for a new business model enabled by technologies being embedded in both products/services and processes.



[1] [n Market
Po ss Strategy,
Co (adapted
fro

Figure 1: Disruptive Technology Enabled Business Model

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

History has repeatedly shown that DTs offer incumbent enterprises opportunities to strengthen and penetrate their market position whilst providing new product/market combinations to emerging enterprises. The two cases from the transport/logistics industry, as applied by the Assessment Framework, demonstrates that disciplined implementation of appropriate marketing strategies and the proper identification of key operational objectives are keys to the successful utilisation of DT. In another words, the paths that our case study organisations have followed show that DT-embedded processes and products create opportunities for generating new business models that have the advantages of both market creation and penetration. Thus, the case studies presented here support our earlier-stated hypothesis and challenge the conclusions of previous research by suggesting that, in addition to the experimentation and exploitation strategies discussed in literature, in the face of DT, the best practice model may well be a mixture of the two strategies with the ultimate goal of minimising the negative impacts and maximising desirable consequences. We have named this the "DT optimisation model".

While the two case studies provide initial evidence and support for our hypothesis, further research is needed to test if the findings in other industry sectors confirm these initial conclusions. Furthermore, it would be interesting to map the different paths firms take when moving from one position to another in our market creation/market penetration matrices. Finally, it would be important to see if critical success factors of organisations in these various stages evolve and are differentiated from each other.

REFERENCES

Abetti, P. A. (1989) *Linking Technology and Business Strategy,* The Presidents Association. The Chief Executive Officers Division of American Management Association.

Abetti, P. A. (2000) Critical Success Factors for Radical Technological Innovation: A Five Case Study, *Creativity and Innovation Management,* **9,** 208-221.

Afuah, A. (2001) Dynamic Boundaries of a Firm: Are Firms Better Off Being Vertically Integrated in the Face of Technological Change?, *Academy of Management Journal,* **44,** 1211-1228.

Castells, M. and Himanen, P. (2002) *The Information Society and the Welfare State. The Finnish Model,* Oxford University Press, New York.
Charpie, R. A. (1970) In *Technological Innovation and Economy*(Ed, Goldsmith, M. L.) Wiley Interscience, London, pp. 1-10.
Christensen, C. M. (2000) *The innovator's dilemma,* HarperBusiness, New York.
Cooper, A. C. and Schendel, D. (1976) Strategig Responses to Technological Threats, *Business Horizons,* **19,** 61-69.
Cornelius, P. K. (2003) World Economic Forum, New York.
Day, G. S. and Schoemaker, P. J. H. (2000) In *Wharton on Managing Emerging Technologies*(Ed, Gunther, R. E.) John Wiley & Sons, Inc., New York.
Dierkes, M., Hoffman, J. and Marz, L. (1998) In *21st Century Technologies: Balancing Economic, Social and Environmental Goals*OECD, Schloss Kirckenberg, Germany, pp. 97-122.
Evans, N. D. (2003) *Business Innovation and Disruptive Technology. Harnessing the Power of Breakthrough Technology... for Competitive Advantage,* Financial Times Prentice Hall, Upper Saddle River, NJ.
Gallaire, H. (1998) In *21st Century Technologies: Balancing Economic, Social and Environmental Goals*OECD, Schloss Kirckenberg, Germany, pp. 47-75.
Harrison, N. and Samson, D. (2002) *Technology Management: Text and International Cases,* McGraw-Hill, New York.
Hippel, E. V. (1988) *The Sources of Innovation,* Oxford University Press, New York.
Kelly, P. and Kranzberg, M. (1978) *Technological Innovation: A Critical Review of Current Knowledge,* The San Francisco Press, San Francisco, CA.
Levi, N. (1998) *Managing High Technology and Innovation,* Prentice Hall, Princeton, NJ.
Lievano, R. J. (1999) Disruptive technologies: opportunities for the small firm, *The Arrowhead Journal of Business***,** 58-68.
Marquis, D. G. (1969) The anatomy of successful innovations, *Innovation*.
McKelvey, M. and Texier, F. (2000) In *Technology and Knowledge*(Eds, Saviotti, P. P. and Nooteboom, B.) Edwar Elgar, Northampton, MA, pp. 227-248.
Miller, R., Michalski, W. and Stevens, B. (1998) In *21st Century Technologies: Balancing Economic, Social and Environmental Goals*OECD, Schloss Krickenberg, Germany, pp. 7-32.
Nooteboom, B. (2000) *Learning and Innovation in Organizations and Economies,* Oxford University Press, Oxford.
Paija, L. (2001) In *Innovative Clusters. Drivers of National Innovation Systems.*OECD, Paris, pp. 19-44.
Perrons, R. and Platts, K. (2003) In *EurOMA - POMS Conference*, Vol. 2 (Eds, Spina, G., Vinelli, A., Cagliano, R., Kalchschmidt, M., Romano, P. and Salvador, F.) Como, Italy, pp. 241-250.
Roberts, E. B. (1991) *Entrepreneurs in High Technology,* Oxford University Press, New York.
Schumpeter, J. A. (1934) *Theory of Economic Development,* Harvard University Press, Cambridge, MA.
Tidd, J., Bessant, J. and Pavitt, K. (2001) *Managing Innovation. Integrating technological, market, and organizational change,* John Wiley & Sons, West Sussex.
Tushman, M. and Anderson, P. (1986) Technological Discontinuities and Organizational Environments, *Administrative Science Quarterly,* **31,** 439-465.
Utterback, J. M. (1994) *Mastering the Dynamics of Innovation,* Harvard University Press, Boston, Massachusetts.