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Pioneering New Technologies: Management Issues and Challenges in the Third Millennium

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FOREWORD

The principle objectives of the Conference ***'Pioneering New Technologies: Management Issues and Challenges in the Third Millennium'*** are to present the latest thinking and practices about the integration of management and technology and to bring about a more robust dialogue between practitioners and academics regarding best practices for using new technologies in building and sustaining competitive advantage. Towards that end the conference opened with key speakers from industry, government and academia; panels provided a forum among managers and academics on education, work and innovation; workshops for practitioners were held on change, new product development, new management technologies and technical leadership; and papers were presented on current issues and new theories surrounding management and technology. This Proceeding contains the approximately 100 selected papers that were presented at the Conference and submitted in full length for publication.

Technological leadership is critical for the 21st century. Pioneering new technologies will require new forms of leadership as well as require sophisticated technology development. Among the important issues to address will be growing internationalization of markets and technology, developing appropriate tools to value and assess technology potential, understanding how new forms of organization will effect innovation, the new product development process, sustainable development and the technology-human resource interface. All these subjects are treated amply in these proceedings.

Pioneering technology is the seed of future growth. Without proper management attention we cannot capture the value of this potential. The IEEE Engineering Management Society in choosing the theme ***'Pioneering New Technologies: Management Issues and Challenges in the Third Millennium'*** for their 1998 International Conference recognizes this challenge. The world-wide attention attracted by the conference attests to the importance of this topic and the value of IEEE EMS in providing a forum and resource for helping understand the dimensions of the issues involved and in laying the foundation to find solutions.

We believe that this volume contains some of the best current papers on management and technology. Its interdisciplinary character will foster theory development and new insights into technology management practices.

Lois S. Peters
Technical Program Chair
IEEE EMS '98

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BUSINESS OPPORTUNITY AND TECHNOLOGY FUSION IN TERMS OF INNOVATION DYNAMISM

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Introduction

A paradigm of technological innovation consists of a technological development period and a diffusion period for the new products. The former period is termed the technological trajectory, and the latter period , the diffusion trajectory. According to the analysis of past technological innovations, the technological trajectory having a time span of ca.20~30 years joins with the diffusion period in a cascade fashion. Another trajectory termed the development trajectory was found to exist just before the diffusion period. Business opportunity to launch venture businesses can be found at the early period of the development trajectory. Existing industries absorb new innovation technology to make a technology fusion. It is noteworthy to learn that such technology fusion takes place along the development trajectory.

I. Background

The relation of technological innovation and economic development has been analyzed for a long time and the diffusion of the innovation products has been discussed.. J.A. Schumpeter discussed economic development in terms of technological innovations and ascribed economic growth to the innovation as an engine of growth.

The diffusion of innovation products has been studied for a couple of decades. Griliches Z.[1] first disclosed that the diffusion of hybrid corn, a new agricultural product, can be expressed by a logistic equation (1):

$$dy/dt = a\,y\,(y_o - y) \qquad (1)$$

where y is the demand for product at time t, y_o is the ultimate market size, and a is a constant.

Mansfield E.[2],[3],[4], Metcalfe J.S.[5], Norris K. and Vaizey J.[6], Nakicenovic N. and Glübler A.[7], and Fisher J.C. and Pry R.H.[8] recognized the applicability of the logistic equation to the diffusion of innovation products. And, Fisher and Pry [8] transformed the equation to express as a straight line which can confirm that the data firmly fit the logistic equation. That is, the logistic equation can be transformed to the equation (2) :

put $F = y/y_o$,

$$\ln F/1 - F = at - b \qquad (2)$$

This analysis has been skillfully adopted by the later analists to examine whether the process obeys the logistic equation or not. Recently, logistic treatment has been criticized and some other models have been proposed.. Davies P. [9] , David P. [10], and Stoneman P. [11] proposed alternative or modified equations for the diffusion of products. The actual diffusion of products is not always smooth and quite often fluctuates with the turbulence of various economic circumstances. This makes it difficult to evaluate which equation is valid.

The author has studied in detail the process of technological innovation by the use of logistic equation and found that there is a dynamism of the innovation process with unique characteristics. This is the report of these studies on the dynamism of innovation.

II. Diffusion of Innovation Products

The author [12] has analyzed the details of diffusion phenomenon of innovation products according to the Fisher & Pry plot and found that the diffusion can be clearly expressed by a logistic equation. The actual course of product diffusion sometimes encounters various kind of turbulence such as economic depression to cause delay of the diffusion, but after the recovery of a sound economic condition the diffusion resumes the normal course of logistic function. That is, the straight line of the diffusion function illustrated by the Fisher/Pry plot always has the same slope irrespective of interference by economic turbulence. This kind of behavior proves that the diffusion of innovation products is governed by a clearly defined diffusion coefficient to make a definite diffusion rate. Fig.1 shows the actual transition of ethylene production in Japan which indicates heavy interference of diffusion by complicated economic depression mainly caused by an oil crisis. The Fisher/Pry plot of ethylene production in Japan, however, clearly indicates as shown in Fig.2 that there is a straight line with a well-defined slope across the time of oil crisis. The case of ethylene production in the United States indicates the same result as in Japan.

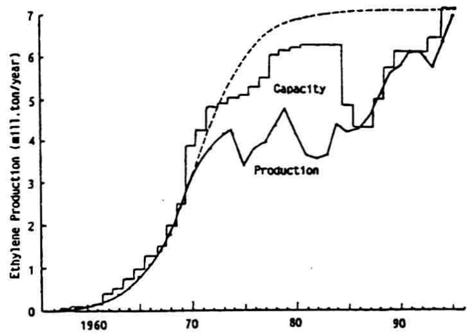


Fig. 1 Ethylene Production in Japan

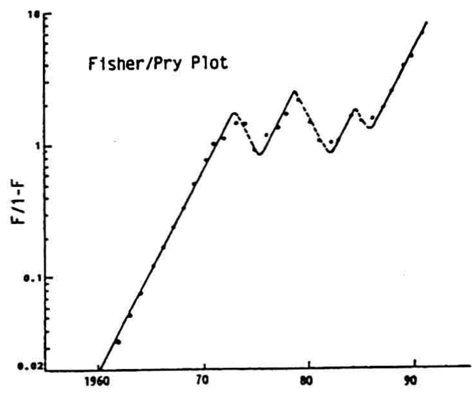


Fig.2 Fisher/Pry Plot of Ethylene Production

III. Technological Trajectory and Innovation Paradigm

The diffusion of innovation products starts a fairly long time later, after the emergence of radical invention of the key technology. That is, innovation products appear in the market and begin to diffuse after a long period of development of technology. According to an intensive analysis of various technological innovations since the first Industrial Revolution, it was observed that almost all key technologies were concentrated during the development period before launching new products to the market and key technologies make a cluster of inventions during such development period as shown in Table I. So that the period of technological development can be termed the "technological trajectory". A technological trajectory can be easily identified by checking how inventions are clustered during a definite time span and usually the time span of the trajectory can be determined by knowing first and last important inventions. It takes rather a long time to finish the technological development, e.g. ca. 60 years in the age of the first Industrial Revolution, though it has been shortened to 20~30 years nowadays as shown in Table II.

Table I. Identification of Technological Trajectory

Paradigm	Year	Inventions
Steam Engine	1769	Steam engine by J. Watt
	1784	Double acting engine
	1790	Usage for spinning factory
	1798	Cornish engine
	1803	Steam locomotive
	1807	Steamboat by R.Fulton
	1813	Stevenson's locomotive
	1825	Railway by locomotive
Electric Power	1840	Magnetic generator
	1845	Electromagnet generator
	1856	T-type generator
	1867	Self-excited generator
	1881	Thermal power station
	1886	Alternating current
	1891	AC transmission
	1895	Water power generation at Niagara Falls

Table II. Time Span of Technological Trajectories — Distribution of Key Inventions

(Years)

Paradigm	Span	Paradigm	Span
Spinning machine	55	Television	49
Iron making	63	Aircraft	36
Steam engine	56	Synthetic polymer	46
Acid, Alkali	57	Computer	28
Telegraph, Telephone	62	Electronics	27
Electricity	55	Fine ceramics	30
Steel making	49	Advanced composite	29
Synthetic dyestuffs	48	Robot	33
Automobile	53	Biotechnology	33

The technological trajectory has a definite time span and could have an S-shaped curve because the first period of technology development may be time consuming while the last period is mature and so slows. The knowledge transfer from person to person is the key phenomenon of technological development so that the state of technological trajectory can be expressed by the same logistic equation as the diffusion of innovation products. Therefore, the author has illustrated a technological trajectory as a logistic S-curve having the time span determined above. As a matter of fact, many studies, such as Modis T. [13] and Marchetti C. [14], have indicated that various human activities like music masterpieces and scientific activities of great persons can be well expressed by a logistic equation.

Thus, a paradigm of technological innovation can be expressed by two S-curves of technological trajectory of development period and diffusion trajectory of innovation products. Fig. 3 illustrates the interrelation of the actual technological trajectory and product diffusion of various innovations. Fig. 3 (1) illustrates innovation paradigms of energy and motive power exemplified by the steam engine, electricity, and automobile. Fig. 3 (2) shows innovation paradigms of information and communication technologies; e.g., telegraph, telephone, vacuum tubes, electronics and computers. All of these paradigms clearly indicate that the technological trajectory joins with the diffusion trajectory of innovation products in a cascade fashion. So that, an innovation paradigm can be commonly expressed as a cascade joint of technological trajectory and diffusion trajectory of products as shown in Fig. 4. During the period of the technological trajectory, various patents of key technologies are accumulated so that the S-shaped curve can be looked upon as the transition of the cumulative number of patents.

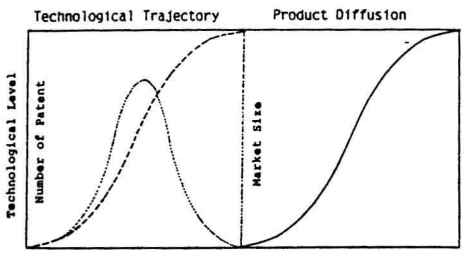


Fig. 4 Innovation Paradigm —Technological Trajectory and Product Diffusion

IV. Development Trajectory and Business Opportunity

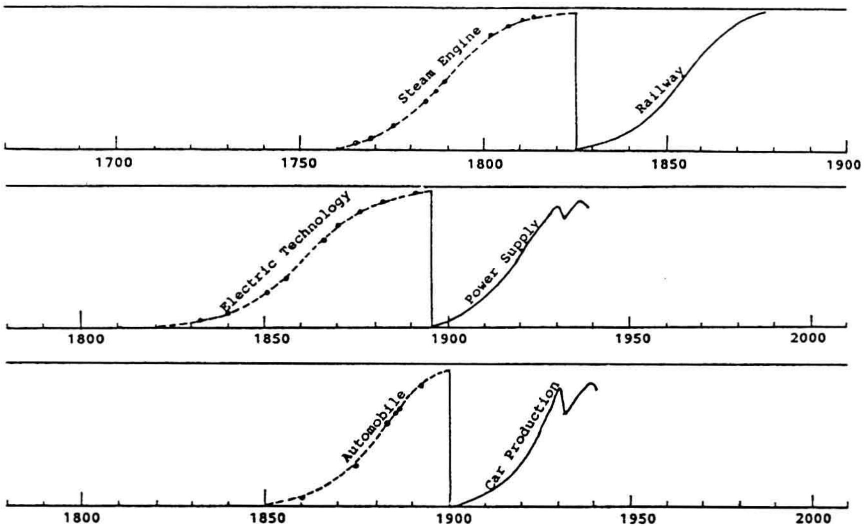
Fig. 5 illustrates three cases of innovation paradigm: synthetic dyestuffs, electronics, and biotechnology. These paradigms, of course, have their technological trajectories and diffusion trajectories in a cascade fashion, respectively. In cases of synthetic dyestuffs and biotechnology, however, technological trajectories are those of scientific ones. Though most key technologies came from academia, these actually functioned as the core frameworks of technologies.

Further, there are additional trajectories called development trajectories situated slightly earlier than diffusion trajectories. These trajectories consist of various incremental inventions and technologies for commercialization. These mean that even during the diffusion period, incremental innovations incessantly proceed to cope with technological improvement and application purpose, but these are completely different from the core technologies composed of technological trajectories.

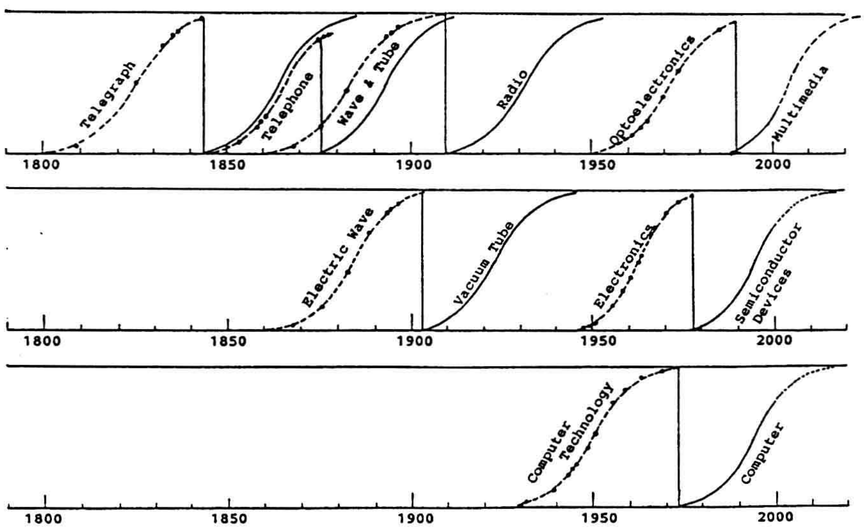
In the case of synthetic dyestuffs, the development trajectory is composed of the development of new commercialization products. These were achieved by collaborative research between academia and the relevant chemical industry because the technological trajectory was set up by mainly academic activities.

In the case of the electronics paradigm, the development trajectory is composed of development of hard devices and software. The development trajectory of computers can be traced by the advancement of mainframe and personal computers.

In the case of biotechnology, the development



(1) Energy and Motive Power



(2) Information & Communication

Fig. 3 Paradigm of Technological Innovation — Cascade of Technological Trajectory and Product Diffusion

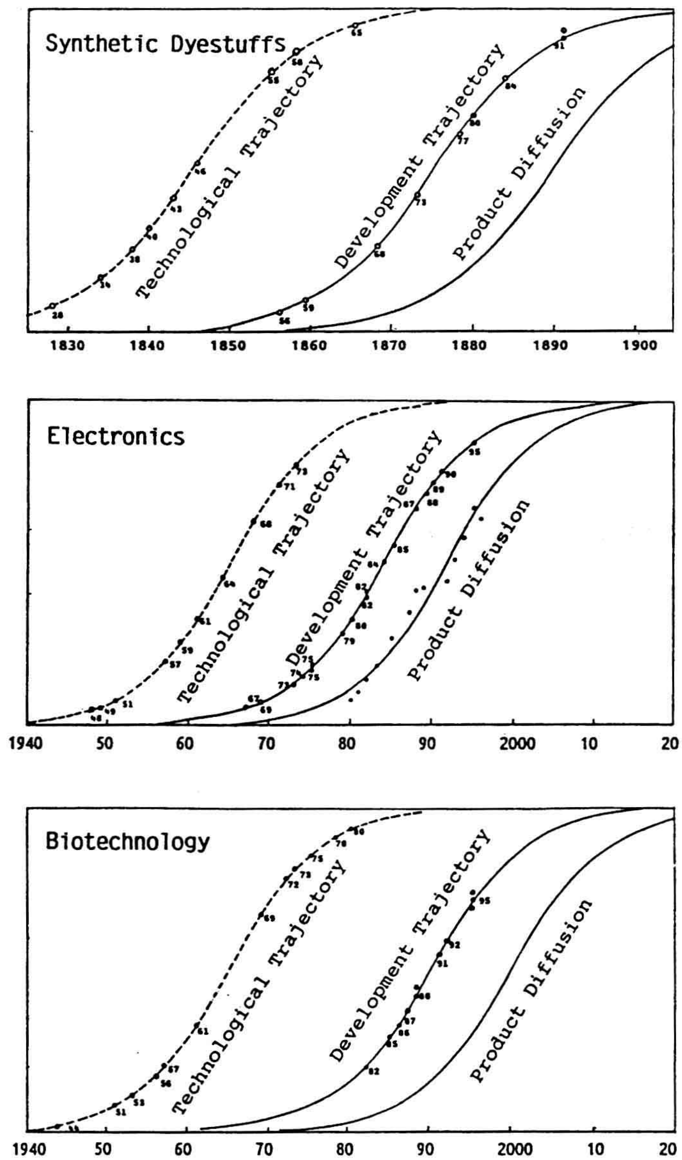


Fig. 5 Location of Development Trajectory in the Innovation Paradigm