PATH DEPENDENCE -
THE US CEMENT MANUFACTURING TECHNOLOGY IN 1950-1980

2ND INTERNATIONAL CONFERENCE ON PATH DEPENDENCE
March 3-4, 2011

A work - in - progress paper

Abstract

In the 1950's energy costs in the US were much lower than those in Europe. Since the early 1900s there were two manufacturing processes, the energy consuming wet process and the dry one. Because of low energy costs the US cement industry used wet process. In 1950 energy saving technology, suspension preheating, was introduced in Europe. This technology was introduced in the US in 1953. Unfortunately, it had problems with alkaline. The industry kept on manufacturing with wet processes. Anyway the US cement industry did not have any particular problem. The demand and profits were high. In the 1960s several US cement manufacturers were alleged for spatial monopolies since they manufactured both cement and concrete. Trials took top management's attention and thus, they neglected the technology follow up. In the mean time the suspension preheater technology was widely adopted elsewhere. In the early 1970s the oil crises rose manufacturing costs in the US. Foreign companies entered the market with the modified preheating technology. The alkaline problem was solved. At the end of 1970s foreign companies owned 55 per cent the US cement industry. It seems that the lock-in the wet processes was costly to the owners of the US cement industry.

Keywords: path dependence, industry evolution, business history, cement industry

1. INTRODUCTION

After the second world war the energy cost in the US has been much lower that those in Europe. This difference has certain consequences in several industries. In this paper we look the US cement industry. In the cement manufacturing since the early 1900s there have been two manufacturing processes, the wet process and the dry process. The dry process is using less energy. In the 1930's the suspension preheater, a energy saving technology was patented in Europe. However, it took almost two decades until the technology was commercialized in 1952.

In the low energy cost US the cement industry used wet technology. The suspension prheater technology was introduced in the US in 1950. Unfortunately that time the US soil was not suitable for this technology. The manufacturing process had certain problems with alkaline. The industry kept on manufacturing with wet processes. The US cement industry did not have any particular problem. Mainly due to the Interstate high way program the demand was high and the industry was making nice results. In the 1960s the industry integrated to forward to the concrete manufacturing. Soon several cement manufacturers were alleged for spatial monopolies. The trial took long time and exhausted the management time. The companies were still locked in the wet manufacturing processes although elsewhere the suspension preheater technology was adopted.

In the early 1970s the oil crises hit the US cement industry hard. The high energy prices rose the manufacturing cost of cement. The industry was in bad shape. Foreign companies entered the market with modified preheating technology. The alkaline problem had been solved with by-pass systems. At the end of 1970s foreign companies owned 55 per cent the US cement industry.

In analyzing the path dependence of the US cement industry we apply the the cyclical model of technological change proposed by Anderson and Tushman (1990) and it modified version (Uusitalo, 1995). It seems that the lock in the wet processes was costly to the owners of the US cement industry. Moreover we define in this study the innovation as the first piece of product produced by a new process in the word market instead of Anderson and Tushman (1990) definition as the first piece of product produced by a new process in the US market. This definition is more suitable in analyzing the path dependence of the US cement industry in its choice of manufacturing technology.

Moreover we found, that Anderson and Tushman (1990) recognized the "re-launch" of the suspension preheater[1] kiln in the U.S. in 1972. As was mentioned suspension preheating was introduced in West Germany in 1950 and the first kiln with suspension preheater went on stream in the U.S. in 1953 (Nordberg, 1954, Garrett and Murray, 1974b and Biege and Parsons, 1977).

The rest of the paper is divided in five sections. The first section addresses the theoretical base, path dependence, the cyclical model of technological change (Anderson and Tushman, 1990), and Uusitalo's (1997) modified version of it. The second section is devoted to the research methodology. The third section deals with the empirical part. This section includes brief illustrations of the product, the technology and the case description of the evolution of the U.S. cement industry in 1950-1980. In the fourth section the path dependence of the US cement is analyzed with the help of the modified cyclical model of technological change. In the fifth section theoretical and managerial implications plus suggestions for future research are presented.

2. THEORETICAL BACKGROUND

Path dependence

According to Arthur (1989) there may be the circumstances under which the economy might become locked-in by 'historical events' to the dominant position of an inferior technology. David (1985) provides an important study of historical events leading to lock-ins in his research on the QWERTY typewriter keyboard. According to Leibowitz and Margolis (1995) the literature of path dependence, both theoretical and empirical, has several claims that path dependent processes lead us to inefficiencies, even for products sold in open markets. The same literature seems to argue that the lock-ins and errors occur, even in a world characterized by deliberate decision making and individually maximizing behavior.

Leibowitz and Margolis (1995) define three types of path dependence: first-degree, second degree and third degree path dependencies. These three types of path dependence make progressively stronger claims. First-degree path dependence is a statement of an intertemporal relationship without claim of inefficiency. Second-degree path dependence stipulates that

[1] Suspension preheater in this paper means 4-stage suspension preheater if nothing else is said.

intertemporal effects disseminate error. Third-degree path dependence requires in addition to the intertemporal effects propagate error also that the error was avoidable.

According to Teece et al. (1997) this isn't realistic. They also argued that history matters. A firm's previous investments and history constrain its future behavior because learning tends to be local and opportunities for learning will be close in previous activities. If too many parameters are changed simultaneously, the ability of firms to conduct meaningful natural quasi experiments is attenuated. Thus, the term denotes the significance of past development to current and future development.

According to Nelson and Winter (1982) existing knowledge bases can basically be separated into two distinct "technological regimes" which differ in regard to their opportunities and technological cumulativeness. At the centres there is the "creative accumulation regime" vs. the "creative destruction regime". The first regime is characterized by a lower level of opportunities and a higher level of cumulativeness whereas the second one is characterized by a higher level of opportunities and a lower level of cumulativeness.

Occasionally, however, disruptive technologies emerge: technologies that result in worse product performance, at least in the near-term. It was disruptive technology that precipitated the leading firms' failure. Disruptive technologies bring to a market a very different value proposition than had been available previously (Christensen, 1997). According to Christensen (1997) investing aggressively in disruptive technologies is not a rational since 1) disruptive technologies are simpler and cheaper promising lower margins and profits, 2) they typically are first commercialized in emerging or insignificant markets and 3) Leading firms' most profitable customers generally don't want, and indeed initially can't use, products based on disruptive technologies. A disruptive technology is initially used by the least profitable customers in a market.

The Cyclical Model of Technological Change

Since the 1980's several scholars have used biological analogies throughout the social sciences to explain the dynamics that govern technical and institutional changes as a social evolutionary process of variation, selection, and retention (Van de Ven et al., 1994). Variation means a major technological or institutional change. Selection or emergence of a dominant design occurs principally through competition among alternative novel forms. This period, era of ferment, is characterized by technological substitution and design competition. This period of substantial product class variation and, in turn, uncertainty, ends with the emergence of a dominant design. Retention involves the forces that try to maintain certain technical and institutional forms that were selected in the past. In this era many incremental innovations occur (Tushman and Anderson, 1986, Anderson and Tushman, 1990). Technological innovation is defined as the first commercial introduction of a product or a process in an industry when that introduction constitutes a technological change as defined above (Anderson, 1988:17). Tushman and Anderson (1986) further characterized technological discontinuities as competence-enhancing or competence-destroying. Anderson and Tushman's (1990) cyclical model of technological change is illustrated in Figure 1.

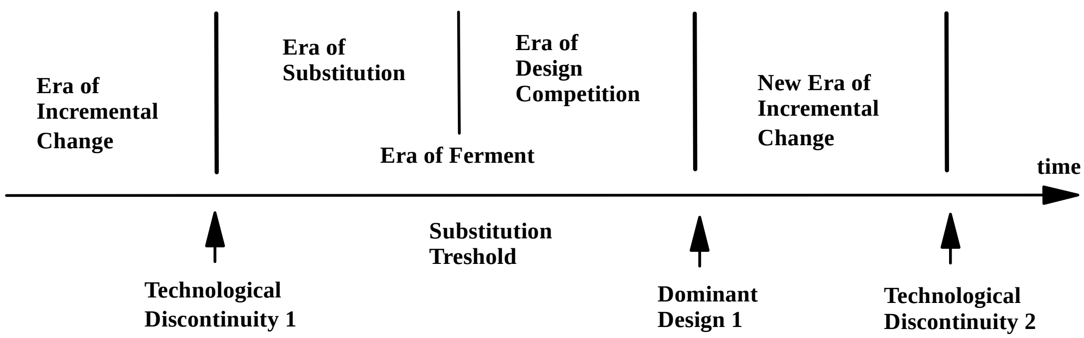

Figure 1. Cyclical model of technological change (Anderson and Tushman, 1990)

A Modified Version of the Cyclical Model of Technological Change

We use Uusitalo's (1995) modified version of the cyclical model of technological change instead of Anderson and Tushman's (1990) original model. This is because Uusitalo (1995) has redefined the performance parameter and innovation. Anderson and Tushman (1990) used production volume, number of barrels-per-day for cement, as the performance parameter in their evaluation of technological progress. However, production capacity measures only the efficiency of an organization and not the effectiveness of organization (Pfeffer and Salancik, 1978).

In measuring production volume Tushman and Anderson (1986) and Anderson (1988) neglected an important technological change, the suspension preheater kiln, in the U.S. cement industry in the early 1950s. Preheater kilns were first introduced in the U.S. in 1953 (Nordberg, 1954: 68). The use of this kiln made it difficult to produce cement with the low alkali content required in the U.S. market. Uusitalo (1995) used Pfeffer and Salancik (1978)'s external effectiveness (in the market place) of an organization as the performance parameter. In the cement industry this was the sales price (derived from both fixed and variable costs) of a barrel of cement.

Anderson and Tushman (1990) defined innovation as the first piece of product produced by a new process in the US market. Since we look the path dependence of the US cement industry in its choice of the manufacturing technology we have to follow the technological progress world wide. Thus, we define in this study the innovation as the first piece of product produced by a new process in the word market.

3. METHOD

Case Study Approach

The present study adopted a longitudinal, historical and contextual case study approach. According to Yin (1984: 42-44), a single case study is an appropriate design under when the case represents a critical case in testing a well-formulated theory, proposition or model. The single case can represent a significant contribution to knowledge and theory building. Since the present case, the suspension preheating, can be regarded as a critical case in testing a well formulated typology, the choice of the innovation was appropriate. Pettigrew (1985) argues that to understand a change one has to study it as a continuing process in the context in which it appears, and he encourages one to adopt a contextual and historical perspectives on processes of change, whatever the content of the change might be.

A single case study design has certain advantages compared with multiple cases. The most important is the depth of the analysis, both in terms of the number of factors studied and sources of information used (Yin, 1984). A single case analysis is the best way to get a holistic picture and understanding of the research problem. Patton (1990: 95) has argued that "qualitative inquiry is highly appropriate in studying processes because depicting a process requires detailed description." Since the unit of analysis in the present case study was suspension preheating in the cement industry, the final design of this study was an “embedded, single case study design” (Yin, 1984: 41).

As in any research approach, the case study has its limitations. One of the biggest concerns has been the lack of rigor in case study research. The methods of analysis are not well-formulated in the use of qualitative data (Miles, 1979). Case study research is very time-consuming and results in a massive amounts documentation the handling of which requires special skills (Yin, 1984). Another limitation of case studies is that they provide very little basis for scientific generalization.

The Choice of the Case Industry, the Innovation and the Research Period

Since the purpose of this paper is to analyze path dependence of the industry we need to enhance the depth and quality of data collected, as recommended by Berg and Smith (1988) and Eisenhardt (1989). The cement industry and the innovation was selected because 1) the innovation, suspension preheating was radical and complex enough to evaluate its path dependence, 2) Anderson and Tushman (1990) included the same industry and innovation in their study and 3) the studied industriy is well documented.

The European market has been also included in the analysis to show that one cannot understand technological development in the U.S. cement industry without reference to events in Europe. This was especially important in the case sincethe company introducing new technology came from Europe (Mehta, 1970 and Schroth, 1972). The research period is 1950-1980. Technological change, suspension preheating, was introduced in 1950 and thus the research period was long enough to analyze the diffusion of this innovation and the path dependence of the US cement industry.

Measures

Modified cyclical model of technological change. See A Modified Version of the Cyclical Model of Technological Change

Data Sources.

To improve the validity of path dependence examination we used the triangulation methods described by Jick (1979) and Pettigrew (1990) to construct case studies from a variety of information sources: interviews (business managers in the Cement industry), industry studies, manufacturing technology studies (Duda, 1976;4), business periodicals, books written by businessmen, the trade journal, Rock Products form 1950-1984, company correspondence, academic studies (McBride, 1979) and journals, news clippings from the mass media and statistics.

Data Analysis

The analysis of the data is important in the case of explanatory and causal studies. The concept of internal validity deals with establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from false relationships. Internal validity can be enhanced by doing pattern recognition (Mintzberg, 1979) or seeing evidence through multiple lenses (Eisenhardt, 1989). The high level of internal validity in this study was assured by subanalyses which approached the research phenomenon (i.e. the evolution of the cement industry during the research period) from many different perspectives. These subanalyses were combined at the end of the analysis in a way which resembled pattern recognition and seeing evidence through multiple lenses

4. THE EVOLUTION OF THE US CEMENT INDUSTRY AND ITS MANUFACTURING TECHNOLOGY IN 1950-1980

This section provides a brief illustration of the diffusion of the suspension preheating system in the cement industry in the U.S.

The Diffusion of the Suspension Preheating in the U.S. Cement Industry in 1950-1990

In cement manufacturing raw materials (usually limestone and clay) are passed through crushers, where giant machines reduce masses to small rocks a few inches in diameter. Smaller ones are then ground to a powder. This may be done with water, forming a slurry of fine particles in suspension, or without water, creating a fine flower. The ground material must be blended in the proper proportions for the type of cement desired. The cement produced in any plant reflects its raw material compositions, yet the range of variation is so narrow that the product is essentially a commodity. The blend is fed into a kiln and burnt there.

In the 1950s manufacturing processes were different in Europe and the U.S. (Clausen, 1955 and 1960). The first kiln with the suspension preheater went production in Europe in 1950 (Nordberg, 1954:69). The suspension preheater kiln was applied successfully for many years in Europe and other parts of the world (see Table 1). The first suspension preheater kiln in the U.S. went on stream in 1953 (Nordberg, 1954). It was pointed out that suspension preheaters cut fuel costs and increase output. The suspension preheater was not a success in North America. In the mid 1960s the pre-heaters were out (Bergström, 1964: 84). Problems of build-up and clogging in the preheater were encountered. (Clausen, 1955) Norbom, 1974: 95, Ritzmann, 1974).

Table 1. World and U.S. data on suspension preheater kilns

Developer & manufacturer	**Origin**	**U.S. representative**	**Year developed**	**World sales to 1966**	**1971**	**U.S. sales 1971**
Humboldt [1]	Germany	Fuller	1950	180	267	16
Wedag	Germany		1962	15	Include above	0
F.L. Smidth	Denmark	F.L. Smidth	1955	24	75	1[2]
Polysius	Germany	Polysius	1958	55	132	0
Krupp [3]	Germany	Krupp	1964	11	26	3
MIAG	Germany	Allis-Chalmers	1968	0	5	2
Total				285	505	22

Notes: [1] Humboldt purchased Wedag about 1969. [2] Excludes of five 2-stage systems sold in U.S. [3] Krupp purchased Polysius about 1970.

Source: Fig. 22 in Garrett and Murray (1974b: 59)

The kiln exit gas by-pass to prevent build up and glogging was used successfully in Europe and other parts of the world. (Norbom, 1974: 97-98). The by-pass arrangement let the re-introduction (in 1972) of suspension preheaters in the U.S. cement industry. Figure 2 reports the kiln start-ups (totally 65) in 1970-1981. Wet process was still popular. In 1972 two kilns with 4-stage suspension preheaters were started up in the U.S. In 1977 the first 4-stage suspension preheater with a precalciner alkali bypass system was installed. A French company brought the technology to its recently acquired U.S. subsidiary (Grancher, 1977: 76).

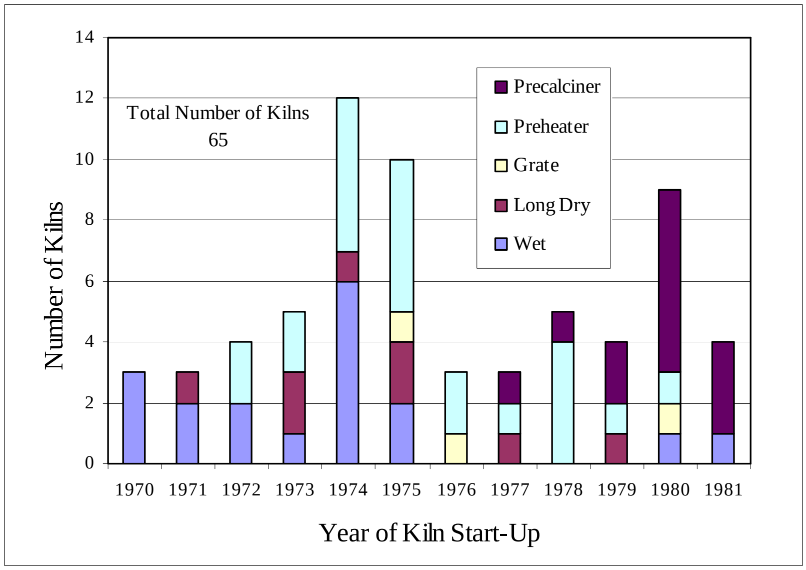

Figure 2. Number of Kiln Start-Ups in U.S. Per year and by type (Cooke, 1979: 2)

5. THE PATH DEPENCE IN TECHNOLOGY

The new definition of innovation is applied in the modified cyclical model of technological change (Uusitalo, 1995 and Anderson and Tushman, 1990). The innovation was defined as the first introduction of a product or process in the world market. The new definition of innovation was applied in the modified cyclical model of technological change (see Uusitalo, 1997) to track the events taken place in the eras of ferment of suspension preheating cement manufacturing process.

Suspension preheater in the cement industry

The first start up of a kiln with a suspension preheater in the world market was in 1950 (see Figure 3). In the U.S. the first similar one was introduced in 1953 instead of 1972 proposed by Tushman Anderson (1990). Following the new definition of innovation we regarded the arrival of the suspension preheater kiln in the cement industry in 1950 as a competence-destroying technological change. Although 13 plants came on stream in the U.S. during 1955-58, it did not emerge as the dominant design in the U.S. (Garrett and Murray, 1974b: 59). A kiln with suspension preheater & precalciner emerged as the dominant design in 1979 (see Figure 2 for the market share of new installation of different kiln types). Tushman Anderson (1990) had the same result. In 1979-1981, in three consecutive years, the market share of suspension preheaters with a precalciner were more than 50 per cent.

The period included several events and matters, some of which had also impacts on the length of the era of ferment. Several European companies sold licenses to the U.S. companies (see Table 3). In the mid 1950s, at the introduction of suspension preheaters in the U.S. cement industry was not successful. Because of extremely low fuel prices there was no economic pressure to switch from a well-known system, such as a long dry kiln, to a new system that offered significant fuel savings (Schroth, 1972: 71). The companies made high profits (ROI was 18 percent) also. Thus, suspension preheater did not solve any pressing organizational problem. This is in accord with Tushman and O'Reilly (1997) who said that organizations are more reluctant to accept innovation when there is no pressing organizational problem to be solved.

The cement made by suspension preheating systems had also he high alkali content, which had two causes. First, the sticky alkalies caused builb-up and choking in the transition between kiln feed end and the preheater and in the hottest place of the preheater. These areas require periodic cleaning. Second, it refers to the cement users' problem of concrete deterioration caused by alkalies reacting with certain types of aggregates. The Federal Government and several states recognized this and established minimum standards of 0.6 per cent total alkali in cements purchased for their funded projects. To meet this specification, the cement producer must attain about 0.55 per cent total alkali in the cement linker (Nordquist, and Heian, 1973). Theses incidents were those minor things to keep the industry using the wet manufacturing process. These minor things were the few minor random shocks .proposed by David (1985) to keep the history unchanged in path dependence.

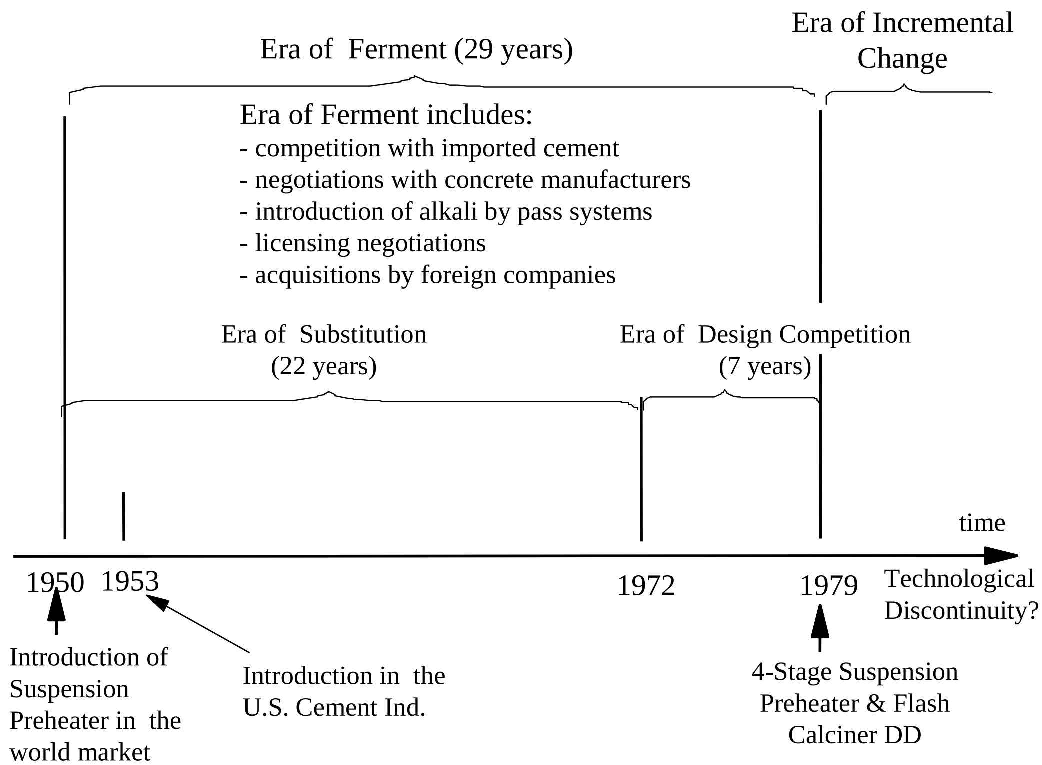

Figure 3. Application of the modified version of the cyclical model of technological change

The time between 1950 and 1972 (22 years), when the suspension preheting technology was struggling with alkali problems, is, in fact, the era of substitution. The technology competed unsuccessfully with existing wet and long dry processes. In the 1960s there were several spatial anti-trust lawsuits against cement manufacturers when they entered to concrete manufacturing. This took time and energy from top management (McBride, 1979 and Allen, 1971). Because the increasing fuel costs and energy crisis in the early 1970s the energy efficient preheater kilns became more popular. The cement industry stayed in Nelson and Winter's (1982) terms at the centre of the "creative accumulation regime" and did not move to the centre the "creative destruction regime" (that in the suspension preheating).

At the same time the bypass system for suspension preheters for reducing the alkali content were introduced. During the era of design competition (1972-1979) several preheater technologies competed with each other. In 1972 the number of 4-stage suspension, Grudex suspension, Lepol preheater kilns in operation were 12, 10 and 5, respectively. That time sixteen 4-stage suspension preheater and two Lepol kilns were under construction or in design and no Grudex kilns had been sold in last three years (Garrett and Murray, 1974a: 77). In the early 1970s imports of cement into the U.S. rose dramatically. Foreign cement manufacturers recognized the poor shape of the U.S. cement industry and started invasion. In 1976 suspension preheater with precalcining was introduced in the use by a local company acquired be a French manufacturer. The events in the era of ferment are summarized in Figure 3.

Evaluation of the Definition of Innovation Applied in studying path dependence

In this section we apply the previous analyses of eras of ferment of suspension preheating in evaluating of the path dependence of it. In Table 5 eras of ferment in the Anderson and Tushman (1990) and present studies are compared.

Table 4. Comparison of findings in Anderson and Tushman (1990) with those of this study

	Suspension preheating in the US Cement Industry		
Study	**Uusitalo, 1995**	**Anderson and Tushman (1990)**	
Introduction / the world	1950	-	
Licensed to the U.S.	1952	?	
Introduction / the U.S.	1953	1972	
Industry Standard /the U.S	1979	1979	
Era of Ferment (years)	29	7	
Era of Substitution	22	-	
Era of Design Competition	7	-	-

Source: Table 1 in Anderson and Tushman (1990: 610-611)

However, if the technology is licensed from abroad or a foreign company starts to manufacture in the U.S. with this technology either in a green field or an acquired production unit, the above definition leaves out all the sociopolitical dynamics (including license negotiations, extensive training, negotiations with trade unions, and acquisition negotiations etc.) and puts them in the calm era of incremental change of the previous technological change. It would seem that this definition of innovation is not appropriate when the path dependence is studied, since the manufacturing process was brought to the U.S. by a foreign manufacturer (after acquisition of a local company; a kiln with suspension preheater and precalciner).

6. CONCLUSION

Certainly Anderson and Tushman's (1990) cyclical model of technological change creates a good platform for analyzing social, political and organizational influences on technology's evolutionary cycle and thus, pathe dependence. However, the model is even more powerful when innovation is defined as the first introduction of the product in the world market. This gives excellent opportunities to analyze the international changes also technological in the world market. Moreover, the new definition of innovation emphasizes the most important and useful part of the cyclical model of technological change: the era of ferment including design competition and substitution.

Theoretical implications

The important theoretical aspect in this re-examination of the definition of innovation is to recognize how problems in operationalization of key concepts can lead to serious errors in conclusions. It is interesting to note that Tushman and Murmann (1998) also concluded that there are neither social, political nor organizational influences within nonassembled, simple products. They said (ibid. p. 252):

> ”If products are made up nested hierarchies, the phenomenon of dominant designs applies most fundamentally at the subsystem and linking levels of analysis. Except for simple, nonassembled products where the best technology most likely dominates, in more complex products, innovations patterns for each sub-system and linking mechanism are shaped not by optimizing processes, but by evolutionary processes of variation, selection and retention.”

Linkages existed also in the cement industry. On the one hand, the alkali content of cement depends on the quality of the raw material and production process. On the other hand, the high alkali content in cement causes problems in concrete manufacturing.

The definition of innovation

To evaluate which is the best way to define innovation in models like Anderson and Tushman's (1990) model while studying U.S. industries I, first, look the industry studied. Then, we look events in other industries. Finally, we discuss the implications. In the cement industry international technology transfer had occurred since the birth of the industry. After the Second World War the international operations increased, as well. The first entrants (the Swiss Holderbank) to the U.S. was a large, well performing company. Enclosed two citations from Grancher give Holderbank's view of global R&D and international operation within the cement industry.

> "Today [1988] U.S. cement is 55% owned/controlled by other than traditional domestic producers From virtually nil during the 1960s (when Holderbank – Dundee built and placed on stream its Michigan and Missouri plants), to just over 15% owned by the end of the 1970s to the rapid pace of acquisitions of the 1980s not seen ending." (Grancher, 1988: 534). "Cement's immediate *shortage gap* has been provided for by purchased product from producers elsewhere. Its *capital gap* is increasingly being met by investment funds from foreign sources. Its *technological gap* in energy efficient operation is being filled by process, equipment, and engineering of overseas origin. An extension of this internationalization is expected to include a heavy reliance on *research and development* experience and approach from abroad. " (Grancher, 1980: 58)

According to Peter et. al (1978) Holderbank comprised in 1978 over 50 cement plants, located on four continents, plus consulting and engineering offices in Switzerland, Canada, Egypt, and India. The total shipments of the group's plants had grown from 5 million tons in 1957 to about 30 million tons in 1977. Authors said that with this experience and information from these worldwide operations, Holderbank's management could fully understand the situation then existing in North America. The topic of energy saving had become foremost, whereas a few years ago the main concern was focused on labor productivity and automation. Authors refer to CEO of one U.S. producer who asked the industry's technical personnel to find inexpensive ways to convert from wet to dry processes, achieve more capacity and efficiency for less money, and discover breakthroughs. According to Peter et. al (1978) breakthroughs were more unlikely in the cement industry but considerable technological progress had been made, especially in recent years. This, however, necessitated practice-oriented R&D, which should be part of the corporate objectives within the cement industry. As summary in the late 1960s the cement industry had a time of crises; obsolescence (Harwell, 1968) and in the 1970s many foreign cement manufacturers came to industry with new technologies (Grancher, 1980 and 1988).

In both window and plate glass industries, international technology transfer and other foreign operations had taken place during the last century. Window glass: Pilkington and St. Gobain, from Europe, licensed the Lubbers machines the U.S. in the 1910s; since 1920s European companies licensed both Colburn and Pennvernon drawn window glass processes from the U.S. while U.S. companies licensed Fourcault machines from Europe Plate glass: PPG acquired its first plant in

Europe already in 1904; together with Ford Pilkington installed the industry's first continuous plate manufacturing process in 1923; in 1934 the US and European plate glass manufacturers made an international cartel to share the world markets (Bain, 1964); in the 1950s the U.S. companies licensed twin grinding technology from Pilkington, Researchers have also regarded the flat glass industry as an international industry. Ray (1969) noticed the unique international structure of the flat glass industry. Milner (1988) described the French flat glass industry in the 1970s as a highly export-dependent, multinational industry. We can conclude that the flat glass industry was international.

We can see path dependence on technology also in other US industries. In the 1960s there was a U.S. brand dominated hierarchy in the U.S. auto market: GM, Ford and Chrysler. In the 1960s U.S. car manufacturers researched new type of energy source and engines. However, they did not follow what happened for instance in Japan. Japanese car manufacturers enhanced the conventional engine and smaller cars. In the early 1970s the oil crises hit the U.S. companies, which were not prepared for manufacturing small and fuel economic cars. At least in the 1980s there was nation dominant hierarchy in the U.S. auto market: U.S. car, Japanese and European (Kotler, 1988: 284). Christensen (1997) reported how Honda brought off-road bike to the U.S., entered then to other segments and finally challenged on Harley-Davidson. Transistor was invented in the U.S., but Japanese licensed it, began radio manufacturing and entered successfully to the U.S. market. The U.S. radio manufacturers did not followed the innovations outside the U.S. (Drucker, 1985).

Would the U.S. cement manufacturers have been better of for, for instance, the oil crisis had they followed evolution of technology (suspension preheating) outside the U.S. What about the other companies referred?

As a summary it seems that researchers, who try to make the life of business managers easier, should take the international or global business into account and define the innovation as the first commercial introduction of a product or a process in the world market. Here we can apply Cooper and Schendel’s (1976) ideas but in the international context. They studied innovation from the perspective of other companies not that of the innovator. Authors requested the monitoring of new developments in the competing technology through scanning and forecasting. They argued that steam locomotive manufacturers should have followed the progress in power to weight ratio in diesel locomotives. In the same way cement producers could have carefully followed the progress of alkali bypass systems in preheating technology outside the U.S.

Managerial Implications

The lesson of this exercise for managers is that it might be dangerous to look only the technology within home country even though it is the US. It is also wise to follow closely what is going outside. Moreover, the troubles of alkaline in the suspension preheater technology should have been solved on time. It seems that the lock-in the wet processes was costly to the owners of the US cement industry. This third degree path dependence (Leibowitz and Margolis, 1995) was shocked out its pathe by the oil crisis in the early 1970's.

New streams of research

According to Tushman and Rosenkopf, 1992:3) technology can be described as systems ranging from: a) nonassembled products, b) simple assembled products, and c) closed assembled systems to d) complex, open systems. The more complex the system, the greater the technical uncertainties, and the greater the impact of sociopolitical processes in shaping technical advances are. Thus, while the technical system itself may suggest logical evolutionary paths, as the system gains complexity, nontechnical forces weigh more heavily on the process of technological evolution (p. 314) and Rosenkopf and Tushman (1994) defined the organizational community as the set of organizations that are stakeholders for particular technology. For simple or nonassembled products, dominant design emerge from technological logic. They refer to Anderson and Tushman (1990): "For example, suspension preheating cement manufacture became the industry standard because it was a significantly more fuel efficient method of producing high volumes of cement". The more complex the product, the more subsystems, the greater the number of internal and external interfaces and the greater the technical and contextual uncertainty are. The greater these uncertainties, the greater the intrusion of sociopolitical dynamics in the evolution of a particular technology are (Tushman and Rosenkopf, 1992: 340). According to Tushman and Rosenkopf (1992: 342 Figure 4) there is little social/political/organizational influence on the emergence of a dominant design for nonassembled products. The era of incremental changes is also very calm.

Based on our analysis of the path dependence of the US cement manufacturing technology it seems that nonassembled products, such as cement, plate glass and window glass, seem to have treated as too simplistic products. However, the manufacturing processes of nonassembled products are not necessary simple, which makes their diffusion complicated. This suggestion requires further attention.

REFERENCES

Anderson, P. (1988) ”On the Nature of Technological Progress and Industrial Dynamics.” Unpublished Ph.D. dissertation, Columbia University.

Anderson P., and M.L. Tushman (1990) ”Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change.” Administrative Science Quarterly, 35: 604-633.

Arthur, W. Brian (1989), “Competing technologies and lock-in by historical small events”, Economic Journal, 99 (March): 116-31.

Bain, T. (1964) ”The Impact of Technological Change on the Flat Glass Industry and Union’s Reaction to Change: Colonial Period to the Present.” Unpublished Ph.D. dissertation, University of California, Berkeley.

Berg, D.N., and K.K. Smith (1988) The Self in Social Inquiry: Researching Methods. Newbury Park, CA: Sage.

Bergstrom, John H. (1964) Cement plants of the 60’s, Rock Products, May: 77-88.

Biege, N. W., and L. J. Parsons (1977) ”The theory and development of bypass systems for preheater and flash calciner kiln systems.” 19th Conference Record in I.E.E.E. Cement Industry Technical Conference, Omaha, Nebraska, USA, May.

Christensen, C. M. (1997) “The Innovator’s Dilemma When New Technologies Cause Great Firms to Fail”, HBR Press, Boston, Mass.

Clausen, C. F. (1955) Men or Fuel? Why European Cement Practices Are Different, *Rock Products*, Feb: 78-84.

Clausen, C. F. (1960) “Low-alkali cement from high-efficiency kilns.” Rock Products, Jan: 147-148, 152-154 and 164.

Cooke, P. H. (1979) ”Present state of precalcining processes, A comparative approach.” 21st Conference Record in I.E.E.E. Cement Industry Technical Conference, Innisbrook, Florida, USA, May.

Cooper, A. C. & Schendel, D. (1976) Strategic Responses to Technological Threats, Business Horizon, February, 61-69.

David, P. S. (1985), 'Clio and the economics of QWERTY', *American Economic Review,* 75 (2), May.

David, P. S. (2000) “Path dependence, its critics and the quest for 'historical economics'”, in P. Garrouste, P and Ioannides, S. (eds.) (2000) Evolution and Path Dependence in Economic Ideas: Past and Present, Edward Elgar Publishing, Cheltenham, England.

Downey, K.H, and D.R. Ireland (1979) “Quantitative versus Qualitative: Environmental Assessment in organizational Studies.” Administrative Science Quarterly, Vol 24: 630-637.

Duda, W.H. (1985) Cement-Data-Book International Process Engineering in the Cement Industry, Bilingual, Bauverlag Gmbh Wiesbaden and Berlin, Macdonald & Evans, London.

Drucker, P. (1985) “Innovation and Entrepreneurship”, Pan Business Management

Eisenhardt, K.M. (1989) ”Building Theories from Case Study Research.” Academy of Management Review, Vol. 14: 532-550.

Garrett, H. M., and Murray, J. A. (1974) Improving kiln thermal efficiency-dry process kilns, Part 1. Rock Products, May: 74-77 and 124.

Garrett, H. M., and Murray, J. A. (1974b) ”Improving kiln thermal efficiency-dry process kilns, Part 4.” Rock Products, August: 58-63 and 69-71.

Grancher, Roy A. (1977) Cement expansion in Alabama, Rock Products, October, pp.74-76.

Grancher, Roy A (1980) Cement in the ‘80s, Rock Products, February: 56-60.

Grancher, Roy A. (1988) The very changed condition of the cement Industry, Proceedings of the 30th I.E.E.E. Cement Industry Conference, Quebec City, Canada, May 24-26, 529-541.

Jick, T.D. (1979) ”Mixing Qualitative and Quantitative Methods: Triangulation in Action.” Administrative Science Quarterly, Vol 24: 602-611.

Kotler, P. (1988) ”Marketing Management: Analysis, Planning, Implementation, and Control,” 6. Edition, Englewood Cliffs, NJ: Prentice Hall, 1988.

Liebowitz, S .J., and Margolis, S. E. (1995), Path Dependence, Lock-in, and History, Journal of Law, Economics, and Organization, 11(1), April :205-26.

McBride, M. E. (1979) ”The Federal Trade Commission Policy Toward Vertical Merger: The case of Cement and Concrete.” Unpublished Ph.D. dissertation, Washington University

Mehta, P. K. (1970) “Trends in technology of cement manufacture.” Rock Products, March: 83-87 and 102.

Mescher, E. (1959) ”ACL cement plant justifies Marquette’s choice.” Rock Products, December: 74-81.

Miles, M.B. (1979) “Qualitative Data as an Attractive Nuisance: The Problem of Analysis.” Administrative Science Quarterly, Vol 24: 690-600.

Milner, H. V. (1988) Resisting Protectionism: Global Industries and the Politics of International Trade, Princeton Univer-sity Press: Princeton.

Minztberg, H. (1979) ”An Emerging Strategy of ”Direct” Research.” Administrative Science Quarterly, Vol 24: 683-589.

Nelson, R. R. and Winter, S. G., (1982). An Evolutionary Theory of Economic Change, Cambridge, Mass. [u.a.]: Belknap Press.

Nordberg, B. (1954) ”Cut fuel cost and increase output with suspension preheaters.” Rock Products, Oct: 68-72.

Norbom, H.R. (1974) ”Wet or dry process kiln for your installation.” Rock Products, May: 92-100.

Nordquist, E. A. and Heian, G. A. (1973) Alkali removal via the grate-kiln system, Rock Products, May: 60-64, and 179.

Page, S. E. (2006). “Essay Path Dependence”, Quarterly Journal of Political Science, 1, 87-115.

Patton, Q.M. (1990) Qualitative Evaluation and Research Methods. Newbury Park: Sage Publications.

Peter, Max F., Erni, H. F., and Dr. Schrämli Werner (1978) Full production efficiency requires a fresh look at specifications, Holerbank’s worldwide cement operations provide comparative overviews, Rock Products, April: 117-118, 120-122 and 146.

Pettigrew, A.M. (1985) The Awakening Giant: Continuity and Change in ICI, Oxford: Basil Blackwell.

Pettigrew, A.M. (1990) ”Longitudinal Field Research on Change: Theory and Practice.” Organization Science, 1: 267-292.

Pfeffer, J. and G. Salancik (1978) The External Control of Organizations: The Resource Dependence Perspective, New York: Harper & Row.

Quinn, J.B. (1980) Strategies for Change, Logical Incrementalism. Homewood, IL: Dow-Jones Irwin.

Ray, G. F. (1969) ‘The Diffusion of New Technology - A Study of Ten Processes in Nine Industries’, National Institute of Economic Review, No. 48, pp. 40-83.

Rosenkopf, L. & Tushman L. M. (1994) The Coevolution of Technology and Organization, in Baum, J. & Singh, J. (eds.) Evolutionary Dynamics of Organization, Oxford University Press, Oxford, pp. 403-424.

Ritzmann, H. (1974) ”How to keep alkalies from stealing preheater efficiency.” Rock Products, February: 66-69.

Schroth, G.A. (1972) ”Suspension preheater system consumes less fuel.” Rock Products, May: 70-74 and 126.

Teece, D.J., Pisano, G., Shuen, A. (1997) "Dynamic Capabilities and Strategic Management", Strategic Management Journal, 18 (7), pp. 509-533.

Tushman, M.L., and P. Anderson (1986) ”Technological Discontinuities and Organizational Environments.” Administrative Science Quarterly, 31: 439-465.

Tushman, M.L., and J.P. Murmann (1998) ”Dominant Designs, Technology Cycles and Organizational Outcomes.” In B. M. Staw and L. L. Cummings (eds.), Research in Organizational Behavior, 20: 231-266. Greenwich, CT: JAI Press.

Tushman L. M. and C. A. O’Reilly (1997) Wining through Innovation, A Practical Guide to Leading Organizational Change and Renewal, HBS Press, Boston.

Tushman, M.L., and L. Rosenkopf (1992) ”Organizational Determinants of Technological Change: Toward a Sociology of technological Evolution.” In L. L. Cummings and Barry M Staw (eds.), Research in Organizational Behavior, 14: 311-347. Greenwich, CT: JAI Press,.

Uusitalo, O. (1995) Revolutionary Dominant Design - The Float Glass Innovation in the Flat Glass Industry, Ph.D. dissertation A-108, HSE, 1995.

Uusitalo, O. (1997) ”Development of the Flat Glass Industry in Scandinavia 1910-1990: The Impact of Technological Change.” Scandinavian Economic History Review, 3: 276-295.

Van de Ven, A. & Garud, R. (1994) The Coevolution of Technical and Institutional Events in the Development of an Innovation Organization, in Baum, J. & Singh, J. (eds.) volutionary Dynamics of Organization, Oxford University Press, Oxford, pp. 425-443.

Yin, R. K. (1984) Case Study Research, Design and Methods, Sage Publications.