

# THE EMERGENCE AND CONSEQUENCES OF PATH DEPENDENCE IN THE U.S. CEMENT INDUSTRY, 1950–1980

Olavi Uusitalo, [olavi.uusitalo@tut.fi](mailto:olavi.uusitalo@tut.fi)  
Kjell Grønhaug, [Kjell.Gronhaug@nhh.no](mailto:Kjell.Gronhaug@nhh.no)

Track: 3) Innovation in Industrial Networks

## ABSTRACT

Path dependence is the existence of timeworn routines, cognitive rigidities and structural inertia. It includes sustained persistency and lock-ins. Lock-outs from the path may occur through unexpected external forces. We apply a recently developed theoretical framework both at the organizational and industry level to understand change processes in firms and industrial networks. We have a case study on the U.S. cement industry in 1950-1980. In 1953 a dry energy saving technology developed in Europe was introduced in the industry. This technology had several manufacturing related challenges compared to existing processes. Neither cement manufacturers nor their local equipment suppliers had knowledge or passion to solve the problems. Moreover, extremely low fuel price favored wet technologies. In 1973 the oil crisis rose the fuel price making the industry less competitive. Foreign companies entered with the low-energy consuming dry process. We identified a long-lasting lock-in process to the wet manufacturing process. High demand, low cost fuel, nice profits and collective negligence of suspension preheater technology kept the industry in its technology path. External chocks, the oil crisis and foreign competitors, locked out the industry. In our analysis for the reasons of this evolution we use a network illustration.

Keywords: Path dependence, networks, innovation, US cement industry

## INTRODUCTION

It is commonly observed that prior decisions, investments, and established relationships tend to structure and influence the further development of a firm. It has also been demonstrated that this development may cause firms to lose flexibility and even become locked in; that is, further possibilities may become restricted. This tendency has often been identified as path dependence. Path dependence generally implies that the next step depends on the steps taken before. In economic theory, the notion of path dependence is used to argue that existing technologies have increasing returns in relation to new competing technologies because they are already adopted by users and are baked or hardwired into the competencies of companies. Moreover, new technologies must overcome the costs of adaptation (Arthur, 1989, p. 127; David, 1986, p. 332; (Håkansson and Waluszewski, 2002, p. 561).

Generally, path dependence has been thought to be firm-, individual-, and technology-specific. However, the development and consequences of path dependence are also influenced by other actors in the industry and actors at other levels, such as suppliers (Gadde and Håkansson, 2001). Araujo and Harrison (2000) emphasized that path-dependence provides a useful platform to understand stability and change in the trajectories of firms and technologies embedded in complex industrial networks. Several authors have studied the U.S. cement industry (Allen, 1993; Anderson and Tushman, 2001; Chandler, 1990; Keck and Tushman, 1993; Marby, 1998; Tushman and Rosenkopf, 1996), but none of them have researched the industry from the path dependence point of view. In this paper, we address the development and consequences of the U.S. cement industry's adoption of the suspension preheater (SP) technology from 1950 - 1980. In doing so, we apply Sydow and colleagues' (2009) theoretical framework not only at the organizational level, but also at the industry level and the collaborative relationship level. According to Sydow et al. (2009, p. 705), industry level analysis is important to understand path dependence as well as path dependence in collaborative relationships.

Path dependence means more than the mere existence of timeworn routines, cognitive rigidities, or structural inertia. It is a process (Sydow et al., 2009, p. 690). To gain a better understanding of the logic of path dependence, Sydow and colleagues created a theoretical framework explaining how organizations become path dependent. Path dependence relates to more specific constellations; it includes features such as sustained persistency and lock-in, which are uncommon characteristics of decision processes (Sydow et al., 2009, p. 690).

Path dependence is more than individual decision making. This has been asserted to be the case many times in technological path dependence studies. The mere focus on individuals does not account for an institutional setting in which organizational positive feedback processes happen to occur (Sydow et al., 2009, p. 694). According to Sydow et al. (2009, p. 694), the broader organizational context (e.g., institutionalized practices, hidden assumptions of the organization, organizational culture, status, and role system) informs decision makers and provides the basis for the development of self-reinforcing loops. Unlocking from a path may occur through unexpected external forces such as shocks, catastrophes, or crises; these are likely to shake the system, thereby causing the organization to break away from the path (Arthur, 1994). Facing strategic rigidity or even a threat to the organization's survival, decision makers are certainly

eager to learn more about possible interventions designed to unlock organizational paths (Sydow et al., 2009, p. 702).

The remaining part of the paper is organized in the following way. In the next section, we explain the model of Sydow et al. (2009) as well as the related literature underlying our research. After this, we describe the research methodology applied in the empirical part of the study. Then, we report on the development of the U.S cement industry. We include the global cement equipment manufacturing industry because this is an important element in understanding the cement industry. Next, we analyze our case with a network illustration to explain the development of path dependence in the U.S. cement industry. Finally, we draw conclusions and discuss implications.

### DYNAMIC MODEL OF PATH DEPENDENCE

A lot a valuable research on the dynamic nature of locking processes has been conducted in evolutionary economics and economic history. However, these focused almost exclusively on technological innovation at the field or market level (Arthur, 1989; 1994; David, 1985; 1986; Dosi, 1982; 1997). These studies identified self-reinforcing processes as drivers likely to accumulate in a specific path of action. Based on a review of the path dependence literature, Sydow et al. (2009, p. 690) decided to differentiate clearly the different stages in the formation of a path and to specify their structural properties. They proposed subdividing the whole process of evolving path dependence into three stages, by different causal regimes and different settings for organizational action and decision making (see Figure 1). Sydow et al. (2009, p. 690) call these three phases the preformation, formation, and lock-in phases.

The first phase is characterized by a broad scope of action. The effect of a choice of options cannot be predicted (see Mahoney, 2000, p. 511). Once a decision is made, however, this choice may amount to a small event that unintentionally sets off a self-reinforcing process. Initial choices and actions are linked in routines and practices; they reflect the rules and the culture making up those institutions (e.g., Child, 1997; March, 1994; Tolbert and Zucker, 1996). According to Sydow et al. (2009), the shadow in Phase I in Figure 1 indicates this institutional heritage. This moment of entering into the dynamics of a self-reinforcing process can be thought of as a “critical juncture” (Collier and Collier, 1991), and it indicates the end of the preformation phase.

In the second phase, a new regime takes the lead: the dynamics of self-reinforcing processes (Arthur, 1994). A dominant action pattern emerges, which makes the whole process more and more inflexible. The number of options narrows and it becomes more difficult to reverse the first choice or the first pattern of action. A path is evolving. Driving forces are increasing returns, indicating self-reinforcing processes with increasing benefits. These returns make the whole process more and more irreversible, particularly in cases with high investments and/or high fixed costs (Ghemawat, 1991). Choices are still possible (the shadow of Phase II in Figure 1). Decision processes are still contingent; they are not accidental (David, 1985).

The transition from Phase II to Phase III, the lock-in phase, has a further constriction, which eventually leads to a lock-in. The dominant decision pattern becomes fixed and gains a

deterministic character; finally, the actions are fully bound to a path. The flexibility is lost. The dominant pattern gains a deterministic character. Alternative options are no longer feasible because of high switching costs, sunk costs, monopoly, and so forth. New entrants also act the same way. When more efficient alternatives are available, individuals' and organizations' decision processes and established practices continue to reproduce only this particular outcome. The occurrence of a lock-in renders a system potentially inefficient because it loses its capability to adopt better alternatives. However, a narrowing organizational process and lock-in do not automatically mean immediate inefficiency and losses. Path dependence and efficiency refer to a longer time horizon, also including the risk of becoming dysfunctional. Figure 1 illustrates the process across the three phases.

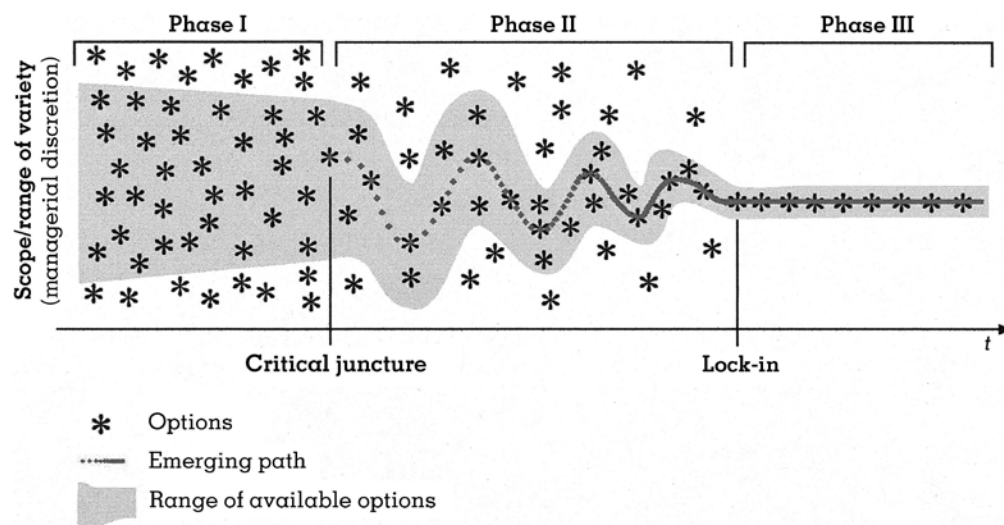


Figure 1. The constitution of an organizational path (Sydow et al., 2009, p. 692)

### Self-reinforcing mechanisms

Sydow et al. (2009) conceptualized path-building processes as processes of a narrowing scope of action that unintentionally create their own pull and are driven by positive feedback. The dynamism flips to rigidity. The authors identified four mechanisms that have an impact on the development of organizational path dependence: 1) coordination effects, 2) complementary effects, 3) learning effects, and 4) adaptive expectation effects. In addition to these four, Sydow et al. (2009) discussed the enhancing context.

Coordination effects are based on the benefits of rule-guided behavior: the more actors adopt and apply a specific institution, the more efficient the interaction among these actors is, since the behavior of the actors is rule guided and can therefore be anticipated. Coordination costs may be lower. Internal consistency (Miller and Friesen, 1984) is very similar to coordination effects. It stresses the advantages of an internal fit among the various elements. Coordination effects are created from the benefits of following the same or related rules to which others are willing to conform. A specific pattern of practices is likely to become fixed.

Economies of scope are a good explanation for complementary. They exist when the cost of producing and selling two or more goods or services together is lower than the cost of producing and selling them separately (Panzar and Willig, 1981). In complementary settings, self-reinforcing processes occur when routines and/or practices are interconnected in a way that makes it more attractive to exploit the synergies, or when referring to the reverse side, to save misfit costs caused by solutions deviating from the established cluster/organizational capability.

According to the learning theory, the more often an operation is performed, the more efficiency will be gained. The operation becomes better performed (i.e., faster, more reliable, and with less errors), which means lower average costs per unit of output (Argote, 1999). The more attractive the chosen solution becomes because of accumulated skills and decreasing cost, the less attractive it is to switch to a new learning solution where actors have to start from the beginning. Learning effects are often reinforced and extended by earnings from coordination costs and complementary. Self-reinforcing adaptive expectation effects relate to the interactive building of preferences. Individual preferences are not considered to be fixed; instead, they are assumed to vary in response to the expectations of others. Often highlighted is the need for social belonging and the desire to end up on the winning side.

Contextual conditions may also have a further reinforcing effect on and in institutions. Pierson (2000) emphasizes institutional density as a salient determinant likely to converge into self-reinforcing effects in organizations. According to him, organizations, especially formal political institutions, are more willing to bring about path-building forces than markets because they act in “a far, far murkier environment” (Pierson, 2000, p. 260) with weaker forces to correct inefficient courses of action over time. In general, he regards ambiguity and complexity as pertinent conditions that amount to self-reinforcing effects and subsequent path dependence.

#### Unlock mechanisms

Companies may be locked in technologies, industry routines, and/or recipes or supplier relationships. According to Sydow et al. (2009), the fatal consequences of being locked in raise an important question of whether organizational paths can be unlocked. Unexpected outside forces such as shocks, catastrophes, or crises are likely to shake the system, thereby causing the organization to break away from the path (Arthur, 1994, p. 118). To unlock organizational paths, it is necessary to construe and integrate an outside perspective—that is, an activity that is not under the regime of path dependence. Such integration of an external lens enables knowledgeable agents to reflect on practices in terms of path dependence and potentially opens a window out of the path. According to Hakansson and Lundgren (1987, p. 129) a path cannot exist in a vacuum; it must in some way be related to other paths, other structures: “The critical issue must be: what constitutes a crossing? Given the basic definition of path, a crossing should be where actors, activities or resources meet and habit or routines are confronted or combined”. According to Sydow et al. (2009), the first step to breaking the path requires understanding and reflecting on being path dependent and the drivers that made this happen. This step also brings distance to the replicating dynamics. However, organizations often tend to stay in the path without recognizing and even neglecting hidden features and weak signals of the inefficiency of path dependence. This usually requires a huge amount of unlearning, which is difficult.

Switching to a new course of action takes a long time to match the learning effects of the existing course. In those cases, creating an effective alternative for the restoration of choice requires an extra effort — a (possibly costly) subsidy to help the new alternative catch up with the existing one (Arthur, 1994). Path breaking requires a thorough understanding and acceptance of the social mechanisms driving the path process. Understanding these mechanisms, in turn, provides a platform for developing path-breaking interventions (Sydow et al., 2009). In our research framework (Figure 2) we have a path dependence process. The process has self-reinforcing mechanisms, which may be hidden so that one does not see him entering the path. Coordination effects include for instance industry wide coordination. Complementary effects deal with synergy between different things. Learning refers to experience and then learning for new. The keyboard QWERTY is an excellent example of learning effect. It was impossible to tell users that for instance Dvorak keyboard was much better than the one (QWERTY) they were used to. Adaptive effects related to herd behaving. It is nice to have the thing since others have it, as well. Enhancing context means for instance complexity and confusion. If these conditions exist people/firms like to play safe and keep the existing solution. Finally there is the locked in situation, which prevent firms to act in new ways. The unlock mechanism is not regard belonging to path dependence. Unlocking from a path may occur through harsh external forces such as shocks, or crises.

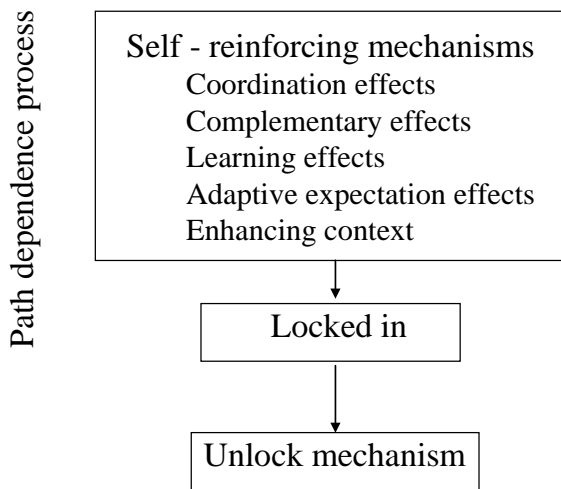


Figure 2. Research framework

## RESEARCH METHODOLOGY

### Case study approach and the choice of the industry

Because of the process character of path dependence, this study adopts a longitudinal, historical, and contextual case study approach as suggested by Sydow et al. (2009, p. 704). The focus and context is the U.S. cement industry. A key characteristic of the industry is a detailed description of the case. We try to capture the actual development of path dependence which in the cement industry can be seen as a gradual change. Pettigrew (1985) argues that, to understand a change,

one has to study it as a continuing process in the context in which it appears. The suspension preheating innovation is included because of its impact on the industry's development. The industry and its development are extremely well documented. Because the technological change, namely four-stage suspension preheater kiln technology, was introduced in 1950 in Europe, this study includes European cement manufacturing equipment suppliers such as Humboldt, Polysius, Krupp, and FLSmidth (Mehta, 1970; Schroth, 1972). The research period is 1950–1980.

#### Data sources

The data underlying the case analysis came from several sources, both primary and secondary. To enhance the descriptive validity of our case illustration, we used the triangulation methods described by Jick (1979) and Pettigrew (1990) to construct case studies from a variety of information sources: interviews, company and industry histories, industry studies, business periodicals, books written by businessmen, trade journals, company correspondence, academic studies and journals, and news clippings from the mass media. Interviews with the former managing director of Partek, a Finnish cement manufacturer, and with persons from FLSmidth and Allborg Cement Plant in Denmark were conducted to guarantee an accurate and truthful understanding of the cement industry. Company and industry histories, academic studies, and manufacturing technology books (Smeds, 1998; Åberg, 1972; Stensson, 1997) provided basic knowledge of the history of the international cement manufacturing technology transfer and the cement industry. Two books on cement technology (Duda, 1985; Chosh, 1983) were also used.

The account of the development of the U.S. cement industry from 1950–1980 was based on an extensive review of issues of *Rock Products* during 1950–1984, *Cement and Lime Manufacture* during 1950–1970, and *Cement Technology* during 1970–1980. Conference records of the IEEE Cement Industry Technical Conference from 1969–1984 were examined as well. Several articles from business periodicals (*Business Week*, *The Economist*, *Fortune*, *International Management*, and *Management Today*) provided the management point of view on the evolution of the cement industry. Archival records (e.g., industry statistics, production volumes, import and export records) were also used.

#### Measures

The effect of the technological change (i.e., suspension preheating) was measured using the performance parameter indicating the change in production costs of the manufacturing process of cement. The case study approach and the focus on only one technological change also allowed us to take into account pertinent qualitative environmental attributes (Downey and Ireland, 1979), particularly alkali content for cement and the problems of the new technology provided in the United States. An understanding of how path dependence can influence the definition of technological innovation should include an international aspect. Technological change was defined as the first commercial introduction of a product (cement) or a process (suspension or precalcining preheating) in an industry worldwide (see Uusitalo, 2013). We had to be able to identify and distinguish the various manufacturing processes of cement in the cement industry. Below is shown our variables, measures, and data sources.

Table 1. Summary of variables, measures, and data sources

Variable	Measure	Data Source
Performance parameter	Change in production costs (selling price)	Rock Products (1935), Duda (1985), Nordberg (1954), Norbom (1974), Mehta (1970)
	Alkali content in cement Manufacturing challenge	Clausen (1960), Carlsen (1966), Cooke (1979), Schroth (1972)
Technological discontinuity	Change in production costs (selling price)	Duda (1985), Norberg (1954), Ritzmann (1974)
Technological innovation	Manufacturing processes Cement (made by suspension preheating or precalcining technology kiln) sold	Duda (1985), Carlsson (1978) Norberg (1954), Garrett and Murray (1974a) Biege and Parsons (1971)
Path dependence	Energy (oil) supply and price	Stevens (1974), Capone and Elzinga (1987), Rose (1974), Snyder (1978)
	Local, small-size plants Small industry	Chandler (1990) Marby (1998)
	U.S. position in the world	Jones (2005)
Locked in	Coordination effect	Marby (1998), Levine (1971) Duda (1985), Clausen (1955)
	Complementary effect	Technology Carlsson (1978)
	Learning effect	Reduced cost Evans and Hetz (1970)
	Adaptive expectation effects	Switch the technology Stevens (1974)
	Enhancing context	U.S. position in the world Alkali content in cement
Unlock	Technological ambiguity Spatial monopolies	Garrett and Murray (1974a) McBride (1979)
	Energy (oil) supply and price Internationalization	Stevens (1974), Capone and Elzinga (1987) Allen (1993)

### Data analysis

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 pattern recognition (Mintzberg, 1979) or by examining evidence through multiple lenses (Eisenhardt, 1989). The high level of internal validity in this study was ensured by subanalyses that 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 (see also Uusitalo, 2007) in a way that resembled pattern recognition and examining evidence through multiple lenses (see Table 2). As

far as reliability is concerned, a critical point in a case study is that the operations of the study (i.e., data collection and analysis) can be repeated to achieve the same results. According to Yin (2009), this is done by developing the case study protocol and the case study database. During the research process, the empirical data were filed to form a proper database.

Table 2. The research phenomenon seen through multiple lenses

<b>Lens</b>	<b>Focus of Analysis</b>
Technology	Wet, dry, preheater, and precalcining kiln technologies in cement manufacture
International technology transfer	The viewpoints of technology owners and recipients Wholly owned subsidiary, licensing, or joint venture
Industry	The cement manufacturing equipment, cement and concrete industries
Regional	
Concentrated	The cement industry in the United States
Fragmented	The cement industry in the United States and in Scandinavia
Global	Licensing, four-stage suspension preheaters and precalcining
Company	
Large multinational companies (MNC)	F.L. Smidth, Holderbank, Lafarge, Ideal
Small	Scandinavian manufacturers, U.S. companies
Vertical integration (equipment suppliers and processing industries)	The cement manufacturing equipment producer, cement and concrete industries

## THE U.S. CEMENT INDUSTRY

This section reports on the development of the cement industry and the diffusion of the suspension preheating system in the United States. First, it provides a brief illustration of the waves of globalization in the 1960s to the 1970s because these events had impacts on path dependence. Second, it provides a brief description of the cement manufacturing industry, including the main cement manufacturing technologies, cement equipment manufacturers (CEMs), and the internationalization of the U.S. cement industry.

### Waves of globalization and contextual conditions

The 1950s onward saw the beginning of the reconstruction of a new global economy. From 1950–1973, the smooth annual real Gross Domestic Product growth of developed market economies was around 5 percent. The U.S. dollar became the world’s major reserve currency. U.S. corporations assumed leading positions in many industries. The Japanese economy grew so fast that it became the world’s second largest capitalist economy by the 1970s. World trade barriers were reduced under the auspices of the General Agreement on Tariffs and Trade signed in 1947. This process peaked in the 1960s when the Kennedy Administration in the United States radically reduced tariff rates (Jones, 2005). In the 1940s, the U.S. oil industry was the only well operating oil industry in the world. The recently discovered and opened Texas oil wells kept the energy supply high and thus, energy prices low. There was no oil import at that time. In 1950–1970 the energy (fuel) prices changed little (Capone and Elzinga, 1987, p. 108).

## Cement manufacturing in Europe and the United States

The cement industry is characterized by a low value-added product that requires a high initial capital investment in production equipment and a long payback period for investments. These structural features make economies of scale important. The unit costs of cement are sensitive to industrial usage rates. In the latter part of the nineteenth century, cement was exported from Europe to the United States.

Portland cement and the process of sintering to strengthen cement were invented in the United Kingdom in 1824 and 1845, respectively. In the 1840s, the first cement plants started production in France. The first cement plant in the United States was built in 1871. Burning, or using the kiln, is the most important and expensive phase in the manufacture of cement. The rotary kiln, a horizontally laid long pipe (with a diameter of 2 m, a length of 23 m, and a capacity of 40 tons/day), was introduced in 1885 in the United Kingdom and the next year in the United States. There are two fundamental methods for the preparation of the feed for rotary kilns: the wet process and the dry process. In the wet process, slurry with a water content of approximately 18 to 45 percent is prepared in wash mills, by wet grinding, or by a combination of both procedures. In the dry process, the raw materials are dried, ground, and mixed to form a fine, homogenous powder. This powder is fed into the kiln where the heat promotes the necessary chemical reactions. No water is used. The kiln exhaust gases are the main source of heat used to dry the raw materials. The clinker made in kilns is then ground into cement powder (Duda, 1985).

The manufacturers soon noticed that cement could not be delivered over long distances due to its characteristics and logistics costs. The manufacture of cement is dependent on mineral supplies and energy. Thus, manufacturers restricted the plant activities to the region where it was located due to the impossibility of long distance exports.

The U.S. industry expanded from 1910–1929, with 88 companies manufacturing in 168 plants. The depression of 1929 stopped the growth for 17 years. Before 1945, the industry was less concentrated and had relatively small firms. Because of high transportation costs, the firms operated in regional markets served by 5 to 10 plants (Chandler, 1990). By 1954, 75 companies operated 157 plants (Levine, 1971, p. 79). In the cement industry, the cement manufacturers produce cement with the equipment (or technology) acquired from CEMs. By the 1950s, cement manufacturers were local companies while the equipment producers were Europe-based companies. Less than 10 companies dominated the equipment business. Before World War II, some of them also had subsidiaries in the United States.

In the early 1950s in Europe, where labor costs were relatively low and fuel costs high, dry processes were used; in the United States, where the situation with labor and fuel costs was the opposite, wet processes were employed. Thus, kilns had developed in different directions. In the United States, fuel accounted for about 25 percent of the total manufacturing cost, whereas in Europe the fuel cost was between 50 and 75 percent of the total. Since wages were low in Europe, producers there spent money on challenging heat-utilizing equipment even if it required reasonably more manual operation and supervision. In the United States, firms used large, simple units that required minimum operating labor (Clausen, 1955).

Preheating dry, pulverized cement raw material while in suspension in rotary kiln exit gases is practical and lowers energy costs. Suspension preheater technology, a new dry cement manufacturing process, was developed in Europe in the 1930s. This technology, which saves fuel but slightly raises labor costs, was introduced in Europe in 1951. Japanese manufacturers licensed the suspension preheater technology and used it in new plants in the 1950s and 1960s (Duda, 1985). By 1966, a total of 285 kilns (excluding those in the United States) operated with the preheating technology delivered by six European equipment manufacturers. The European cement manufacturers quickly adopted this new energy-saving technology (Duda, 1985).

In Germany, by 1974, 67 percent of the kilns were suspension preheater kilns and only 5 percent were wet process kilns. The respective percentages in the United States were 7 percent and 58 percent. The kiln sizes were also different. In the United States, 86 percent of the kilns (accounting for 68 percent of the total capacity) were rated for 1,000 short tons per day (stpd), and 47 percent were even below 500 stpd. In Germany, 27 percent of the kilns were larger than 2,000 stpd, accounting for half of the total output. Moreover, 11 percent of the kilns and 31 percent of the total output were over 3,000 stpd (Schroth and Diener, 1974).

#### Cement equipment manufacturers

According to Carlsson (1978, p. 131), “In the 1950s, 1960s and 1970s there had been only a handful CEMs in the world (one Danish, a few West Germany and Japanese and two American companies) who compete in designing and selling whole systems. These companies operate mainly on licenses from the other manufacturers.” FLSmidth (FLS) was founded in 1882 in Denmark; by 1900, it became known worldwide as a company providing cement burning technology and equipment. By 1973, the company had delivered 1,400 kilns to the cement and allied industries. At that time, 40 percent of the world’s cement capacity was based on FLS equipment. The company opened subsidiaries in the United Kingdom and in the United States in 1890 and 1895, respectively. In 1912, FLS founded a cement manufacturing company in the United Kingdom. In the 1940s, it built a manufacturing equipment plant in the United States. Later on, it opened subsidiaries all over the world. By 1973, an average of 95 percent of the orders placed with FLS were for export.

Humboldt was founded in 1856 in Germany. It produced screens, drum washers, jigs, conveying systems, and mills for mining. In the 1930s, it was reorganized twice. In the late 1940s, Humboldt quickly picked up the technology for cement manufacturing. Humboldt installed the first four-stage suspension preheater technology in use in Germany in 1951. Polysius was founded in Germany in 1859. In 1888, it entered the cement business by selling equipment to producers. By 1890, the company’s reference list included 13 cement plants, including one in Switzerland and one in England. In 1893, Polysius formed a joint venture with a U.S. partner to manufacture and sell rotary kilns based on the U.S. technology in Europe. By 1904, when Polysius acquired the joint venture, it had erected 45 rotary kilns. By 1907, Polysius had supplied about 100 kilns. In the 1920s, it founded a subsidiary in the United States. However, the 1930–1932 economic crisis forced the company to close the subsidiary. In 1928, the Lepol kiln was introduced, featuring a gas circuit that lowered fuel consumption. By 1940, Polysius had sold 120 Lepol kilns. In the 1950s, the Dopol SP system was introduced. In 1964, Krupp from Germany introduced its counterflow suspension preheater technology. By spring 1967, it was in

operation in 5 cement works, and 19 more were under construction. Krupp acquired Polysius in 1971.

Fuller was founded in 1926 in Pennsylvania in the heart of a cement-producing area focused on cement and cement raw material conveying. During the first 20 years, Fuller was an engineering concern using subcontracting. In 1946, it built its own plant. In 1947, Fuller had five large, well-equipped plants. The company licensed both the SP system in 1953 from Humboldt in Germany, and the flash calcining system in 1974 from Ishikawajima-Harima Heavy Industries in Japan. In Japan, Kawasaki Heavy Industries, Mitsubishi Heavy Industries, and Ishikawajima-Harima Heavy Industries introduced their precalcining kilns in the early 1970s. Allis-Chalmers was founded in 1847 in Wisconsin, and it licensed the Lepol technology from Mr. Lellep (Polysius) from Europe. The first double-gas Lepol, or the double pass Allis-Chalmers/Lellep (ACL) kiln, started production in the United States in 1957. By 1950, the CEM industry was international, with some global companies such as FLS from Denmark and Fives-Cail Babcock from France.

#### The U.S. cement industry from 1950–1980

In the 1950s, most cement plants were small with capacities less than 0.4 million tons. They located near their main markets less than 400 km away and cement was shipped by rail (Levine, 1971). Increasing labor costs made the construction of larger plants appealing. In the early 1950s, the demand increased and caused a shortage of capacity. The federal highway program worth \$33 billion increased the demand. In the mid-1950s there was a rush of capacity. Cement prices increased. Many new plant additions were subject to unrealistic construction schedules and were poorly located. Old facilities were reopened and retained with the intention that should demand go down, these plants would be retired and demolished. When overcapacity increased, price and service competition intensified (Grancher, 1969, pp. 64–65). In the late-1950s, the demand sank causing overcapacity. The industry turned into a low-profit one as the companies cut prices and absorbed cost increases in a desperate effort to lower the volume in over expanded plants. Capacity utilization was below 73 percent. For securing their markets companies acquired local concrete manufacturers. In the late 1950s and the 1960s, there were about 80 vertical integrations to concrete manufacturers. The Federal Trade Commission (FTC) accused in 14 trials cement companies for creating spatial monopolies (McBride, 1979; 1983; Allen, 1971). As a result, all companies charged with monopoly had to withdraw from concrete manufacturing. Cement companies were also banned from starting concrete manufacturing from scratch.

The U.S. cement industry was a small industry. In 1970, its annual sales (\$1.45 billion) were less than the individual sales of 84 U.S. industrial firms. In 1976, the industry sales reached \$2.5 billion. The four largest firms had less than 30 percent of the total sales while the eight largest accounted for 45 percent. The cement industry was not concentrated. It had 52 companies serving regional markets; not a single company operated nationwide. In the 1950s the industry' return on investment (ROI) was 14 to 20 percent while in 1963-1975 it did not reach 15 percent (Grancher, 1976, pp. 84–86). During the 1960s, cement companies were tempted by diversification and threatened by conglomeration. Cement firms diversified, and diversified firms bought cement companies. As late as the mid-1950s, less than 15 percent of the capacity was owned by firms with significant outside interests. By the end of the 1960s, the industry looked very different, with 26 diversified companies owning 75 percent of the capacity. The remaining

18 firms were mostly small, single-plant operations that made only cement (Mabry, 1998, p. 407).

The concerns of air pollution and dust started in Lehigh Valley in 1948 when cement plants deposited dust in every part of neighboring town (Bell, 1958, p. 80). The Clean Air Act of 1970 also hit the cement industry. In the early 1970s, the cement industry faced the tremendous capital cost of meeting stringent and discriminatory regulations (MacLean, 1973, p. 93). Before dust collection systems were developed well enough (by the late-1960s) a dry plant was more dusty than a wet plant. The dust collection system was more challenging to install in dry process kiln than wet process one, because there was a major problem introduce dust slurry (mixture of dust and water) into dry process kiln. Large preheater kilns are generators within cyclones, however, by 1969 dust collection systems good reduced the level remarkably. Dust collected could often be returned profitably to the process.

Computer control was launched in the cement industry by 1960. The actual value added provided by computers in terms of online control were minimal in the early 1960s. In the first year, computers were extremely difficult to operate because of the machine language and the lack of hardware reliability. The emphasis in the late 1960s was on blending programs and stabilization of kiln cooler operation. By 1970, the goals of that time were more modest than the original objective of the introduction of computers in 1960. The benefits of good blending included minimized kiln upsets and higher clinker quality. Reasons for the lack of success were 1) programming difficulty, 2) limitations in the reliability of instruments external to the computer, 3) the lack of adequate personnel with modern control theory and cement process background, and 4) the lack of a positive attitude (Krekel and Loague, 1971).

Holderbank, a Swiss cement manufacturer, entered the United States in 1958 by building a huge plant (with a capacity of 1.1 million tons/year) in Dundee, Michigan, with a cost of \$23 per ton compared to the cost of other U.S. plants at \$37 to \$64 per ton. In 1954 it had entered Canada by acquiring a local company and constructing a plant in 1957. In 1967, Holderbank opened its second U.S. plant (with a capacity of 1.3 million tons/year) with the largest kiln in the world. All North American plants used wet manufacturing technology. Lafarge from France had exported cement from France to the United States since the 1890s. In 1956, it opened a cement plant in Canada. In 1967, it started to export to United States in cooperation with a local cement manufacturer. Since 1948, Lafarge has used the dry manufacturing process (Barjot, 2009).

In the 1960s, cement manufacturers created distribution channels by building terminals. There were 70 terminals in 1960, 230 in 1964 and 300 in 1969. In ten years, the import of both clinker (to be ground into cement) and cement to the United States rose from one million tons in 1964 to six million tons (7 percent of the cement sales) in 1973. The imported clinker and cement from 1970–1974, reaching a total of 23 million tons, was equivalent to one year of production of 45 midsize U.S. cement plants. Local cement manufacturers also imported either clinker or cement to 1) supplement production, 2) maintain a market, 3) serve as a replacement for production rather than investment until production was onstream, 4) utilize distribution, and 5) serve as a separate investment. Local manufacturers made long-term contracts with foreign suppliers. Some of them built grinding units for imported clinker and used distribution terminals as outlets. It did

not matter whether cement came from the United States or abroad (Europe countries, Canada, Bahamas, Mexico or Venezuela) (Grancher, 1975, pp. 108–109).

In the early 1970s, the U.S. cement industry was in crisis; the manufacturing technology was obsolete and foreign companies entered the market. The oil price doubled from \$3.55/barrel in 1973 to \$8.58/barrel in 1974 (Capone and Elzing, 1987, p. 109). In 1974 the industry demand dropped due to one of the worst housing slumps. Because of the commonly used wet process, the fuel bills at the average plant shot up 40 percent (Snyder, 1978, pp. 105–106). In 1983, about 34 percent of the U.S. cement manufacturing capacity was owned by foreign firms. Lafarge, Holederbank, Societe des Ciments from France, Heidelberg Cement from Germany, and Blue Circle from the United Kingdom were the largest foreign investors.

#### The diffusion of suspension preheating in the U.S. cement industry from 1950–1980

Fuller was the first to introduce the suspension preheater of the Fuller-Humboldt type in the United States in 1953. SPs cut fuel costs and increase output (Nordberg, 1954; Biege and Parsons, 1977). The original installation was still in operation in 1975. From 1955–1958, Fuller sold another 12 SP systems in the United States. The four-stage suspension preheater kiln was applied successfully for many years in Europe and in other parts of the world (see Table 3). However, the four-stage preheater was not a success in North America, and by the mid-1960s it was out of use. In the 1950s, partly due to the high demand created by the U.S. Interstate Highway Program, cement manufacturers in the United States also made high profits (ROI of 18 percent).

Table 3. World and U.S. data on suspension preheater kilns

Developer & manufacturer	Origin	U.S. representative	Year developed	World Sales to		U.S. Sales to
				1966	1971	1971
Humboldt (1)	Germany	Fuller	1950	180	267	16
Wedag	Germany		1962	15	Incl. 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 around 1969.  
 (2) Excludes five two-stage systems sold in the United States.  
 (3) Krupp purchased Polysius about 1970.

Source: Figure 22 in Garrett and Murray (1974a, p. 59)

The cement made by suspension preheating systems had a high alkali content for two reasons. First, the sticky alkalis caused buildup and choking in the transition between the kiln feed end and the preheater. These areas require periodic cleaning. Second, cement users face the problem of concrete deterioration caused by alkalis reacting with certain types of aggregates. The U.S. Federal Government and several states established minimum standards of 0.6 percent total alkali in cements purchased for their funded projects. To meet this specification, the cement producer must attain about 0.55 percent total alkali in the cement linker (Nordquist and Heian, 1973). The

preheaters did not work; however, the kiln exit gas bypass (to prevent alkali trapping and buildup problems) was used successfully in Europe and elsewhere.

The bypass arrangement led to the introduction in 1972 of four-stage suspension preheaters in the U.S. cement industry. From 1970–1975, a total of 37 kilns were started up in the United States. The wet process was still popular. In those years, 16 wet process kilns were started up compared to 21 dry process kilns (14 of which were kilns with a four-stage suspension preheater) (Cooke, 1979). In the mid-1970s, Fuller introduced a precalciner system with the flash calcining process—the secondary furnace (SF)—in the United States, under a license from Ishikawajima-Harima Heavy Industries (IHI). IHI started research in 1963 on the development of a calcining system outside the kiln on the SP unit licensed from Humboldt. The first kiln with a four-stage SP and a calcining system (IHI-SF) started in Japan in 1971 (Kapoor, 1975; Garrett and Murray, 1974a).

In Germany, the first industrial four-stage suspension preheater with a precalciner system started in 1968. The precalciner system had the following advantages: 1) reduced alkali and sulfate buildup, 2) improved control and kiln stability, 3) ability to burn low-grade fuels, 4) possibility of very large production units, and 5) reduction of NO<sub>x</sub> emissions (Cooke, 1979). The National Cement Company acquired by La Societe des Ciments Vicat of France in 1974 was the first company to invest in a four-stage suspension preheater with a precalciner system in the United States in 1975. Production started in 1977. From 1976–1982, a total of 19 kilns out of 42 new kilns were four-stage suspension preheaters with precalciner systems (see Table 4). Table 4 shows five types of kilns: 1) wet process, 2) dry process (also called long dry), 3) ACL with a grate, 4) four-stage suspension preheater, and 5) four-stage suspension preheater with a precalcining unit. During that time, only two wet process kilns went into operation.

Table 4. Number of kilns in operation in the United States, per year and by type

Year	Wet	Dry	ACL	Preheater	Precalcining	Total
1976			1	2		3
1977		1		1	1	3
1978				4	1	5
1979			1	1	4	6
1980	1			2	7	10
1981	1		1	2	6	10
1982			1	1	3	5
Total	2	1	4	13	22	42

## ANALYSIS AND DISCUSSION

In the analysis of the emergence of path dependence in the US cement industry we apply network literature. We construct a network by 1960 (see Appendix 1). The umbrella organization, The Portland Cement Association (PCA) (founded in 1916) represented(s) cement companies in the United States and Canada. The industry is embedded in the context which includes the fuel price, the U.S. attitude and government (pollution laws and act). According to Editors (1959, p. 91) by 1960 the cement industry consisted of three types of companies: small,

family-owned and larger conservative companies (or progressives). The one great difference between these companies was the attitude to management. The last group, progressives, advocated professional management. One of the advocates said: “Besides, there is too much inbreeding in the cement industry. We need outside viewpoints”. Those opposing professional management said: “Professional managers feel obliged to make more money every year, regardless of circumstances. If they fail to do this for two or three years in succession, they expect to be fired. This results in the wasteful use of assets, frequent price rising and high-pressure campaigns that aren’t needed”. Most management employees had come up through ranks which was seen a good thing because the industry was such a special industry.

Next we look the CEM network with suspension preheating technology, see Table 3. By 1960 Fuller was the only licensee of his technology. Polysius and FLS operated via own units. Allis-Chalmers is with since it licensed grate (Lepol) technology from Europe. In the United States in 1950s it was thought that wet process was better although dry process had lower fuel costs. The advantages of wet process were ease of handling and blending the ground raw mix and more consistent clinker quality (Mehta, 1970, p. 83). Suspension preheating had three reasons for failure (Schrott, 1972, p. 71): 1) insufficient knowledge about the influence of small raw mix components 2) insufficient knowledge about producing low alkali cement by means of a continuous by pass. Contrary to ordinary dry kiln alkali content could not be lower by wasting kiln dust and 3) extremely low fuel prices. Moreover, the dust control was in suspension preheater kilns were more challenging than other type of kilns.

In Appendix 1 there are three other groups. First we have within the cement industry those companies which diversified outside and those who integrated vertically to concrete manufacturing. Most probably these companies were managed by professional. The third group is the company which diversified into the cement company.

The nets or groups in Appendix 1 form very heterogeneous and complex picture of the US cement industry by 1960. We analyze now the different groups and the individual company, Holderbank from the path dependence and the diffusion of suspension preheater technology view point. It seems that the PCA was just an organization collecting data. In 1973 it arranged a visit to Japan and gave summary lessons: “The cement industry of Japan has assumed international leadership in the development of new cement manufacturing process technology and in the application of this technology to new plant design. These changes resulted in revolutionary changes in cement plant operations” (Grancher, 1974, pp. 87–88). Had the PCA been keen on technology development it should have arranged this kind of trips to Europe and Japan already two decades earlier. The small and family-owned companies were reluctant towards new technology since they did not like the change and they probably did not have money. The large conservative firm provided they had professional management were eager to look new things probably technology, as well. However, investments in new technology not functioning well may eat short-term profit.

None of the local CEMs were interested in these challenges. Allis-Chalmers developed the grate (ACL) technology. It co-operated by 1970, far too late, with MIAG. As was mentioned Fuller entered to manufacturing not until the late-1940s. Moreover it had developed since 1957 its own different kiln burning technology (Pyzell) which was abandoned not until 1974 (Garrett and

Murray, 1974b, p. 99-100). It seems that the PCA and local CEM had Not Invented Here attitude. The European CEMs had been in the business for long time. Some of them even had cement manufacturing. The companies diversifying outside the industry and integrating downwards had probably no management resources for evaluating technologies. Probably the companies entering the cement industry were most open to new technology. Unfortunately Holderbank invested in the wet process and thus reinforced the “excellence” of wet process. The difference came from the size of the plant. Anyway it was again easier for local manufacturers to keep existing technology.

All in all the network by 1960 reinforced the path of wet processes. The industry was full of heterogeneous groups having versatile objectives. None of the group provided challenges in technology sense for local CEMs. Collaborative relationships became path dependent as well, thereby affecting the development of an organization, and vice-versa. The CEM industries were criticized by the cement industry:

The only advancement in process equipment, since World War II, came from Europe (the Suspension Preheater), and this was ill received in our country. Was this because the cement industry did not like the looks of it, or was it because our supplying industry [CEM] did not get involved deeply enough into the physical phenomena which this system present? (Evans and Hertz, 1970, p. 9)

... a lack of broad industry perspective within the membership of the various component industries and their representative bodies, which lessens ability to meet challenges. ... But the fact still remains that we depend on our supplying to furnish the process equipment, and some real effort on their part is needed to attract high caliber engineers to develop some of the better process ideas into operative equipment, which will produce a finished product that suits our market conditions. (What cement’s future hinges on, 1972, p. 106-7)

Because of the abundant supply and low cost of energy in the late 1940s, the U.S. cement industry used low-priced energy in their wet process kilns. The low-priced energy also allowed small kilns and small plants to be built all over the United States. These choices brought the whole industry to the path during the mid-1940s. This is Phase I (Figure 3) in Sydow et al.’s (2009) framework. In the 1950s, the low energy price, U.S. control of the foreign trade, and the US dollar as the main currency were the factors that prevented domestic industries from looking outside the United States.

The energy-saving dry method, the SP system, was introduced in the United States in 1953. The unit was the fourth in the world. It indicated a good start in the newly developed dry process system and provided other technological choices for the industry. The demand grew from 1950–1956 partly because of the highway program. In 1957, highways consumed about 28 percent of the cement manufactured in the United States. The cement price rose about 3 to 5 percent a year, and the cement manufacturers made nice profits. However, the SP systems did not work well. Unfortunately, not a single local CEM was committed to fixing this problem. The industry to keep existing wet technology. Luckily, the price of oil did not rise in the 1950s. The industry was unable to invest its profits in the development of their plants and technology. 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. High demand attracted newcomers and many old shutdown plants were reopened. The industry had stepped strongly

into Phase II (Figure 3). These were the few minor random shocks proposed by David (1985) to keep the history unchanged in path dependence.

In the 1960s the unchanged fuel price had naturally no impact on the cement industry. Cement companies diversified and companies outside entered the cement industry. There was forward to the concrete business leading to several spatial anti-trust lawsuits. All these events prevented the top management from focusing cement manufacturing technology. In 1968, Harwell wrote about the cement industry: “Obsolescence, not the popularly cited evils of overcapacity and depressed prices, is the devil that plagues the cement industry. With over 70 percent of the industry’s production facilities hopelessly outmoded, the situation has reached the crisis stage.” (p. 60).

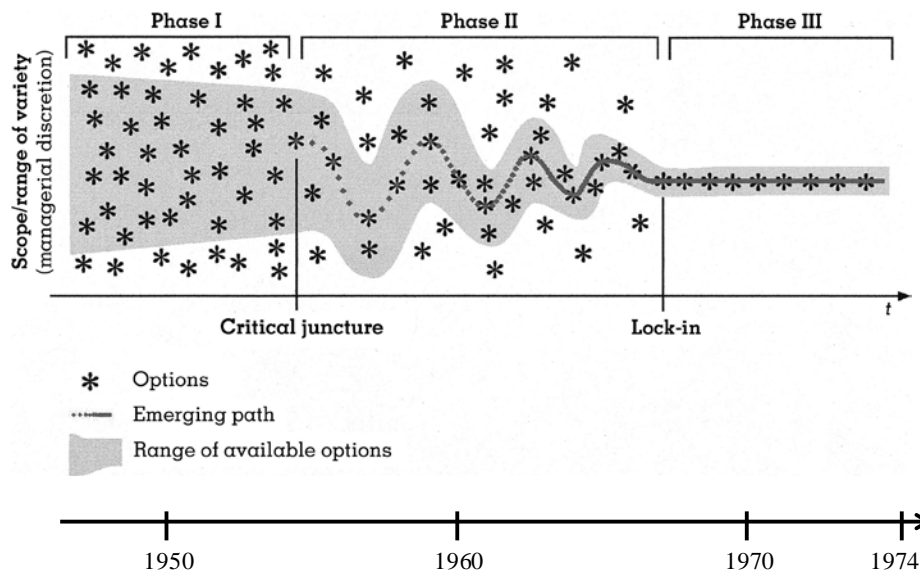


Figure 3. Application of Sydow et al.’s framework (2009, p. 692)

Computers did not solve the kiln problems of the cement industry. They operated equally well (or badly) with both the wet and dry processes. Pollution or dust control started in the late 1950s. By 1970 new laws led to the closure of many small and old-fashioned cement plants causing a shortage of cement. Cement firms imported either cement or clinker. The air pollution challenges were more easily solved by new, less energy-consuming modern dry processes with preheaters or precalciners. In the late 1960s, the industry was in Phase III (Figure 3). As operating divisions of large corporations, cement manufacture - due to its low profit - did not receive capital for new equipment. (Grancher, 1975, pp. 85–86).

The FTC policy restricting horizontal integration had on the U.S. cement industry following impacts: 1) encouraged diversification away from core competencies, 2) It discouraged investment in the cement industry by domestic producers, 3) kept older, smaller, and less efficient plants operating much longer, 4) prevented scale economies, and 5) kept the industry fragmented and populated with small companies having limited managerial, technological, and capital-raising abilities. Marby (1998, p. 405)

Because of the cement manufacturers were not allowed to integrate forward to cement industry and secure the cement sales they diversified very different areas. The focus was lost. In the conglomerate firms cement division (and especially the manufacturing technology) received less top management attention and financial resources. The firms outside industry were not interested to commit the cement industry. When the horizontal nation wide growth was prevented the industry was full of small, obsolete and financially weak firms. The industry started also to import cement. The oil embargo of 1973 caused the obsolescence of the cement industry's entire productive base (Grancher, 1980, p. 57). In 1973, record imports and the oil crisis opened foreign eyes to the opportunities for investing and making profit in the U.S. cement industry. In the early 1970s it was too late for the U.S. cement manufacturers to switch energy saving dry technology.

Weak signal may cause unlocking from the path. However, the U.S. cement industry was already so blind see weak signals such as internationalization / globalizing of the industry. There were hardly any reactions when the Swiss Holderbank built its huge plants (five to six times larger than the average U.S. plant) in 1958 or in 1965. Nobody was interested in the fast-growing Japanese market or the European and Japanese CEMs. The oil crisis in 1973 was the final shock to awaken not only the local manufacturers but also foreign ones. Foreign companies entered the market. As a result, from 1976–1982, the industry invested in 44 kilns, of which 21 were precalciner kilns and 14 were preheater kilns (Table 4). The oil crisis and the internationalization was matter to unlock the path.

## CONCLUSION

We reported on the decades-long path dependence (lock-in) of the U.S. cement industry on the wet manufacturing process. We applied Sydow et al.'s (2009) model of path dependence at the industry level. We also provided potential reasons, low energy price, diversification, spatial monopolies, unattractive industry for talented people, for this long-lasting lock-in with the energy-consuming wet processes of the U.S. cement industry. The external development of the dry manufacturing process did not unlock the wet process in the industry. Only external shocks, first the oil crisis and then the entry of foreign companies, unlocked the path for the industry. The model seems to work well in our case of industry-wide path dependence. This is a new path dependence tool for network analysis as Araujo and Harrison (2000) called for.

We recognized the path dependence of the cement industry and emphasized the need for new technology. However, suspension preheating technology was not a crossing strong enough Hakansson and Lundgren (1987). According to Stevens (1974, p. 91), "The reduction of fuel usage per ton of cement will happen only after a large expenditure of money is made for the building of new plants and the installation of efficient equipment in the older plants." Schroth and Diener (1976, p. 64) said that large single-kiln plants would be helpful in reducing manpower.

According to Grancher (1980, p. 68):

The shared blame [of the situation of the U.S. cement industry] in the end of 1970s] must be placed where it belongs. First, during the latter 1950s, it was poor management practice that led the industry to disastrous consequences—initially into overcapacity then ill-conceived marketing concepts, and finally in disappointing diversification moves to carpeting, department stores, swimming pools

whatever—anything to escape the confines and reputation of cement production. It was also during this period that cement salesmen were allowed to become prostitutes of the industry, selling themselves and their products to the lowest bidder. The net result was the dubious distinction of cement making establishing the worst earnings period within the American manufacturing.

We also identified self-reinforcing mechanisms. The coordination effects, which are a rule-guided behavior, were seen in the small size of the plants, the vertical integration to concrete manufacturing, the diversification due to decreasing profits, and the process control to increase productivity and importing. We can see the neglected development of the industry as one coordination effect. The industry participants regarded the U.S. cement industry in the late 1950s until the 1970s as the field of “sunset” (Evans and Herz, 1970, p. 9). Robert R. Salyard, an American Cement Company executive, also said that the cement industry should attract more talent, both technical and nontechnical, to continually upgrade production, marketing, and technical skills to keep the industry competitive (What cement’s future hinges on, 1972, p. 107).

The complementary effect relating to economy of scope was the vertical integration to concrete manufacturing and distribution terminals. Learning effects refer to the learning gained from the repeated use of the same solution. The operation becomes more skillfully performed (i.e., faster, more reliable, and with less errors), which in turn means decreasing average costs per unit of output (Argote, 1999). The more attractive the chosen solution becomes because of accumulated skills and decreasing cost, the less attractive it is to switch to new learning sites (where the actors would have to start from scratch) (Sydow et al., 2009, p. 705). This was the case with the wet technology, which had been in use for decades. The manufacturers felt no need to bother with other things since “setting up a new course of action takes quite some time to match the learning effects of the existing course (even when it has been proved inferior). In those cases creating an effective alternative for the restoration of choice requires an extra effort—a (possibly costly) subsidy to help the new alternative catch up with the existing one” (Sydow et al., 2009, p. 703).

Adaptive expectation effects relate to the ability to vary in response to the expectations of others. This was seen in importing. The enhancing context included several matters such as alkali content in cement (which has an impact on suspension preheating technology), antitrust trials, and the Clean Air Act. Only the harsh unlock mechanism, such as the oil crisis and the entry of foreign companies, worked. According to Mabry (1999, p. 406), “The restriction on horizontal integration damaged the long-term competitiveness of the industry and weakened the ability of many companies to compete effectively as markets globalized and multinational cement producers moved aggressively into domestic markets.”

However, if we look beyond 1980, we are unsure whether the U.S. industry was unlocked at all. Instead, it was sold to foreign companies, as Allen (1993) showed. In the years 1980, 1987, and 1990, the foreign ownership shares were 15 percent, 53 percent, and almost 70 percent, respectively.

The most important messages of the this paper for managers are the complexity of a “simple industry” (see Appnedix 1) and the identification plus understanding of the weak crossing points of paths (Hakansson and Lundgren, 1987) and how they can be hidden in other activities (in this case diversification and vertical integration).

## **Bibliography**

- Allen, B.T. (1971), Vertical Integration and Market Foreclosure: The Case of Cement and Concrete, *The Journal of Law and Economics*, April: 251-74.
- Allen, B. T. (1993) Foreign Owners and American Cement: Old Cartel Hands, or New Kids on the Block, *Review of Industrial Organization*, 8, 697-715.
- Anderson, P. and Tushman, M. L (2001) Organizational Environments and Industry Exit: the Effects of Uncertainty, Munificence and Complexity, *Industrial and Corporate Change*, 10, 3, 676-711.
- Araujo, L and Harrison, D. (2000) Technological Trajectories and Path Dependence, a paper published in the 16th IMP-conference, Bath, U.K.
- Arthur, W. B. (1989). Competing technologies, increasing returns, and lock-in by historical events. *Economic Journal*, 99(394), 116–131.
- Arthur, W. B. (1994). *Increasing returns and path dependence in the economy*. Ann Arbor: University of Michigan Press.
- Bell, J. H. (1958) Air pollution laws come to Lehigh Valle, Rock Products, May: 80-84.
- Berg, D. N., and K. K. Smith (1988) *The Self in Social Inquiry: Researching Methods*. Newbury Park, CA: Sage.
- 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 16-19.
- Capone, C.A. Elzinga, K.G (1987) Technology and Energy Use Before, During and After OPEC: Th U.S. Portland Cement Industry, *The Energy Journal*, 8, 3:93-112.
- Chandler, A. Jr. (1990) *Scale and Scope: The Dynamics of Industrial Capitalism* (Cambridge, MA).
- 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 21-24.
- David, P. S. (1986). Clio and the economics of QWERTY. *The American Economic Review*, 75(2), 332–337.
- 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*, 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.
- Editors (1959) Where in the cement industry headed, Rock Products, May, 81-93.
- Eisenhardt, K. M. (1989) Building Theories from Case Study Research. *Academy of Management Review*, Vol. 14: 532-550.
- Evans, R. E. and Herz, J. H. (1970) Seven years of process computer control at California Portland Cement, a paper presented at I.E.E.E. Cement Industry Conference, Indianapolis, IN, USA, May 12-14.
- Gadde, L-E. and Håkansson, H. (2001), *Supply Network Strategies*. John Wiley & Sons, Chichester.
- Garrett, H. M., and Murray, J. A. (1974a) Improving kiln thermal efficiency-dry process kilns, Part 4. Rock Products, August: 58-63 and 69-71.
- Garrett, H. M., and Murray, J. A. (1974b) Improving kiln thermal efficiency-dry process kilns, Part 5. Rock Products, September: 88, 90 and 99-100.
- Grancher, R. A. (1969) Why cement failed, Rock Products, May, pp.63-4, 66, 124-6.
- Grancher, R. A. (1974) United States cement: Return on investment, Rock Products, December, pp. 56-59 and 87-88.

- Grancher, R. A. (1975) Will the U.S. cement industry plans for survival? *Rock Products*, May, pp. 106-10 and 128-9.
- Grancher, R. A. (1976) Why shoot at the cement industry, *Rock Products*, July, pp.84-86.
- Grancher, R. A (1980) Cement in the '80s, *Rock Products*, February: 56-60.
- Hakansson, H (1989) *Corporate Technological behaviour: CO-operation in networks*, Routledge, London.
- Hakansson, H. and Lundgren A. (1987) Paths in time and space - path dependence in industrial networks. In: Magnusson L, Ottoson J, editors. *Evolutionary economics and path dependence*. Cheltenham, US: Edward Elgar, 119–37.
- Håkansson, H. and Waluszewski, A. (2002) Path dependence: restricting or facilitating technical development? *Journal of Business Research*, 55, 7, 561–570
- Harwell, S.R. (1968) For the cement industry: A TIME OF CRISIS. *Rock Products*, April, pp. 60-4 and 114-5.
- Jones, G. (2005) *Restoring a Global Economy, 1950-80 Multinationals and Global Capitalism: From the Nineteenth to the Twenty-First Century*, Oxford University Press.
- Jick, T. D. (1979) Mixing Qualitative and Quantitative Methods: Triangulation in Action. *Administrative Science Quarterly*, Vol 24: 602-611.
- Keck, S. L. and Tushman, M. L. (1993) Environmental and Organizational Context and Executive Team Structure, *The Academy of Management Journal*, 36, 6: 1314-1344.
- Levine, S. (1971) The rock products industry – an overview: Portland cement, *Rock Products*, October:77-80.
- Mabry, J. B (1998) Regulation, Industry Structure, and Competitiveness in the U.S. Portland Cement Industry, *Business and Economic History*, 27, 2, 402-412.
- McBride, M. E. (1979) *The Federal Trade Commission Policy Toward Vertical Merger: The case of Cement and Concrete*. Unpublished Ph.D. dissertation, Washington University
- McBride, M. E. (1983) Association Spatial Competition and Vertical Integration; Cement and Concrete Revisited, *The American Economic Review*, 73, 5:1011-1022
- Mehta, P. K. (1970) Trends in technology of cement manufacture. *Rock Products*, March: 83-87 and 102.
- Mintzberg, H. (1979) An Emerging Strategy of "Direct" Research. *Administrative Science Quarterly*, Vol 24: 683-589.
- 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.
- Panzar, J. C. & Willig, R. D (1981) Economies of scope. *American Economic Review*, 71: 268–272.
- Patton, Q. M. (1990) *Qualitative Evaluation and Research Methods*. Newbury Park: Sage Publications.
- Pierson, P. (2004) *Politics in time*. Princeton, NJ: Princeton University Press.
- 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.
- Rose, S. (1974) The far-reaching consequences of high –priced oil, *Fortune*, March:106-11, 191-2 and 196.
- 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.
- Schroth, G. A. and Diener, D. K. (1976) Trends in the U.S. cement industry. *Rock Products*, February: 60-62 and 63.
- Snyder, L. (1978) The Fundamentals Are Changing in Cement, *Fortune*, August 28:105-6.

- Stevens, F. C. (1974) Fuel economy demand challenges U.S. cement industry. *Rock Products*, May: 88-91.
- Sydow, J., Schreyögg, G., & Koch, J. (2009). Organizational path dependence: Opening the black box. *Academy of Management Review*, 34(4), 689–709.
- Teece, D. J., Pisano, G., Shuen, A. (1997) Dynamic Capabilities and Strategic Management, *Strategic Management Journal*, 18 (7), pp. 509-533.
- Tushman L. M. and O'Reilly, C. A. O. (1997) *Wining through Innovation, A Practical Guide to Leading Organizational Change and Renewal*, HBS Press, Boston.
- Tushman L. M. and Rosenkopf, L. (1996) Executive Succession, Strategic Reorientation and Performance Growth: A Longitudinal Study in the U.S. Cement Industry, *Management Science*, 42, 7: 939-953.
- Uusitalo, O. (2007) The Impacts of Technological Change on the Industry - The Case of the Scandinavian Cement Industry in the 20th Century, The 23th International Conference on Industrial Marketing and Purchasing, in *Competitive Papers*, Manchester, the UK, 27-30 August, 2007.
- Uusitalo, O. (2013), International Technology Transfer and its Implications to Dominant Design Theory, in Timothy M. Devinney, Torben Pedersen, Laszlo Tihanyi (ed.) *Philosophy of Science and Meta-Knowledge in International Business and Management (Advances in International Management, Volume 26)*, Emerald Group Publishing Limited, 435-467
- 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. (2009). *Case study research: Design and methods* (4th ed.). Newbury Park, CA: Sage Publications.
- What cement's future hinges on (1972) *Rock Product*, May:105-7 and 131.

**Appendix 1. Networks in the U.S. cement industry by 1960**

