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The history of modern industry has often been written in terms of technological change. This paper describes a more complex, co-evolutionary model of techno-organizational change: an iterative process in which changes in technology and changes in organization are each spurred by the other, each foreclosing some possibilities to the other, while opening different possibilities.

## TECHNO-ORGANIZATIONAL CO-EVOLUTION

Competition among today's firms to define "best practices" -- that is, the most efficient and quality conscious production methods -- reflects the struggle to shape the newest paradigm in industrial history. A number of authors have noted transformations that have ushered in new production systems. C. Perez and C. Freeman identified five major shifts, focused on the factory system; steam power and powered transportation; the use of steel and electricity and the emergence of large corporations; oil-based energy and the rise of mass production; and information technology.

This analysis will make explicit what can be seen in these descriptions, namely that technological change is associated with organizational change. A change in one of these elements of a production system requires adaptations that can spark innovations in the other component of the system. On a small scale, if a new conveyor design links two production processes such as manufacturing and packing, this may foster teamwork between two departments. Teamwork may in turn lead to improvements in equipment. With each iteration several possibilities for adaptive response can co-exist, but once a choice is made it will shape future options for change. An examination of the five paradigm shifts noted above sheds further light on this process.

The *factory system*, a major characteristic of the first industrial revolution, was initially an organizational innovation that brought under one roof the pieces of production that had been scattered (or "put out") among rural cottages. This made it easier to coordinate production and to control labor. Note that this description reverses the usual treatment of the industrial revolution as originating with the introduction of water-powered machinery. In fact, it was the concentration of labor that made the development and use of machinery feasible.

In the 1830s the *steam engine* liberated factories from dependence on flowing water. New processes for the production of materials, such as iron and pottery, and new forms of

transportation, such as railroads and steamships, increased both the productive capacity and the kinds of goods that could be factory-made. Laws, forms of business organization, and workers' organizations began to reflect industrial, rather than mercantile or agrarian interests. "Productivity soared with these innovations, leading to a broader-based regime of accumulation, and the production of wage goods for the new working class from the new factories." [87] Systematic attention began to be paid to innovation as such.

With the development of *electric power*, complex technological systems spread rapidly through urban regions and industries. Inventions in new products and processes brought on a new wave of investment and raised productivity further still. The notion of modernism emerged, identified with the dynamism of machinery. Giant corporations emerged and began to integrate what had been separate, market-based activities. Standardization and production with interchangeable parts set the stage for the mass production industries of the 20th century.

The fourth paradigm shift has been called an "industrial divide" by Michael Piore and Charles Sabel, who describe it as a "parting of the ways between craft- and custom-based production and mass production." [89] *Mass production* is centered on the standardization of products (and consumer tastes), processes, labor, cost, and accounting methods. It requires mass markets and a consistently high level of consumption. The crisis that could result when these conditions failed was exemplified in the Depression of the 1930s, stemming from a critical shortfall in demand. Momentum was regained after World War II with mass production and mass consumption supported by an elaborate institutional regime that included collective bargaining of wages, regulation of both domestic and international monetary systems, social security and other welfare measures, and liberal trade policies. Standardization spread to services like fast food and retailing. This whole system, termed Fordism, had a "golden era" from 1945 to 1968. For the past several years, however, Fordism has been declining, partly because the rigidity of mass production makes it unable to cope with shifting markets and the consequent demand for product and process flexibility.

A new paradigm is now struggling to emerge -- the fifth in this industrial series. Its characteristic *information technologies* appear to be best complemented by organizational redesign that can take advantage of the possibility that had been so outstandingly neglected in Fordism: work-place initiative. Flexibility is one of the qualities most sought in today's "best-practice" systems. Information technologies offer this quality because they are programmable and can be adapted to changing product demand and innovative processes. However, these technologies are not compatible with the rigid standardization of mass production systems.

Japanese manufacturers were the first to make the necessary organizational adaptations to the new possibility, in what came to be called lean production techniques. Other adaptations emerged as smaller firms created cooperative clusters or networks (e.g., in industrial districts such as Emilia-Romagna in Italy, Baden Wuertemberg in Germany, and the Tokyo-Osaka axis in Japan).

## PARADIGM SHIFTS AND DIFFUSION

The idea of a paradigm shift can be found in several schools of thought. The terminology itself originated with Thomas Kuhn's discussion of changes in scientific thought. The Schumpeterian school emphasizes the role of innovation and diffusion of technological developments. Economics links innovation with investment.

With each paradigm shift, new best practices emerge that firms ignore at their peril. In each of our historical cases the leading edge technologies fulfilled three conditions: they could be used in most sectors; they were cheaper than the technology being supplanted; and they could draw upon abundant raw materials. Changes that occur in this way are not best understood as technological determinism, but rather as compatible technology and organization jointly forming best practices that outperform competing methods of production. Similarly, with the emergence of information technology, we see the development of new organizational forms that can best exploit its potentials.

This line of argument (which has its critics) implies a mismatch between the new information technology and the older organizational forms that were compatible with the mass production paradigm. Information technology contributes most to productivity and profitability when it is employed in systems characterized by flexibility, responsiveness, and adaptability; therefore the firms that adopt such systems gain a competitive edge. However, the general literature on paradigm shifts leaves open the question of how firms should proceed with the organizational part of this techno-organizational shift. Some observations on relatively successful experiences are summarized below.

## ADOPTION OF NEW ORGANIZATIONAL FORMS

New models of organization can arise through either of two processes: the creation of new organizations, or the transformation of existing ones. Transformation is the commoner process, but experts are divided on how to achieve it. One school of thought prefers change from the bottom up; the other from the top down. The former approach is participative, but can lack leadership and direction; the latter is autocratic, but can fail to foster sustainable change, since people may not take responsibility for making the change work.

In fact, most programs of organizational change fail, often because many of those who will be affected see their interests as threatened. The keys to successful change are leadership and involvement. Leadership must demonstrate that losses will be offset by gains, paying close attention to the basic interests of employment security, wages, preservation of skills, and a sense of dignity of worth. "[C]hange works best, resulting in sustainable new structure, when it involves those who have a stake in the outcome." [100] Resistance to change must be taken seriously, its sources understood, and special efforts made to educate and include those who feel threatened. Those affected must feel that the process of change is legitimate in the context of agreed upon rules and principles. Often these principles are established and situated within a framework of industrial relations that provides a familiar arena for negotiation of the conditions and consequences of change.

Large corporations that are in the process of introducing the current "best practices" frequently find that the biggest challenge is to bring on board the middle management and technical

personnel who feel threatened by the need to share power. Successful efforts to date have often started with small pilot programs that could give concrete forms to the concept and demonstrate success. A "yeast effect" lets changes on the shop floor work their way up to top management at the point when problem-solving teams require management cooperation to get things done. An important part of the shift occurs when management can redefine itself in a "problem solving" light, in place of its former identification with "command and control."

The process of techno-organizational co-evolution requires a series of choices based on probing and testing the environment. Those firms that appear to have made the transition successfully have become "learning organizations" that can continuously find and institutionalize the strategies and structures best suited to meet their needs.