THE DIFFICULTY OF PROJECTING IMPACTS FROM TRAJECTORIES OF EMERGING TECHNOLOGIES

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The Context of Innovation

Of all human activity, surely one of the most problematic is forecasting future events. This is doubly so when there is no history upon which to base predictions. Forecasting the impacts of a new technology usually falls into this latter category. As an example of how wrong forecasts of technology can be, IBM estimated the *total* market for large computers at about 50, when the 650 computer was introduced, in the early 1950s. The currently installed user base of large systems in the US is approximately 100,000 as of 1983 (not even considering a three order of magnitude increase in the meaning of 'large').

The difficulty in predicting the impact of a new technology lies not in the mathematics of forecasting, which is highly developed, but in the assumptions used by forecasters, the inability to identify factors that may deflect, or enhance a technology, and in estimating accurately the behavior of direct and indirect consumers. There is a tendency also, when a new technology arrives, to confuse *possible* with *likely* outcomes. The forecaster traces the locus of all possibilities for the technology, which then becomes its predicted trajectory.[1]

The reasons for these shortcomings are straightforward. We are human and by nature, optimists. Because a technology has the potential to be used in a particular way we then make the assumption it *will* be used that way. We are not sensitive to complexities in the technology or its application. We do not anticipate difficulties in adaptation. And, we are reluctant to acknowledge individual differences among consumers, presuming that others are just like ourselves.

The literature on the diffusion of technology, often referred to as the *innovation* literature, suggests a variety of factors that influence adaptation. The most obvious are the characteristics of the technology itself, including the advantage that it has over previous methods, its affordability, its comprehensibility, the extent to which its adaptation can be staged, the extent to which the technology can be tested on a limited basis, the reversability of the commitment to the technology, the credibility of its advocates and the extent to which the technology is compatible with generally accepted

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[1]A case in point are the writings of the "cybernetic" school, in the late 1950s and early 60s, that predicted the imminent arrival of 1) machine intelligence, and 2) completely automated factories with the wholesale replacement of workers at *all* occupational levels [Wiener 61, Hodges 83]. In spite of the current attention being given to Expert Systems, most of the difficult problems in Artificial Intelligence (AI), for example, common sense understanding and machine learning, remain to be solved and we are many years away from integrated manufacturing systems [OTA 84].

practices, norms and values [Rogers 62, Havelock 73, Bikson 81]. While the details of the technology certainly play an important role in explaining innovation, they do not capture all of the factors needed to account for outcomes, especially those factors that describe the organizational context in which decisions about technology are made.

Organizational factors that influence the adoption of technology consist of the environment in which a firm is embedded, that is, the structure of its industry, community setting and general economic conditions; the position of the firm in the industry including rank, firm size, composition of staff, and the acceptance of innovative behavior in the industry; firm characteristics composed of structure, degree of centralization of decision making and extent of formalization; and task design involving degree of specialization, organization of work, autonomy, and work load of individuals [Bikson 81].

Both of these perspective presume a passive role is played by adopters, all of whom are supposed to have the same action rationale. In contrast, social interaction models of diffusion emphasize the importance of the implementation process per se, those situational factors surrounding the introduction and use of the technology in a particular setting. These factors might include the reasons for adoption; key actors who champion or guide the innovation, as well as those who resist it; the support of top management; involvement of users; training; alignment of incentives and counter incentives to change; and flexible and adaptive goal directed planning [Bikson 81, Keen 81, Turner 85].

Given all of the factors that may influence adaptation, it is evident why forecasting the impacts of a technology is so difficult. Any analysis that purports to predict impacts and consequences of a technology, and to explain causes, must consider most of these factors. While new ones may be added, not addressing those that have been shown to be important by other researchers is a major deficiency of any study.

Threats Posed by Computer Technology

In his paper, *Democracy in an Information Society*, Ted Sterling does the reader a service by identifying potential threats posed by computer and information technology in a free society. These threats include reduced participation in the process of governance; distortions in the electoral process, particularly in the composition of political parties; reduced stability in democratic structures; the role of a free market; the elements of contradiction in capitalism that could lead to a decrease of individual freedom and democratic rights, especially technological advances creating "a large pool of impoverished unemployables who might destabilize society." This is a *big* meal to consume in one seating!

As best I can make out, the line of argument of the paper goes something like this:

> Sterling is concerned about the possibility of computer management systems, belonging to large institutions, such as, government agencies, the banking system, multi-national corporations, etc., influencing our economic, social and political systems and that these influences may be "anti-human." Large organizations will use their computer systems "to manage and to even act as substitutes for parts of their bureaucracies" and to

"integrate" their activities. He then argues that "computerized packages appear to give rise to social organizations and social functions that are usually associated with anti-democratic developments," that they "appear to promote centralization," that they "appear to limit participation," and that they "make it easier and cheaper to monitor citizens." He observes that it not need be this way, that computerized packages could "just as easily decentralize organized life, increase participation, and help protect individual privacy." Sterling attributes "the emerging shape of our society in the world of computers" not to "a conspiracy of powerful businessmen and government officials" who "seek to insure a central position for themselves", but to "the consistent pursuit of self-interest by upper-level management" because they make "the final decisions about which technology their organizations will absorb and how that technology will be bent to their purposes." (liberally adapted from pages 45-46)

Two questions appear fundamental in evaluating Sterling's position:

* Is the contention that computing promotes anti-democratic activities, leads to centralization, limits participation and makes it easier to monitor citizens supported by evidence?

* Are the reasons he provides for these outcomes plausible?

Our approach will be to investigate one of the issues raised in detail.

Centralized Control

Sterling's argument that computing leads to increased centralized control in organizations rests on the "economies of designing, writing, implementing and maintaining large scale programming packages." He points out that "large programming systems are very much easier and cheaper to design and install for centralized than for decentralized organizations since, in the latter, systems have to be programmed for communications within different levels of the pyramid." He continues, "from the design point of view, it is much simpler for an input or output terminal to communicate with a central programming stream and with a central programming stream to communicate with a terminal than it is for one terminal to communicate with another terminal." He then concludes that because of this the hierarchical structure of large organizations will be reinforced and, consequently, that computing will promote centralization.

There are a number of difficulties with this line of reasoning. First, Sterling confuses a centralized *application system* (as contrasted with a distributed application system) with the centralization of *control* in an organization. The factors that govern whether an application is designed as centralized or not include the structure of the company's processing centers, the availability of a distribution network, the experience of key actors and technical staff, economics, and the benefits of providing data entry, storage and/or data access from remote locations, and the like. There are also many possible combinations of equipment configuration, processing location, data location and access, along a continuum from centralized to distributed, so that it is never clear whether any large application system is centralized or distributed.[2]

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[2]How should one classify an airlines reservation system with several regional processing centers, one major data base and terminals on every sales agent's desk?

Centralization of control refers usually to the level at which certain classes of decisions are delegated. There are no research results which show highly centralized organizations, where most key decisions are vested in top management, have application systems that are more centralized than those in which key decisions are decentralized. Neither has there been any research that demonstrates centralized application systems increase the centralization of control in an organization, although some authors have argued that computer application systems, independent of whether they are centralized or distributed, may increase the *potential* for monitoring of employees [Zuboff 82]. In fact, if the research results indicate anything it is that employees perceive computer application systems increasing their decision latitude, which would be considered as contributing to decentralization of control [Turner 84a, Turner 85].

What has been also shown in the research is that when there is a match between the organizational structure of a company and the structure of its computing services (that is, data or information processing) department, better performance results [Olson 80].

Second, there are some specific *technical* inaccuracies with Sterling's argument. It is not at all clear that a large programming system is either easier or cheaper to design for a centralized organization, if centralized is taken to mean 'centralization of control.'[3] The level at which decisions are made in an organization probably has little to do with the cost or degree of difficulty in designing a system. As long as the organizations were the same approximate *size*, the systems would probably be comparable in complexity. If, however, Sterling's contrast is between an application system with a *batch* processing organization and one with an *on-line* organization, a case could probably then be made that the on-line system was more complex [Turner 81], but this would not contribute to the centralization argument.

Many operating systems provide a capability that permits terminals using the same system to "talk" to each other (for example, the TALK, ADVISE and SEND commands in DEC's TOPS20) and some also provide the ability to tie computers of the same family together in a "network" that allows the exchange of messages and data between machines, and hence, terminals (for example, DEC's DECNET). Other operating systems provide access methods for handling terminal messages (for example, IBM's TCAM and CICS) that simplifies greatly the design of on-line systems. Consequently, it isn't that the communications aspects of these systems make them more complicated, but rather that their

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[3]One of the deficiencies in Sterling's argument is that he never defines what he means by 'centralized.' King [King 83] provides an excellent discussion of the centralization issue and information systems. He identifies three general categories of centralization: Centralization of control, concerned with the location of decision making activity; centralization of physical location; and centralization of function, referring to the position of an activity within the structure of an organization.

asynchronous nature requires more complicated internal control schemes. Sterling continues to confuse on-line with decentralized and his statements, in this regard, are inaccurate. In any event, it is hard to see why the "hierarchical structure of large organizations will be reinforced" by these systems and how computing "promotes centralization."

If anything, the current trend, referred to as *end user* computing [Rockart 83], driven by the influx of micro-computers and information centers, is toward decentralization of information systems. While this creates management problems in coordination and control, it does provide many people in organizations with more access to data and computation facilities than they had previously.

Space does not permit a discussion of Sterling's other themes. In general, the conclusions are the same: His positions are not supported by either his arguments, or the evidence.

Organizational Processes

With regard to the second question, whether the reasons provided by Sterling are plausible, part of difficulty appears to be the way Sterling has chosen to depict large organizations. He evidently perceives them as being directed by a single omnipotent individual, with a consistent goal, who effortlessly shapes the remainder of the staff to his desires:

> As management has the ultimate authority, those computerized packages tend to be selected or specified which suit management best. (p. 15)

and again:

> In the end, computing will reinforce the power and influence of those individuals and groups who control resources and power in an organization. (p. 15)

What a conveniently simple conception of organizations! Outcomes occur because leaders desire them. Somehow, this fails to capture the richness of Allison's [Allison 71] models of bureaucratic machinations, either organizational process or political, where many crucial decisions follow from organizational routines rather than from central choice. In his analysis, Allison found that principal actors differed markedly in their perceptions of problems, their estimates of the consequences of different courses of action, and in their preferred solutions. How can we then accept Sterling's position that choices about computerized packages are made *solely* by the individual at the top? Moreover, there is no reason to believe that all of the people at the top, in many different types of large organizations, would be of the same mind in this matter.

Consequently, one must dismiss Sterling's explanation of why these outcomes occur as being simplistic. His notions are not supported by research findings; they are speculation. He has not considered *any* of the factors from the implementation literature. His explanations rule out much of the work in organizational psychology and sociology, management science, public administration and other fairly well developed fields that produce whatever small insights into human and organizational behavior have been made. Even though Sterling bungled the job, the central issue remains: *Is Technology likely to transform radically our business and social institutions*?

The Trajectory of Technology

In a recent article that provides a complete and balanced review of the impact of computer technology on organizations, Attewell and Rule [Attewell 84] observe that these questions are not *new*, they have been issues of social and economic thought since the nineteenth century. They go on to point out that many writers consider the effects of computer technology as foregone conclusions, "as though they could be determined, a priori." They maintain that the results of studies are mixed and inconclusive and that "a priori arguments are particularly inappropriate in light of the range and variety of" factors at work in these situations.

Given the range of factors suggested by the implementation literature, it seems unlikely that the concerns raised by Sterling are likely to occur. We can not say, a priori, that computer systems will encourage "anti-democratic" developments, promote "centralization," limit "participation," or increase "monitoring" of citizens. Then, are there any dangers? I believe so. But, these are *relative* rather than *absolute* concerns. One is that in deciding to implement computer systems, rationales for efficiency may be used to mask political motives. The technology may be used as a vehicle , in certain situations, to achieve self-serving, or even illegal ends. These must be recognized and opposed. If a manager doesn't understand, or is unwilling to understand what a system does, the system shouldn't be built. Culpability should not be confounded by the presence of technology. In many respects the risks have become greater because of technology's ability to obscure motives and consequences.

Another danger is that in re-allocating tasks between people and machines the resulting jobs may become poorer, for example, more specialized, less variety, shorter cycle-times, or machine paced [Turner 84a]. The reasons why this can occur are complicated, having to do more with the values of system implementors than with the technology itself [Turner 84b]. Labor is a critical resource that must not be depleted, which suggests that greater emphasis be placed on working life quality.

Associated with this issue is concern for workers who may become displaced by technology. It would be unwise, as a policy matter, to prohibit replacement of tasks performed by people (by those performed by machine), since this process is the primary source of improvements in productivity. There is a need, however, to provide alternate job opportunities and training for workers who may become dislocated. If this were not to occur, and there turns out to be considerable displacement, then it could lead to Sterling's "pool of impoverished unemployables."

Another danger is inflated expectations. Fueled by over-energetic salesmen, people may come to believe that technology will solve social, political, economic and even managerial problems. When benefits are not forthcoming, disillusionment may result precluding more appropriate use of the technology. Particularly troublesome are the *hidden costs* of computing, factors often overlooked in implementation that disrupt work settings and produce unanticipated consequences.

Are the changes likely to be radical? Probably not.

Organizations have too much inertia and people have too many habits. If we have learned anything from the studies technological innovation it is that the process determines the outcome. Outcomes are not predetermined, they are the result of a complex interaction of many factors during implementation. The process of applying the technology may produce more lasting changes than the technology itself.

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