instrument, system, or technique is introduced. Because choices tend to become strongly fixed in material equipment, economic investment, and social habit, the original flexibility vanishes for all practical purposes once the initial commitments are made. In that sense technological innovations are similar to legislative acts or political foundings that establish a framework for public order that will endure over many generations. For that reason, the same careful attention one would give to the rules, roles, and relationships of politics must also be given to such things as the building of highways, the creation of television networks, and the tailoring of seemingly insignificant features on new machines. The issues that divide or unite people in society are settled not only in the institutions and practices of politics proper, but also, and less obviously, in tangible arrangements of steel and concrete, wires and transistors, nuts and bolts.

The Social Shaping of Technology

DONALD MACKENZIE

. . . The idea that technological change is just "progress," and that certain technologies triumph simply because they are the best or the most efficient, is still widespread. A weaker but more sophisticated version of technological determinism—the idea that there are "natural trajectories" of technological change—remains popular among economists who study technology.

In my experience, the idea of unilinear progress does not survive serious engagement with the detail of the history of technology. For what is perhaps most striking about that history is its wealth, complexity, and variety. Instead of one predetermined path of advance, there is typically a constant turmoil of concepts, plans, and projects. From that turmoil, order (sometimes) emerges, and its emergence is of course what lends credibility to notions of "progress" or "natural trajectory." With hindsight, the technology that succeeds usually does look like the best or the most natural next step.

However . . . we must always ask "Best for whom?" Different people may see a technology in different ways, attach different meanings to it, want different things from it, assess it differently. Women and men, for example, may view the same artifact quite differently. Workers and their employers may not agree on the desirable features of a production technology.

Such discrepant meanings and interests are often at the heart of what is too readily dismissed as irrational resistance to technological change, such as that of the much-disparaged Luddite machine breakers. We must also ask "Best for whom?" even when we are discussing such apparently "technical" decisions as the best way to automate machine tools or typesetting. These two technologies were the subjects of now-classic studies of Cynthia Cockburn (who focused on the shaping of technology by gender relations) and David Noble (who focused on its shaping of relations of social class). . . .

From Donald MacKenzie, "The Social Shaping of Technology" originally appeared as "Underpinnings" in *Knowing Machines: Essays on Technical Change* (Cambridge, MA: MIT Press, 1996), pp. 5–8.

Nor is this issue—the different meanings of a technology for different "relevant social groups," and the consequently different criteria of what it means for one technology to be better than another—restricted to situations of class conflict or other overt social division. The customers for . . . supercomputers . . . for example, were all members of what one might loosely think of as the "establishment": nuclear weapons laboratories, the code breakers of the National Security Agency, large corporations, elite universities, and weather bureaus. Responding to their needs, but far from subservient, were the developers of supercomputers, most famously Seymour Cray. All were agreed that a supercomputer should be fast, but there were subtle differences among them as to what "fast" meant. As a consequence, the technical history of supercomputing can be seen, in one light, as a negotiation—which is still continuing—of the meaning of speed.

We also need to delve deeper even where there is agreement as to what characteristics make a technology the best. . . . Technologies, as Brian Arthur and Paul David point out, typically manifest increasing returns to adoption. The more they are adopted, the more experience is gained in their use, the more research and development effort is devoted to them, and the better they become. This effect is particularly dramatic in the case of "network" technologies such as telephones or the worldwide computer network called the Internet, where the utility of the technology to one user depends strongly on how many other users there are. But the effect can be also be found in "stand-alone" technologies. . . .

This means that early adoptions—achieved for whatever reasons—may give a particular technology an overwhelming lead over actual or potential rivals, as that technology enjoys a virtuous circle in which adoptions lead to improvements, which then spawn more adoptions and further improvements, while its rivals stagnate. Technologies, in other words, may be best because they have triumphed, rather than triumphing because they are best.

Hindsight often makes it appear that the successful technology is simply intrinsically superior, but hindsight—here and elsewhere—can be a misleading form of vision. Historians and sociologists of technology would do well to avoid explaining the success of a technology by its assumed intrinsic technical superiority to its rivals. Instead, they should seek, even-handedly, to understand how its actual superiority came into being, while suspending judgment as to whether it is intrinsic. . . .

. . . [E]xpectations about the future are often integral to technological success or failure. Most obviously, a belief in the future success of a technology can be a vital component of that success, because it encourages inventors to focus their efforts on the technology, investors to invest in it, and users to adopt it. These outcomes, if they then bear fruit, can reinforce the original belief by providing evidence for its correctness.

Self-validating belief—"self-fulfilling prophecy"—has sometimes been regarded by social scientists as pathological, as permitting false beliefs to become true. The classic example is the way an initially arbitrary belief in the unsoundness of a particular bank can produce a run on that bank and thus cause it to fail. Nevertheless, self-referential, self-reinforcing belief is pervasive in social life, as Barry Barnes has argued eloquently. The most obvious case is money, which can function as a medium of exchange only when enough people believe it will continue to do so; but all social institutions arguably have something of the character of the self-fulfilling prophecy. Some of the most striking phenomena of technological change are of this kind. One example . . . is "Moore's Law": the annual doubling of the number of components on state-of-the-art microchips. Moore's Law is not merely an after-the-fact empirical description of processes of change in microelectronics; it is a belief that has become self-fulfilling by guiding the technological and investment decisions of those involved.

Of course, I would not suggest that self-reinforcing belief is all there is to phenomena such as Moore's Law. Expectations, however widespread, can be dashed as technologies encounter the obduracy of both the physical and the social world. As a result, many technological prophecies fail to be self-validating—for example, the prophecy, widespread in the 1960s, that the speed of airliners would continue to increase, as it had in previous decades. In recent years even Moore's Law seems to have lost some of its apparently inexorable certainty, although belief in it is still a factor in the justification of the enormous capital expenditures (of the order of $1 billion for each of the world's twenty state-of-the-art chip fabrication facilities) needed to keep component density growing. . . .

Problems with "Skill"

NINA LERMAN

Machines and tools have been described, discussed, and classified, and the processes of their invention and manufacture carefully examined. By contrast, the words for the human side of technological activity—skill, know-how, technical knowledge, technological knowledge—evoke a range of associations, but offer little of the precision and subtlety applied to investigations of hardware. The term "skill," a favorite of labor historians and historians of technology alike, implies a coarse skilled/unskilled dichotomy, which is occasionally expanded, but hardly refined, by the problematic term "semi-skilled." Using these terms is comparable to describing "sophisticated" as opposed to "unsophisticated" or "semi-sophisticated" hardware. In addition to the coarseness of the classification, "unskilled" often connotes low "intelligence," ambition, or social status, which silently superimposes other hierarchies, clouding the issues at hand. "Know-how" is useful for its simplicity, but its ingenious mechanical connotations make it an unlikely description of either knitting or nuclear engineering.

Using the term "knowledge," on the other hand, elevates all interactions with hardware, from churning butter to building locomotives, into the realm of other cognitive activities. The choice of adjective, at this stage, seems largely arbitrary, but recent authors have used "technical" to apply to the more elite or "cutting edge" domains of science, medicine, and new technologies. In general, "technological knowledge," when broadly defined parallel to current usage of "technology," is—at least connotationally—more inclusive. Such a term also provides an effective means of shedding old assumptions; for example, labor historians have not written about the unionization of

From Nina Lerman, "The Problem with 'Skill,'" in "From 'Useful Knowledge' to 'Habits of Industry': Gender, Race, and Class in Nineteenth-Century Technical Education" (unpublished Ph.D. dissertation, University of Pennsylvania, 1993), pp. 3–7.