THE ETERNAL AND THE EPHEMERAL: BRIDGES, DISPOSABLE DIAPERS, AND THE LIMITS OF TECHNOLOGICAL CHANGE

Benjamin Sims
Systems Ethnography and Qualitative Modeling Team
Statistical Sciences Group
Los Alamos National Laboratory
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This paper examines two sociotechnical systems that are centered around two very different kinds of technological artifacts: bridges and disposable diapers.

I use these examples to explore a topic which has been a long-standing interest of mine, which is how to reconcile a social constructivist view of technological innovation with ideas about technological determinism.

Partisans of both these perspectives often paint them as mutually exclusive, but I have the sense that this is really not the case. This has in part been influenced by my experience as a sociologist, working with engineers and designers who seem to experience technology more in terms of the constraints it imposes than as an infinitely flexible creative medium.

I think the comparison I present here is very suggestive about some of the constraints that may frequently limit the direction of technological change. I should say, at this point, I don't regard what I'm about to say as an airtight argument, but rather a somewhat provisional attempt to work through some of the ideas this comparison brings up – so I welcome any input.

Much recent social constructivist work on technological change emphasizes the invention of new technological artifacts and the radical sense of "interpretative flexibility" that such invention can entail.[1]

Concepts like "technological frame" have been introduced to describe how technologies, and our interpretations of them, are stabilized within a broader technological and cultural context.[2] These concepts have helped put theories of technological change on a sound sociological footing, in my opinion.

Arriving at a technological frame is not the end of innovation. Most technological change occurs through the gradual evolution of technology within a frame, rather than through ground-breaking invention.

Looking at this aspect of technological change is useful because it focuses our attention on what design and innovation look like in an environment of constraint, when many paths of change have already been closed off.

This shows that a social constructivist approach to technological change need not lead to a view of technology as being particularly flexible in response to our varying interpretations of it. I argue that this leaves room for a constructivist account of technological determinism, at least the "soft" kind of technological determinism that says that technology tends to evolve along certain paths regardless of our immediate social needs.[3]

However, it is a combination of institutionalized social, economic, and technical constraints that directs technological change along these paths – not some determinism inherent to technological artifacts themselves, as stronger forms of technological determinism assume. This paper is a preliminary assessment of some typical forms these constraints might take.

I will use two cases I have encountered in my work, which happen to deal with two very divergent technologies: bridges and disposable diapers.

Despite the best efforts of some very good researchers, both civil infrastructure and domestic technology are still not always part of mainstream discussions in our field about the nature of technology and technological change.[4]

On bridges, I talk from my thesis research on "seismic retrofit" of freeway bridges in California.[5] On disposable diapers, I draw on my recent work consulting with a major consumer products company on managing risk in diaper design changes.[6]

It is not difficult to come up with a long list of differences between these two technologies: bridges are as permanent as technological artifacts get; disposable diapers are made to be thrown away after a few hours' use. Bridges are industrial forms for conveying cars, trains, etc.; diapers are regarded as domestic things for moms and babies to use. Bridges tend to be unique artifacts, designed and then built once; one diaper design is mass-produced by the millions. Bridges are public works projects, usually financed by taxpayers; diapers are made by consumer products companies for sale in an intensely competitive marketplace.

So it's interesting that it turns out that the constraints on technological change in the transportation infrastructure and in the baby products arena turn out to center on some common themes.

In particular, both bridge and diaper designers face the following constraints: First, they are constrained by the *systems characteristics* of the technologies they are involved with. Second, they are constrained by the *local embedding* of system elements. Third, they are constrained by the persistence of *existing technological artifacts* that can't easily be replaced.[7]

Bridges

First, bridges. Bridge design is a field of civil engineering. Civil engineers also design things like roads, airports, sewers, tunnels, dams, etc. I group these under the rubric of “massive infrastructure.”

Massive infrastructure has three characteristics that match up with the design constraints mentioned above. First, infrastructure in general takes the form of large technological systems that enable a wide range of activities; no one bridge or road can be considered as an isolated artifact. Changes in any one element of the system must take its impact on the rest of the system into account.

Second, compared to telecommunications infrastructure, for example, this kind of infrastructure is *locally* massive. As a result, civil engineering projects must take account of local natural, technological, and social circumstances in a particularly direct way. There are a lot of local interfaces involved: a bridge must be supported by the soil or rock underneath it, it intersects locally with other infrastructure, and it is deeply implicated in local political and community interactions.

Finally, because civil infrastructure is so massive, it is expensive and difficult to build, and to modify once it is in place. As a result, it persists even as engineering practice changes.

The case of seismic retrofit in California provides some good examples of these constraints. In the 1990s, with the help of a couple of earthquakes, California came to realize that many of the existing freeway bridges in the state, large and small, were not up to current seismic engineering standards. So engineers at the California Department of Transportation carried out an ambitious project to “retrofit” all of their bridges to meet current standards.

[PICTURE OF RETROFIT]

Systems characteristics: Here, the retrofit case doesn’t add much to what I’ve said about civil engineering in general. However, the idea of retrofit implies a willingness to change an individual artifact only to the extent that it does not change the overall structure of the system.

Local embedding: Bridges become part of the local landscape. Because they are seen as permanent structures, bridges are often put into service to carry other local infrastructure: water lines, communications, lighting, etc. Any effort to replace or fix a bridge must take these local intersections of infrastructure into account.

Bridges also become part of the local social landscape in a number of ways. They become part of the fabric of people’s daily lives, particularly for commuting; after it has been in use for a while, taking a bridge out of service or changing its configuration can have a major impact on community routines and connections.

Bridges can become socially embedded in more dramatically cultural ways as well. Efforts to retrofit the Golden Gate and Bay Bridges in San Francisco had to consider the symbolic and aesthetic value people attached to these structures. The San Diego-Coronado Bay Bridge is another example, where irreplaceable community murals were painted on the bridge columns in “Chicano Park.”

Making decisions about changing or replacing these symbolically-loaded structures required a great deal of political effort and interaction with the community, as well as the development of clever engineering solutions.

Existing technological artifacts: The concept of retrofit itself speaks to the difficulty of dealing with old technology in civil engineering. Engineering knowledge had changed to the point where older freeway bridges were no longer considered adequately designed.

Yes, it would theoretically have been possible to simply tear down and replace all the bridges in the freeway system, but the potential cost, in terms of taxpayer dollars, was understood to be politically unacceptable. So bridges were renovated in place instead.

Retrofit design is harder than the design of new bridges, because existing structures have had a life independent of designers for some time, and have been modified in various ways. Engineers may have to go look at a bridge in the field to devise a workable retrofit strategy. In some cases, it was only after retrofit work began that engineers would discover that, for example, the bridge had already had some seismic improvements installed. Retrofit engineers were acutely aware of working in a very constrained design environment.

Disposable Diapers

It might not seem like a simple disposable diaper could be entangled in these kinds of constraints. But it can be misleading to look at an artifact in isolation. Indeed, from a design standpoint, diapers are not treated as individual artifacts. Instead, they comprise a complex technological system; design efforts are oriented toward the system rather than the artifact alone. Diaper design isn’t the exclusive domain of engineers; it is done by multi-disciplinary teams.

Systems characteristics: First, Diapers aren’t completely trivial systems, even in isolation; those of you who have not recently taken care of children may not realize what high-tech marvels they have become.

[HAND OUT DIAPERS]

They are composed of dozens of different parts and layers.

Second, diaper companies don't make a single kind of diapers, but rather a line of many different diaper models. Diapers typically come in at least 5 sizes; different sizes of diapers may have slightly different designs. There are relatively expensive "premium" diapers that are softer, have more stretch, etc, as well as cheaper basic models; there are diapers with fasteners and diapers for toddlers that are meant to be pulled on.

Ideally, you wouldn't, for example, change the fastening system on one model only – instead, you would work through the whole line to see what fastening system works best and provides the best return on investment overall.

Third, designing a new diaper is not just about the diaper itself, it is about designing a production system that will produce the design reliably and cost-effectively.

Local embedding: Diapers are a global business, and most diapers are made by large multinational companies.

On the consumer side, there are a lot of cultural variables to worry about. (How customers in different parts of the world incorporate diapers into their ways of life.)

There are different expectations about how often diapers are changed, the position they are changed in, how much area they should cover to be comfortable, and what kind of graphics are appropriate for baby products. There are differences in the average size of babies. There are vast differences in what people can afford and to what extent diapers are even culturally acceptable in different areas.

This poses a challenge for designers, because a design element that is improved from the perspective of the U.S. market, for example, may be culturally problematic in Europe or Brazil.

On the production side, diapers are locally embedded as well. Factories in different regions have different labor costs, different materials costs and availability, different available equipment, different work practices, work under different currencies.

A design feature that is easy to produce in one region might be impossible to produce in another. If you are a multinational corporation, it is possible to shift different production steps around to different suppliers across the globe, but even doing this requires in-depth knowledge of local circumstances. Taking all these local meanings and circumstances into account is a major constraint on design.

Existing technological artifacts: This is primarily an issue on the production side. Diapers, though relatively flimsy and disposable, are made on large, complex, expensive production lines. These aren't nearly as expensive as a bridge, and in fact are routinely replaced.

But the diaper market is much more competitive and operates on a much faster business cycle than the bridge market (if there is such a thing). As a result, change is much more rapid, and existing production equipment cannot be replaced as quickly as a designer might like.

The business must constantly strike a balance between the cost of replacing equipment and the cost of falling behind competitors technologically. This often generates a pattern of significant innovation followed by incremental improvement over a number of years. This balancing of the new against the old is a constant concern in the design of new diapers.

Conclusion

Trying to understand the results of these common constraints -

In both cases I have discussed, the result of these constraints is a bias toward innovation at the component rather than system level. Diapers are systems composed of many different components, and what these components are and how they are put together do change sometimes.

But most R&D seems to be focused on identifying new materials that are stretchier, feel softer, look better, stick more reliably, etc. Over the last 20 years or so, these kinds of improvements have radically changed the way disposable diapers look and feel, but the basic design concept of disposable diapers has arguably not changed much during that time.

Although the design of diapers is increasingly technically sophisticated, change in the design of bridges is driven much more directly by a body of abstract academic knowledge that is continually evolving.

Over time, this changing knowledge has been used to create radically new bridge designs. But these radical new designs appear only rarely, in certain high-profile projects. In general, the pressure on designers is to produce new bridges or retrofit old ones within the norms of the existing transportation system.

The typical reinforced concrete freeway bridge will be with us a long time, even if some are retrofitted or replaced. Even more certainly, the general concept and layout of the freeway system will remain largely unchanged, even as engineers devote their energy to adding or replacing components of the system.

Studies of invention provide a useful point of reference for how flexible technology can be and how readily it can respond to our needs and interpretations, under the right circumstances. This makes it all the more interesting that many engineers and technologists (such as the ones whose work I describe here) seem to experience their work more as a process of satisfying competing constraints than an open-ended creative process. Here, I have identified some reasons for this that seem to be applicable in two dissimilar cases. These seem to have the potential for further generalization, but that is a subject for discussion and future research.

Author’s contact information:

Benjamin Sims
D-1, Statistical Science Group
Los Alamos National Laboratory
MS F600
Los Alamos, NM 87545

bsims@lanl.gov
(505) 667-5508

Notes

[1] Here, I refer mainly to work like Pinch and Bijker 1987, Bijker 1995, Kline and Pinch 1996, and MacKenzie 1990.
[2] This concept is articulated in Bijker 1995. Similar ideas are discussed in MacKenzie 1990 under the rubric of institutionalization.
[3] On definitions of technological determinism, see Bimber 1994, MacKenzie and Wajcman 1985, and Winner 1977. “Hard” forms of technological determinism emphasize that technological change is driven almost entirely by internal technical imperatives, and that it has a profound and essentially one-way influence on social change. What I have in mind here is closer to certain theories of “autonomous technology” discussed by Winner.
[4] For an overview and assessment of the place of domestic technology in the sociology of technology, see Cockburn 1997.
[5] Sims 1999, 2000. See also Suchman 2000.
[6] On the history, technology, and social impact of disposable diapers, see Gladwell 2001.
[7] For a systems perspective on technological change see, e.g., Hughes 1987. On working with old infrastructure, see Brand 1994.

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