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Organizing Alignment: A Case of Bridge-building

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Abstract. *The project of building a bridge is a canonical example of what John Law (1987) has termed 'heterogeneous engineering', involving the arrangement of human and nonhuman elements into a stable artifact. This paper reports ethnographic research on the work of civil engineers engaged in designing a bridge scheduled for completion by the year 2004. My emphasis is on a view of bridge-building as persuasive performances that both rely upon and reflexively constitute the elements to be aligned. The work of designing a bridge, on this view, is as much a matter of story-telling as of analysis, calculation, and work with concrete and steel.* ***Key words:*** *heterogeneous engineering; ordering; organizational ethnography; performance; planning*

> 'Each one of us is an *arrangement*. That arrangement is more or less fragile. There are ordering processes which keep (or fail to keep) that arrangement on the road. And some of those processes, though precious few, are partially under our control some of the time'. (John Law, 1994: 33)
> '... planners (and others engaged in planning) should think of themselves as characters in a larger story that they are helping to construct, and ... they should strive to act in a manner that is consistent with the characters invoked by their story. Planning is persuasive storytelling about the future, and competing stories abound'. (James Throgmorton, 1996: 52)

This article is meant as a contribution to the development of ethnographically based, practice-oriented approaches to the study of organizational

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knowing and acting.[1] That involves, among other things, heeding the call for a shift from a focus on the universal, the general, and the timeless to an interest in the local, the particular, and the timely (Toulmin, 1990: 186). Taking the work of civil engineering done within a large state agency as a case in point, my starting place is a view of engineering as knowing and acting from particular positionings at particular times, within a network of relations that must be simultaneously elaborated and contained. If building stable artifacts involves the accomplishment of alignments across heterogeneous human and nonhuman elements, my emphasis here is on the work of bridge-building as persuasive performances that both rely upon and reflexively constitute the elements to be aligned.

Knowledge and Action Respecified

Recent practice-based theorizing includes a reconceptualization of knowledge and action as located in 'ecologies' of social–material relations (Fujimura, 1996; Star, 1995). These relations are not given by nature, but are the product of ongoing practices of what John Law has termed 'heterogeneous engineering' (Law, 1987, 1994; see also Suchman and Trigg, 1993). Both 'ecologies' and 'engineering' in this context are meant to break down received oppositions of nature and society on the one hand, society and technology on the other, drawing attention instead to the diverse discursive and material, human and artifactual elements that must be assembled together in the construction of stable organizations and artifacts. The intellectual traditions that underwrite these reconceptualizations (e.g. symbolic interactionism, actor-network theory, cultural anthropology, ethnomethodology) view knowing and acting as always and necessarily embodied, and therefore as located in particular, historically and culturally constituted settings. The generality of knowledges, in this view, comes not from their contextual disembedding but from the extent and stability of relevant social–material relations.

My own approach to the topic of organizational knowing and acting is most deeply influenced by the alternate sociology developed by Harold Garfinkel and his colleagues, named ethnomethodology (Garfinkel, 1996). Michael Lynch characterizes a contribution of ethnomethodology as 'respecifying the central topics in epistemology by identifying them as commonplace discursive and practical activities' (1993: 5, n. 9). Consistent with that project, the focus in the present study is less on what engineers 'know' than on how they talk among themselves and with relevant others, how they translate their own embodied courses of action into written accounts and other materializations, and how they assess the meaning and adequacy of materials created by others (see also Lynch, 1992: 232, f.n. 1). At issue here is not knowledge as a self-standing body of propositions, but identities and modes of action established through ongoing, specifically situated moments of lived work, located in and

accountable to particular historical, discursive and material circumstances.

Within organizational settings there is an intimate relation between forms of discursive and material practice, and action's rational accountability. Learning how to be a competent organization member involves learning how to translate one's experience, through acknowledged forms of speaking, writing and other productions, as observably intelligible and rational organizational action (see also Gherardi, 1998: 376; Gherardi et al., 1998: 274). Demonstrations of competence are inseparable, in this sense, from artful compliance with various professional and technological disciplines, reflexively constituted through those same demonstrations. At the same time, artful compliance necessarily involves endless small forms of practical 'subversion', taken up in the name of getting the work of the organization done.

Modes of Sociotechnical Ordering

In *Organizing Modernity,* John Law writes of relations between social order and modes of ordering:

> Perhaps there is ordering, but there is certainly no order. This is because ... orders are never complete. Instead they are more or less precarious and partial accomplishments that may be overturned. They are, in short, better seen as verbs rather than nouns. (1994: 1)

If we take the liberty of substituting 'knowing', 'acting', or 'organizing' and their nominal equivalents for 'ordering' and 'order', I believe that this passage reads equally well. An organization, on this view, is made up of multiple occasions and multiple forms of ordering. What Law terms modes of ordering are 'contingent but not idiosyncratic' patternings that we can impute to social/material networks that support comparisons across them (1994: 95). The focus is on organizations as ongoing performances involving heterogeneous modes of action and materialization, both of which must be actively affiliated and aligned across a range of often unruly contingencies.

Law's 'relational materialism' takes materials as central to social ordering. At the same time, materials are not given in the natural order of things but are themselves products or effects generated reflexively in and through networks. That is, materials are not simply more and less durable in themselves, but rather some network configurations generate effects that last longer (through their faithful and onoing reproduction) than others. Somewhat paradoxically, power and size on this view are achieved in part through deletions. So, for example, the translation of a 'large organization' involves, among other things and for that moment, deletion of many, partial, fragmented, local and contingent orderings. Similarly, in the case considered here, the creation of 'a bridge' involves the translation of a painstaking arrangement of myriad human and nonhuman elements as a single engineering artifact.

Modes of organizational ordering include the generation of particular places in which monitoring, reflection, and decision-making are said to take place. Wherever they occur, organizational decisions are made through the assembly of what Law calls 'docile and tractable materials':

> These materials *represent* all sorts of events spread out through time and space. They *juxtapose* what would otherwise have been separate. They *summarize* what might have been said in a great many words or figures. And they *homogenize* what would otherwise have been performed and embodied in a variety of different materials and a range of modes of expression. These are the materials . . . [t]hat produce organization. (p. 158, author's original emphasis)

These ordering materializations are central to organizational knowing and action. At the same time they are also organizationally accountable:

> [Organization members] don't just select between the myriad bits and pieces that happen to be lying around and shake them up together in a bag to form a picture. Neither do they invent such bits and pieces, *de novo*. Instead, the components of the picture are *built up.* With difficulty. Often painfully. On the basis of what is already being performed out there. (p. 155, author's original emphasis)

Given this view of organizing, organizational ethnography constitutes a kind of second-order accounting made up of the juxtaposition and alignment of organization members' stories with those drawn from, and accountable to, the ethnographers' own. What Law terms 'modest sociologies' are characterized by an incompleteness without any promise of remedy by further analysis, however much might be added. This is not to deny that our studies can be deepened and extended: on the contrary, it is to assume that they *always* can be. But, just as organizations are open-ended performances, deepening and extending an analysis is not to be mistaken for completing it.

Building a Bridge as Processes of Sociotechnical Ordering

Bridge-building is a canonical example of heterogeneous engineering.[2] For the past two years, I and my colleagues have been engaged in ethnographic research on the design of a bridge scheduled for completion by the year 2004.[3] Bridges are designed rarely in comparison with roadways and other surface structures, being costly projects that once built last from at least 30 to in some cases hundreds of years. In the area where our project is located, six toll bridges have been built and no new bridges are planned. At the same time, the area is threatened with earthquakes. In response to the critical problems experienced in the last major earthquake, the state government has set aside substantial funds for 'seismic retrofitting' of existing toll bridges (see also Sims, 1999).

One of the area's toll bridges is actually a pair of old trestle bridges that connect the north and south shores of a relatively narrow strait. Charged with ensuring the safety of these bridges, engineers at the State

Department of Transportation (called here 'The Department') have argued that, while one of the bridges can indeed be retrofitted, the other is sufficiently old—dating from 1927—that it is both unsafe and uneconomical to try to reinforce it. Instead, they have proposed 'replacement as a retrofit strategy'. In this way, they propose to direct funds for retrofitting to a new bridge-building project.

At the same time, it is a bit misleading to say that the engineers are engaged in designing a bridge if what we imagine by that is the design of the structure itself. In this case, the bridge design as such is outsourced to a specialist design firm, with Department engineers responsible for oversight. But it also turns out that the bridge itself represents a small fraction of the entire project relative to the highway approaches and interchanges that tie the bridge into the landmasses that it connects. And, while the design of the bridge structure is contracted out, Department engineers maintain responsibility for the bridge alignments (that is, for deciding just where the bridge will be located and anchored) and for the design of all connecting roadways. Moreover, it is here that many of the complexities of civil engineering work actually lie.

I have looked elsewhere at the work of engineering design as a technical practice involving writing and reading within the electronic spaces of computer-aided design (CAD) technologies and across a variety of paper-based documents (Suchman, 1999). These practices of design—what engineers themselves consider to be identifying of their work—are in turn embedded in an extended network of organizational activities of sense-making, persuasion and accountability. My focus here will be on these latter activities, considered by engineers themselves to be somewhat peripheral, but also clearly essential, to the 'real' work of design. These activities provided the object of the first approximately 18 months of our study, insofar as the object of the engineering work during that time was the production of a document, the Environmental Impact Statement (EIS), legally prerequisite to moving forward on design and construction of the bridge itself.

Along with the eventual arrangement of materials into the structure of a bridge, historian of engineering Henry Petroski points to the critical place of documents like the EIS in modern engineering practice:

> In the association [in the mid-19th century] of bridge building with drawing and calculation and written argument before any construction was started, a new era was begun. From then on, the grandest dreams could be articulated and tested on paper, and thereby communicated to those who would have to approve, support, finance, and assist in designing a project that could eventually take years, if not decades, of planning and construction . . . (1995, p. 12)

I want to look here at the production of the EIS itself as a process of sociotechnical ordering. As described by the Project Manager:

> The EIS involves a document, and a process, that is described by federal regulation as a tool for decision-making. Through the Environmental process we

> can compare the benefit and disadvantages of the project alternatives. (Video prepared for Public Hearing, 27 February 1997)

The assumed efficacy of techniques and technologies of ordering seems a foundational premise for very large projects like bridge-building. As an observer, one is constantly struck by the thought 'This is simply too complicated logistically, technically and politically; too hard; too much work; too unstable, etc.'. But one is equally struck by the recognition that such thoughts are simply not options (or at least not options very often) for practitioners committed to the project. The question then becomes how, as a practical matter (rather than only as a matter of faith, although I think it must remain that as well) do they do it?

(Re)producing a Stable Alignment of Elements

I have suggested above that, like an organization, a bridge can be viewed as an arrangement of more and less effectively stabilized material and social relations. Most obviously, of course, the stability of a bridge is a matter of its materiality, based in principles and practices of structural engineering. This material stability is inseparable, however, from the networks of social practice—of design, construction, maintenance and use—that must be put into place and maintained in order to make a bridge-building project possible, and to sustain the resulting artifact over time.

Highway projects, of which bridge projects are a part,[4] impinge on multiple locales, each with its own constituency of interested actors. Counties, cities, rights-of-way, environmentally protected areas come along with local politicians, citizens' groups, private property owners, and public interest agencies. Public funding means that each of these constituencies claims some legitimate voice. Project members routinely deal with what Callon (1991) has termed 'punctualised' organizational actors (see Table 1). These actors appear, however, always specifically; in the form of a letter, a mayor, a local politician, an irate citizen. So they are at once generalized *and* specific others to be dealt with. A county supervisor campaigning on the issue of public transportation, a militant group of hikers and cyclists, a new endangered species listed, a new clean air act can each send the Department back to the drawing board of redesign and renegotiation.

Human and nonhuman actors pose multiple, often conflicting demands. The Delta smelt, for example, is a small fish, a protected species whose habitat would be disrupted by the Department's proposed construction plans. Assigned as spokesperson for the smelt, the Fish and Wildlife agency requires the Department to 'mitigate' the disruption of habitat by creating comparable wetlands at another location. This leads in turn to extended negotiations with various regional and local agencies and property-owners in the search for an alternate locale. The location

Table 1: Partial Enumeration of Relevant Actors

Federal/State agencies	County/region	City	Department	Other
Federal Highway Administration (FHWA)	Two county Board of Supervisors	Two cities on north and south shores	Department Headquarters	Delta smelt
Governor	Conservation and Development Committee	Southtown Improvement Association	District	Harvest mouse
State Transport Improvement Program (TIP)	Metropolitan Transportation Committee (MTC)	Mayor of Northtown	Toll bridges	Hazardous waste
Environmental Impact Statement (EIS)	Regional Transportation Plan (RTP)	Home-owners	Structures	C&H Sugar
Federal Emergency Management Agency (FEMA)			Design	Railroad
State Historic Preservation Office (SHPO)			Bridge Replacement Project	Rights-of-way
Fish and Wildlife				Utilities
Coast Guard				
Army Corps				

identified for mitigation on further investigation turns out to be home to another privileged nonhuman, the Harvest mouse, which at present ranges freely over a salt marsh that under the mitigation plan would be turned to wetlands through the construction of sloughs. This play of interests and constraints is replicated across a myriad of actors.

Alignment Work as Persuasive Storytelling

To see more specifically just what is involved in aligning human and nonhuman actors, we can take up the problem of selecting a 'preferred alternative' among various possible design options. While the phrase 'preferred alternative' evokes an individual–rational process of human choice among a set of logical possibilities, closer inspection reveals multiple actors and preferences, defined in relation to a set of possibilities delineated within the professional community of civil engineering and by the practicalities of this particular project. The problem from the point of

view of project members becomes less how to select an alternative, than how to delimit a field of alternatives and to organize their effective presentation to relevant others.

In the summer of 1996, four alternative bridge types were being presented to the public as options: truss, suspension, cable-stayed, and steel-arched designs. A consulting firm was engaged by the Department to study each of the four options and to make a recommendation to the District Structures department, which would in turn provide a recommendation to the Project Manager.[5] She would then take the recommendation to District Management, who would in turn pass it along for final decision by the Department Director. The Project Manager pointed out to the team, however, that the Director himself was not likely to have a strong opinion on the matter. The latter was more likely to come within the local District. It was District Management who would need to be persuaded, in other words, of whatever the team believed to be the best option.

Basic considerations from an engineering standpoint centered on the constructability of the bridge, and its ongoing maintenance requirements. As of the summer, the Senior Engineer on the project reported that, while he tended to prefer the arch design, his mind changed from week to week. The arch seemed to him more 'muscular', more 'stocky', and was also the quickest structure to build. On the other hand, arch bridges were also reputed to be very tricky to put in place, in particular during the 'raising', a critical and vulnerable time during which the bridge is minimally anchored and highly susceptible to winds. On this basis, the District Structures engineer expected the recommendation on constructability to be for a suspension bridge, a well-established and reliable bridge type from a construction point of view.

I am interested in viewing the choice of a 'preferred alternative' less as a decision than as an effect of enormous work on the part of Department engineers, 'more or less successfully hidden behind an appearance of ordered simplicity' (Law, 1994: 5). The ordering work in this case includes most obviously production of the Environmental Impact Statement with its drawings, analyses, tables, conclusions and recommendations. But it includes as well a series of related performances by Department engineers, supported by various human and material allies.
Engineering projects are divided into three 'phases', named Project Approval (centered on approval of the EIS), Design, and Construction. Project engineers during the approval phase of a project face encounters with a diverse range of other actors. These encounters take them across the boundaries of 'normal discourse' within their own professional community, on to the terrain of other more and less powerful rhetorics (see Throgmorton, 1996). Along with the design of plans, engineers are frequently engaged during this phase with the creation of what they term 'artwork'; that is, renderings of proposed highway and bridge designs created not as instructions for building but as illustrations.

Urban planner James Throgmorton has argued for a view of planning as 'persuasive and constitutive storytelling about the future' (1996: 5). He suggests that an extended process of organizing like that involved in bridge construction involves participants in living within and through stories told among themselves and to relevant others (p. 2). The point is not that engineers simply 'make up' these stories, but rather that they are authors, who actively construct views of future events for others (p. 266). In this sense, Throgmorton urges us to abandon either the modernist ideal of planning as a neutral and objective search for universal truths, or the contrasting allocation of planning to the realm of 'politics run amok'. Instead, he suggests, we should 'embrace the idea that planning is scientific *and* political, technical *and* persuasive, and that the "tools" planners use act as tropes (persuasive figures of speech and argument) in the planning stories that they tell' (p. 5, author's original emphasis).

Public Persuasions

A critical constituency for the Project Team comprised the citizens living in two towns located on each side of the bridge. Federal law requires that a draft version of the Environmental Impact Statement be made available for public comment, and that any comments in turn be responded to in the Statement's final version. This extension of the actor network to include public commentary is contained through the designation of a 60-day public comment 'period'. As described by the Project Manager:

> Following the close of the public comment period, [the Department] and the Federal Highway Administration will evaluate all of the information compiled for all of the alternatives, consider all of the comments received, and identify the preferred alternative. (Video prepared for Public Hearing, 27 February 1997)

To meet this requirement, a series of meetings was held during the approval phase of the project at central locations in each of the two affected towns. At these meetings, residents were presented with a (somewhat overwhelming) set of informational displays about critical aspects of the project as the Department defined them, including Noise and Air Quality, Right of Way, Traffic, and the various Bridge Alternatives. Attendees were invited to visit the displays, each of which was staffed by relevant representatives from the Department. The meetings were facilitated by a consulting public relations firm, specializing in community involvement.[6] After a half hour or so of browsing among the displays, the meetings were called to order and the agenda described. The Project Manager then gave an overview of the project, and the Senior Engineer described the various bridge replacement alternatives. The audience was then allowed to ask questions, which were fielded by the Department member with the most expertise in the area. Finally, participants were invited to visit the displays for as long as they liked, and to pose more questions to Department staff.

The bridge alternatives were presented to the public in the form of 'visual simulations', assembled photomontages that placed computer-generated images of the various bridge alternatives against a photographic image of the surrounding environment. Each bridge alternative was shown from three points of view: a 'community' viewpoint (i.e. how the bridge would appear from a known location on the shoreline), an aerial view and a 'motorists' ' view. In addition, a scale model was commissioned from a consulting firm in Chicago for use at the public meetings to help visualize the project plans.

Having taken pains to present all of the options to the local citizenry, the problem for the Department subsequently became how to get those that they considered least workable or desirable *off* the table. While a matrix of logical alternatives is one way of making a problem manageable, the apparent comparability of the options belies the fact that from the Department's point of view some are more sensible than others. Most obviously, one of the options considered and rejected by the Department was the so-called 'no-build' option, which would have retrofitted the existing 1927 bridge rather than building a new one. This option had been rejected at the time that we began our project in the summer of 1996, but as of September of that year the citizens of the two adjoining towns were still interested in the question of whether the 1927 bridge might be retrofit instead of replaced. One particularly active member of the local Town Improvement Association stated that 'the focus of this project is too narrow', in that the 'no-build' option appeared already to have been ruled out. The option favored by the Improvement Association as well as other local citizens who turned out for a series of community meetings held in the Fall of 1996 was to retrofit the old bridge to last until around the year 2010 when, they argued, the area's rapid transit system would be ready to reach as far north as the straits. At that time, the Department should build a single new bridge with four lanes of traffic in each direction and room for public transit. The response from the Department to this proposal was facts and figures regarding the state of the 1927 bridge, the costs of retrofitting it, the limits to the level of safety that could ever be achieved, and the impracticality in terms of cost and disruption of replacing both existing bridges with a single new bridge. Among those local citizens who accepted the need for replacement, many still favored the 'truss' bridge type, basically replicating the existing bridge and its 1958 companion. There again, the Department responded with an accounting of the prohibitive costs of maintenance of that particular bridge type.

At a public meeting in December of 1996, all four bridge types were shown but it was explained that the arches and truss options had been discounted, the former because of high construction costs, the latter high maintenance costs.[7] Of the two remaining options, the cable-stayed would be cheaper to build, but would require a center pier, potentially obstructing the shipping channel, where the suspension option would not. But the citizens remained concerned primarily about the aesthetics

of two non-matching bridges placed side-by-side across the straits. Why, they asked, keep the 1958 steel truss bridge if its maintenance costs were so high? Why not build two new bridges, or one larger one? The Department member speaking for Structures explained that despite their similar appearances there were actually differences in construction between the two existing bridges that meant greater maintenance costs for the older one. Nonetheless, the discussion led to one member of the audience asking 'Are you really taking our input?'. To this the public relations consultant replied that in fact citizen opinions were mixed (more so, presumably, than they appeared at the meeting), that all the alternatives would be included in the Environmental Impact Statement, that citizens' opinions would be recorded and weighed against costs, opinions of various policy makers, and so forth.

In February of 1997 a Public Hearing was held, as part of the Department's solicitation of public comments on the EIS. In a videotape prepared for the hearing, five design options were described by the Department:

- no-build option;
- retrofit and rehabilitation;
- replacement on a western alignment;
- replacement on an eastern alignment;
- replacement on a center alignment.

The Senior Engineer explained how this field had been delineated as follows:

> Five principal alternatives survived preliminary engineering and environmental screening, and were carried forward for the detailed analysis in the Draft EIS. (Video prepared for Public Hearing of 27 February 1997)

Along with these options, the Department was still considering four different bridge types, and several alternative designs for the interchanges on the bridge's south side. Given this already delimited field, an outstanding problem was how to move the 'no-build' and 'retrofit' alternatives, which the project engineers had felt obliged to keep onstage throughout the Environmental process, into the wings. In the videotape, the Senior Engineer explained that the 'No-build' option did not in fact meet the designated purpose of the project; that is, to extend the lifespan of the highway at its crossing over the straits. The 'retrofit and rehabilitation' alternative was described as follows:

> The retrofit alternative would extend the [1927] bridge's useful life by about another 30 years, after which there would be a rapid increase in maintenance needs and costs. Once again the State would face the prospect of another costly retrofit and rehabilitation, or even closure of this structure. (Video prepared for Public Hearing of 27 February 1997)

In contrast, the west bridge alternative was identified as having a projected life of 100 years or more, and as meeting all seismic and traffic

safety standards. It was publically characterized as 'currently [the Department's] most desirable alternative' (video prepared for Public Hearing of 27 February 1997). The east alignment, it was explained, would involve potential displacement of an existing sugar plant, with corresponding costs for acquisition of right-of-way, and would require relocation of the toll plaza on the bridge's north side. The center alignment was characterized as 'particularly challenging from a construction standpoint', as construction on the new bridge would have to be orchestrated in a relatively constrained space between the existing bridges.

The 'preferred alternative' was finally selected by the Department in June of 1997.[8] The decision was made by the Structures division at State headquarters, on advice of specialist consultants hired to assess the cable-stayed and suspension bridge alternatives. The alternative chosen was a suspension bridge. The rationale for choosing the suspension bridge was that it had good seismic responsiveness, no center pier to obstruct shipping in the channel, a well-known construction process and therefore less risk, good aesthetics, and was more environmentally friendly (in part due to the decreased risk of a shipping collision).

Orders of Stabilization

As of December 1996, as far as the Senior Project Engineer was concerned, there were really only two options for the bridge design: either a suspension or cable-stayed bridge type, built on a west alignment. Yet at public hearings in February of 1997 the full range of options was still being presented. Why? This apparent dissimulation was tied in part to the tension between the requirements of project management, on the one hand, and those of public involvement on the other. More specifically, the project was being conducted under a seismic retrofit program that involved an accelerated time schedule for analysis, bidding, design, mitigation, permit acquisition, and other necessary activities. This accelerated schedule conflicted with the prescribed process for public review and commentary. The latter required preparation of the Draft Environmental Impact Statement, a period of public commentary, completion of the Final Statement, and FHWA approval, all in advance of moving forward on design. Yet, in order to meet the accelerated construction schedule, these processes had to be run in parallel.[9] This acceleration, combined with the fact that members of the Project Team were deeply immersed and implicated in the project on a daily basis, meant that they had moved well ahead of the local citizens in their considerations of the space of alternative design options.

My story about selection of the 'preferred alternative' should not be heard as an ideal decision process corrupted, but rather as illustrative of the inevitably hybrid, practical, political, technical, contested, negotiated and situationally specific character of organizing a large modern project. Engineers are at once, albeit differently at different moments, technical

experts, politicians and advocates for a particular point of view (Throgmorton, 1996: 40). In the production of an Environmental Impact Statement, sense-making and persuasion are subtly and inextricably intertwined. Authorship entails both an obligation to make an extremely complex set of considerations comprehensible to the public *and* a great deal of structural and rhetorical power. On the one hand, the report has somehow systematically to present the environmental considerations for a logical space comprising four bridge types, three alternative alignments, and several interchange options. At the same time, at the point that the report is completed the Department has already engaged in extensive activities of sense-making and discussion among themselves, leading them to have effectively discounted a number of the alternatives and to have some favorites, or at least a strong set of considerations and arguments, with respect to those that remain. In presenting the Statement, then, they must adjudicate the requirement for a balanced treatment of the options with an interest in guiding their audiences' attention away from those alternatives that in their view seem unworkable and towards those areas that they see as genuinely open for debate.

This story of bridge-building points as well to the multiplicity of perspectives involved in such large modern projects. A view of artifact construction as heterogeneous engineering emphasizes issues of stabilization of human and nonhuman networks as central. Along with the contingencies of this process as seen from the perspective of engineers, however, one can catch glimpses of other perspectives, collected generally under the heading of 'residents' or 'citizens'. In a real sense there are at least two different artifacts at issue, with associated networks of stabilization, that must somehow be aligned. Project engineers are immersed in a history and daily order of professional practice and practical exigencies. Their orientation is to moving the project forward according to the order of phases and timetables, toward the production of an artifact within budget and with appropriate projections of maintainability and durability. Residents, on the other hand, are working on a different order of stabilization; that of their daily lives. The timeframe of the project to them represents a period of disruptions to be minimized, while the artifact that is the object of that activity is something that they will, quite literally, have to live with long after the project is completed. These two different 'stabilizations'—of artifact, careers, professional networks on the one hand, and of daily life, property, and so forth on the other—comprise different, only partially intersecting fields of knowing and acting.

The problem that the case reveals, then, is twofold. First, engineers face other constituencies, most notably local residents, for whom the bridge represents a substantially different, domestic rather than professional object, and who are oriented along different lines of stabilization (see also Verran, 1998). As Throgmorton points out, while modernist planning assumes a common system of values among affected actors, this is clearly not the case. Traffic flow or neighborhood quiet, access to distant com-

munities or quality of life in local ones—these and a myriad of other issues reveal differences that cannot be resolved through analysis. Second, persuasive resources are unevenly distributed across actor networks. The challenge is how to deal effectively with historically constituted accumulations of discursive power such that, in the case discussed here, engineering discourses speak more loudly than those of citizens. Can those resources be redistributed so as to make the field of discussion and debate a more 'level' one? And, if so, can stabilization still be achieved? The answers to these questions are less a matter of principle than of science *and* politics, technology *and* persuasion.

Conclusion

The construct of *heterogeneous engineering* is meant to underscore the extent to which the work of technology construction is, to a significant degree, also the work of organizing. Particularly in the case of a large modern project like that of bridge-building, an interest in engineering in this sense necessitates building a figurative bridge between the fields of technology and organization studies. While drawing on a somewhat different collection of resources for theorizing than those employed in other contributions to this issue, the analysis offered here shares a commitment to a view of knowing and acting in organizations as always and irremediably a *contingent* process. So, for example, the metaphor of 'organizational learning' as Gherardi defines it:

> . . . stands as a valid alternative to the image of the rational organization, because it depicts an organization grappling not only with trial and error but also with the ambiguity of interpretative processes, of experience, of history, of conflict, and of power. (1998: 374)

Similarly, the emphasis across these perspectives is less on the structures and functions of organizations as represented by organization members or analysts, than on the practical performances through which the work of organizing gets done. Representations of the organization in this view stand not as explanations for organizational action but as products of, and resources for, organization members' own ongoing (re)production and transformation of what it is that the organization comprises or could be. Accounts of the organization in this respect are part of everyday reasoning and acting in organizational life and, as such, are part of our subject matter as researchers (see also Bittner, 1965; Smith, 1994; Weick, 1995).

As a state agency, the Department of Transportation is simultaneously a jurisdictional and a professional bureaucracy (see Gherardi, 1998: 376), charged with developing highways and bridges according to rules of law and of civil engineering. And, indeed, organization members demonstrate a strong orientation both to legal procedures and to conventions of professional engineering practice. They do so, however, not in the mode of simple implementation but of ongoing reconciliation, persuasion,

negotiation, and management of the persistent contradictions and uncertainties endemic to any actual engineering project. The results are arrangements of social and material elements that, aligned well, can be effectively performed as stable artifacts that support the movement of people and goods through time and space. The sustainable reproduction of such enduring alignments, through processes of organizing as much as of construction, is the stuff of which bridges are made.

Notes

1 In contrast to other contributions to this issue that take 'learning' as a central construct and develop its sociality, my own work has been oriented not to questions framed in terms of learning but of socially constituted practice. Nonetheless, I assume learning in the sense developed by Lave and Wenger (1991), Lave (1993), and others taking inspiration from them to be intrinsic to all forms of practice.

2 There is no question that some forms of heterogeneous engineering occur in relation to more established and stable networks than others. Government sponsored bridge-building in this respect offers an interesting contrast to, for example, commercially funded software engineering. For an insightful discussion of the distinctive instabilities of the latter see Newman, 1998.

3 My colleagues in this study were Jeanette Blomberg, David Levy and Randall Trigg, co-members at the time of the Work Practice & Technology research area at Xerox PARC.

4 Like highways, bridge projects are framed in terms of the Department of Transportation's mandate to facilitate traffic flow and the movement of goods.

5 I use 'the Department' here to refer to the State Department of Transportation as an entity. The Department is divided into nine 'Districts', within each of which is a complex ordering of regions and projects. The 'Project' in the context of this paper refers to the particular engineering team assigned to the bridge replacement project studied.

6 The Senior Engineer on the project reported to us before the first such public meeting that they had been coached by the public relations firm to use certain phrases in their interactions with the public. For example, they should say in response to public expressions of anxiety 'We're sensitive to your concerns' rather than (he said jokingly) 'We know the Department is screwing you'. This kind of ironic recognition by the engineering team of the contradictions of their own position with respect to the public was common. The irony should be read less as evidence that the local citizens were being taken advantage of than as the engineers' recognition that the project was being carried out primarily in the interest of other, non-local actors.

7 This account is taken from fieldnotes provided by my colleague, Randy Trigg, who attended the meeting.

8 Here I rely on fieldnotes taken by David Levy from a meeting of 12 June 1997.

9 In fact, early in 1997, the Department had contracted out for design of both the cable-stayed and suspension bridge types in a West alignment. This was well in advance of the final approval of the EIS and the selection of a preferred bridge type. The consultants were told to design both bridges to 35 percent completion or until an option was chosen, whichever came first. This was con-

sidered to be the only way to keep on schedule, given the accelerated time frame.

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