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Surface Dramas, Knowledge Gaps and Interfacing Practices: On the Integrative Promise of Infrastructural Engineering[1]

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Abstract

The basis of this paper is ethnographic research that we conducted with civil engineers engaged in road construction in Peru, who contend with complex social and material environments in the course of their day-to-day work. Engineering is often understood to involve a framing which is rational, abstract and normative, with standardising and homogenising effects; and yet we discovered the inherently pragmatic and flexible nature of engineers' daily practices. Road construction in Peru is explicitly a project with integrative ambitions; the production of enhanced connectivity not limited to linking together places which would otherwise be disconnected, or poorly connected. Large-scale infrastructural projects such as road construction must also ensure sustainability and social acceptance. With the expectation that technical projects should also integrate social concerns, the 'social' appears as that which the technical has failed to carry forward – a relational space that is disengaged and left behind – and in this way expert knowledge practices can produce 'knowledge gaps'. Material and conceptual integration has to be achieved through negotiation and worked out on the ground. When engineering faces problems of dealing with the apparent disjunctures and discontinuities between the worlds of engineering practice and the everyday world of social relations, we found that the metaphor of the interface helps to hold in view the inevitability of internal discontinuity and difference.

Keywords: Civil engineering, road construction, logics of integration, progress narratives, risk society, socio-technical relations

Introduction

This paper addresses the figure of the civil engineer. Drawing on our ethnographic study of road construction in Peru, we explore the skills and knowledges that are fundamental to engineering practice, and which in many ways require the engineer to go beyond what might be considered as the core technical expertise of the profession. Our aim is to elaborate on the possibilities and the limits of technical knowledge and the ways in which such limits are both

[1]An initial version of this paper was presented by Penny Harvey to the Knowledge/Culture/Social Change International Conference, held at the University of Western Sydney in November 2011, and organised by the Institute for Culture and Society. We are especially appreciative of the support and feedback from Tony Bennett and his colleagues, and also to colleagues at the ESRC Centre for Research on Socio-Cultural Change in the UK who have followed this project over many years. This paper draws from the conclusions to a book we have written on road construction in Peru entitled *Roads: A Material Anthropology of Political Life in Peru* (currently under review).

embraced and addressed by professional engineers in the course of their work. We are particularly interested in exploring the tensions between the knowledge work of engineering practice, with its appeal to scientific methods and mathematical thinking, and other dimensions of engineering practice that require the engineer to engage the world as they find it in order to effect the transformations that they are contracted to deliver.[2]

The article is written in response to what we suggest has often been a rather limiting understanding of engineering practice that has frequently failed to acknowledge some of the more open, emergent and relational dynamics of engineering work. Engineering, particularly the engineering associated with large-scale public works and development projects, tends to conjure an image of normative control and the systematic erasure of potential alternatives. The 'engine sciences' have certainly earned this reputation over the centuries and the work of historians such as Mukerji (2009) and Carroll (2006) has given us detailed accounts of how engineering became integral to modern statecraft in attempts to manage unruly populations and volatile economies. In the nineteenth century, the promise and capacity of engineering and machinic solutions to social problems was part and parcel of industrialisation and an unreflexive enthusiasm for the potential of machines to bring progress and prosperity. In 1861, William Fairbairn, President of the Institution of Mechanical Engineers, delivered a speech in Manchester in which he reflected on the huge changes in engineering that he had witnessed in his own lifetime:

> When I first entered this city the whole of the machinery was executed by hand. There were neither planning, slotting nor shaping machines; and with the exception of very imperfect lathes and a few drills, the preparatory operations of construction were effected by the hands of the workmen. Now, everything is done by machine tools with a degree of accuracy which the unaided hand could never accomplish. The automaton or self-acting machine tool has within it an almost creative power; in fact, so great are its powers of adaptation that there is no operation of the human hand that it does not imitate (quoted in Briggs, 2006: xiii-xiv).

As the twentieth century unfolded, the centrality of engineering to the architecture of modernism produced a more ambiguous response. The limits of the imposed experiments in social engineering, the devastation of two world wars, the failure to tackle social inequality, and the fears of an emergent homogenised and culturally stagnant future transformed this most promising of professions into a much criticised and politically contentious field of social engagement.

By the end of the twentieth century, these concerns could be summarised in terms of three dominant responses to large-scale engineering projects: (i) a rejection of the hubris of the ambition to transform and improve the world through the application of rational, technical knowledge and procedures; (ii) a challenge to the moral project of human transformation that showed how top-down engineering transformed the complexity and diversity of social practices into obstacles and irritants, "something to be managed, limited and controlled" (Law, 2002b: 138); and (iii) the critique that engineered (designed) management of human practices and environments consistently side-lined the stuff of life – the movement, uncertainty and irregularity from which all creativity stems (Ingold, 2007). Many of the engineers who allowed us to follow their day-to-day working lives on the roads of Peru were aware of these critiques. We found that, in some respects and in some contexts, their practices confirmed the fears and expectations that routinely attach to the professional

[2] For further discussion of the craft skills of expert practitioners, see Harvey and Venkatesan (2010).

engineer. However, in other respects we found a more complex story. Thus, rather than assuming that engineers are enthralled by the logics of modernist development, oriented towards the project of assembling new futures through procedures of standardisation and homogenisation, we began to attend to how what might appear as a hubristic relationship to a complex social world could also be understood as the outcome of attempts to engage cultural and material diversity in the face of an uncertain future.

Locating the engineer

Our ethnographic research was carried out on two roads in Peru. One is located in the Peruvian Amazon and runs between the city of Iquitos and the town of Nauta. This road does not connect to a wider network. It stands alone. It does, however, link the Amazon river and its tributaries to the city, and the city in turn has an airport. The other road that we worked on was Route 26, currently known as the Interoceanic Highway. Unlike the Iquitos/Nauta road, which was built primarily in response to local needs and longings for a faster and more secure connection to a regional hub, the Interoceanic Highway was an overtly international project – at least from the perspective of those who raised the finance and those who were responsible for its construction. For many others along the route these international aspirations were less important and the connection to more local regional hubs were of far more immediate significance. Both roads had their origins in the 1930s in Peru's first wave of national road construction. Both have taken many decades to 'complete' and such completion is constantly deferred as bits of road collapse and require repair. The stories of their emergence as more or less stable surfaces are stories of material drama. Geological fault-lines and volcanic activity in the Andean mountain range make some areas highly susceptible to landslides. The waters that drain from the highlands to form the huge rivers of the Amazon forest rise and fall suddenly, and frequently wash away sections of the road. When the rivers are no longer contained by the rocky gorges of the mountain terrain they tend to move and change their course. Mundane weathering, extreme temperatures and heavy rainfall eat away at newly laid surfaces, leaving holes that threaten to destabilise vehicles or block their passage entirely.

This sense of material flow and blockage is paralleled by the social dramas played out on the roads, which are routinely engaged as spaces of protest and negotiation in the political life of the country. Roads channel commerce and economic potential. To build a road is to create new spaces of speculative venture – new settlements appear and, in the Amazonian region, whole villages routinely move away from the rivers to connect more directly with the faster and more predictable surface of the road. These spaces are then integrated into people's daily lives, their habitual journeys, and, all too frequently, their deaths. Memories and anticipated futures are registered in the many roadside shrines that engage the forces of the Catholic pantheon and of the mountains themselves as people seek protection, good fortune and/or solace in what are experienced as fundamentally unstable spaces. Life is precarious for most people in the Andean and Amazonian regions. Negotiating life in the informal sector involves riding the waves of boom and bust economies, subject to economic and political forces that appear and disappear in their lives. There is no sustained welfare in Peru and there always seem to be vague and undefined 'interests' at work that undermine the best-laid plans. Material and social relations are built and unravel. Investments in plans and normative procedures such as those promoted by construction companies are matched by the need for agility, sharp awareness of opportunities and a healthy respect for the arbitrariness of power, whether in the form of state officials, wealthy traders, catholic gods or natural forces. Such

are the spaces in which the civil engineers with whom we were working sought to intervene. These were the materials and relations with which they were attempting a project of integrated transformation, and these were the social fields in which the politics of knowledge were being played out in civil engineering projects.

We were struck by the complex social and material environments with which the road engineers whom we were working with had to contend, but there is much evidence that dealing with these kinds of complex disintegrative field has always been central to the work of the civil engineer (Ash, 2000; Carroll, 2006; Mukerji, 2009). Whilst many have argued that, historically, we have moved from a paradigm of progress to a risk society (Beck, 1992; Blaser, 2009), on the road we found these two orientations equally visible. Indeed, we argue that engineering practice recognises and fosters the dual orientation to progress and risk as an uncertain yet promising space that calls out for engineering expertise. Modernist development always involved reflexive awareness and internal critique, not least because of the ways in which it produced spaces of externality which complicated straightforward narratives of progress (Beck, Giddens and Lash 1994). The demand for such reflexive awareness and, increasingly, the explicit calculation of risk has become a familiar component of all development projects. The growing importance of 'risk' paradigms was not simply the result of a cumulative awareness of the hazards of 'progress' – as is evidenced by the many unintended consequences of development initiatives such as nuclear disasters, chemical spills, and widespread environmental pollution.. These issues certainly disrupt linear narratives of improvement, but modernist development emerged alongside experimental and questioning approaches to relations of cause and effect, and a fascination with the influence of invisible and unconscious forces, and with the as yet unknown or unrealised relational dynamics that shape social worlds. Furthermore, interest in the tensions between risk and opportunity was not limited to intellectuals and artists, but was also clearly embraced by scientists and engineers – and their political and military employers. Beyond civil engineering, we find that the disintegrative potential of atmospheric relations was fundamental to the development of chemical weapons (Sloterdijk, 2009), and arguably fostered the ambition of the cybernetic revolution to extend the scope of fathomable environmental relations through the development of powerful and self-generating information systems (Pickering, 2011; Dumit, 2004). As computers have become more powerful and their use more ubiquitous, an awareness of the complex array of social and material factors that need to be taken into account in any integrative engineering project has been responded to by methods of continuous calculation (and monitoring) in which variation and oscillation is constantly registered, drawing attention to the intrinsic variability, multiplicity and open-endedness of all environments (Thrift, 2007; Lury, Parisi and Terranova, 2012). These complex relational and differentiating spaces may have been made more explicit in recent times, but they are not new. Since engineering began, these have been the spaces that civil engineers set out to manage, and in which they have worked to enact the material and social transformations which they are contracted to deliver.

Nonetheless, few analyses of engineering within the social sciences have paid much attention to the ways in which engineers deal with these complex working conditions. Engineering is strongly associated with progress narratives and the drive to modernisation and development that characterises the high modernism that Scott (1998) describes, or the more insidious exercise of power that Mitchell outlines in *Rule of Experts* (2002). Scott's critique of high modernism in *Seeing Like a State* (1998), for example, attributes the destructive failures of specific attempts at social engineering to the hubris of planners and engineers. This image of the engineer as detached, autonomous, rationalist planner is habitually produced – perhaps

particularly in social anthropology – in contra-distinction to alternatives, often celebrated for their more emergent or processual engagement with the world. Histories of specific engineering projects are clearly entangled with the power relations of colonial rule and the emergence of the modern nation-state, and are also accounts of how particular political regimes are enacted through the implementation of plans for social improvement – which all too frequently are simply characterised as running roughshod over other concerns, priorities and sensibilities. The reason for this apparent insensitivity to the specificity of local conditions is often attributed to the rationalising impulse of engineering. Lévi-Strauss (1966) defines the engineer as the prototypical modern thinker by contrast with the *bricoleur*, his non-modern counterpart. In similar vein, via a very different philosophical route, Ingold (2011) evokes the rigidity of the engineer setting out to get from A to B, in contrast to the 'dwelling' or 'wayfaring' modes of engagement that he favours as more authentic ways of living.

In many respects this is understandable, for an adherence to reason, abstraction and normative procedure appears to offer engineers a way forward, shaping the knowledge practices that have come to define their particular mode of expertise. Blaser's discussion of framing has helped us to articulate the particular way in which we have come to understand engineering practice:

> Framing basically means the establishment of an undisputable frame of reference within which a series of activities will be carried out. Framing is performed by what we may call a 'governing subject,' that is, any institution concerned with the 'conduct of conduct' with the purpose of achieving predefined goals (Foucault 1994, 237). The particularity of framing is that the governing subject lays down undisputed assertions about reality which will serve as the rationale to frame and sort out competing claims being laid down by those being governed (Blaser, 2009: 445).

We became interested by the way in which 'framing' produces a doubling effect whereby the governing subject is simultaneously responsible for the creation and imposition of the frame, and at the same time these frames, when successfully imposed as rational, abstract, normative devices, appear as if from elsewhere; as standards which are followed rather than imposed. If the frame is truly beyond dispute, the governing subject no longer appears to operate within the sphere of the political but acts simply as a technician, bureaucrat, or expert.

Foucault's interests in such mechanisms of control were finely captured in Mitchell's account of the 'rule of experts' in modern Egypt (2002). Carefully following the networked playing out of relations of contingency, influence and self-interest, Mitchell showed how specific practices (such as the application in Egypt of methods used to combat the mosquito in the building of the Panama Canal) were framed as generics or standards, offering a technocratic ruling elite the capacity to isolate and control a field of relations as if beyond politics. The frames, aptly named 'locationless logics' by Mitchell and the 'God-trick' by Haraway (1988), remove the governing subject from the space of politics and, in the process, also erase the specific ways in which such experts might be held responsible for the effects of their interventions.

Our ethnographic study of the practices of civil engineers working on construction sites does support this analysis to some extent. We have dwelt elsewhere on the instruments and

practices that engineers deploy both to control and keep their distance.[3] In particular our work has addressed the practices of laboratory technicians, which involves the testing and manipulation of soil samples; the articulation and imposition of codes of conduct directed at the regulation of working practices (Harvey and Knox, 2011); and the transparency measures designed to combat the endemic corruption associated with public works. Each of these fields of practice mobilises the familiar instruments of engineering practice: the standards and norms of professional codes and legal provisions; the reliance on metrics, algorithms and computer models to convert concrete measures into projected trends; and the use of technological devices to extend and standardise human perception and analytical capacity. There is no doubt that civil engineering practice enacts the framings of modern disciplinary knowledge. And yet our observations also suggest that this is a story of limited control in which the engineer's disciplinary moves are ultimately only ever going to be provisional attempts to suppress the proliferation of alternative framings.

Both Foucault ([1969] 1989, 1971, 2007) and Mitchell (2002) have provided fascinating diagnostic accounts of political economy, but to do so, they have had to step back from the messiness of practice (Law, 2004). As such, their accounts of disciplinary power enact a scalar shift, or a move away from the complexity of the particular to the strong general account of epistemes, epochs and regimes, and to the chains of association through which modernist planning and control enacts its powerful effects. As ethnographers we appreciate the clarity that such distance affords, but at the same time we remain intrigued by the politics of the specific and interested in how the space of the political might be understood from this perspective. When we attend to what civil engineers are actually doing on a day-to-day basis we are faced with the inherently pragmatic and flexible nature of these practices. Thus, for example, we find that, while standardising metrics and the universals of mathematics are central to engineering practice, the measurements that these techniques afford are never assumed to be stable. The calculation of optimal material interventions are made under laboratory conditions where materials are approached 'as if' (Riles, 2011) conditions inside and outside the laboratory were continuous – but in the knowledge that such continuity is only approximate, and that 'good solutions' aim to be satisfactory rather than correct in any absolute sense. Both measurement and experimentation are ongoing and, while experience guides the expert engineer, they know that there are no ready-made solutions for the material challenges that they face. Similarly, in the field of health and safety we found that stringent rules and regulations were drawn up, communicated and enforced in the sure knowledge that most people were side-stepping and bending the rules most of the time – and that in many ways such flexibility was necessary to safe working. The regulations thus refer to a utopian world where the application of logic and the adherence to rules assumes stability and ensures that things will go according to plan. But in practice, of course, things go wrong all the time, the rules frequently contradict common-sense understandings, and the aspirations to certainty and stability run counter to the basic need for everyone to be attentive to the dynamics of the relations in which they are immersed, and so ready to deal with the unexpected.

If, at the heart of analyses of regulation and control there has been a preoccupation with the ways in which rational practices might be understood through a tracing of relations of connectivity, we suggest that an analysis of engineering practice that acknowledges the negotiation of difference, in which engineers are constantly engaged, requires a somewhat different metaphor. In place of Foucault's genealogical approach or Latour's network

[3] The following paragraph refers to three chapters of our monograph *Roads: A Material Anthropology of Political Life in Peru* (currently under review).

thinking, in what follows we want to draw out the centrality of a notion of interface or potential discontinuity which seems to underpin the core integrative preoccupation of the engineering projects that we observed. In contrast to the metaphors of the network and its connections, or the kinship diagram with its lines of inheritance, we invoke the image of the interface as a more appropriate means of evoking the epistemological practices of the engineers with whom we were working. When the ambition of engineering is integrative, and the problem facing engineers is that of how to deal with the apparent disjunctures and discontinuities between the worlds of Andean people and the worlds of engineering practice, the interface helps to hold in view the inevitability of internal discontinuity and difference.[4]

The integrative promise of engineering

Road construction projects provide us with a privileged site within which to become attuned to the way in which a trope of integration informed engineering practice. Unlike some other engineering projects, road construction in Peru is explicitly a project with integrative ambitions. Roads are designed to link places that would otherwise be disconnected or poorly connected. Integration refers here to the production of enhanced connectivity, and what Brighenti (2010) has referred to as 'territory effects'. As technologies of spatial integration, communication infrastructures work through dynamics of inclusion and exclusion, containment and extension in multiple scales.[5] A road can connect place A to place B, creating a stable sense of continuous space or territory. This logic was the driver for many early construction projects in Peru designed to integrate a fragmented national territory, and to channel the circulations of raw materials, goods and labour in such a way that local, regional and national interests were physically encouraged to converge and conform to a model of dynamic movement within a clearly bounded entity, the modern nation-state. However, the very same roads also opened up the nation to international trade, providing channels whereby an integrated national territory – or a dynamic locality or region – might become included, on a broader scale, in wider international fields. Thus, while commitment to integration as connectivity is fundamental for these projects, it is worth noting that spatial integration is an open-ended notion that works at multiple scales. Connection at one scale can imply disconnection at another, and further integration is always held out as a possibility.

Whilst integration was deployed in relation to the outcomes of road construction projects, it was also, perhaps more surprisingly, mobilised with reference to the complex and varied skills of the road construction process. Engineering, design and construction practice require the co-ordination of many diverse modes of expertise both across technical fields and in relation to other fields of practice such as politics, finance, and the logistics and management associated with the sourcing and deployment of labour and of materials. Construction projects exemplify interdisciplinary practice. Many different knowledges have to be co-ordinated and drawn together. The work of project management in the field of civil engineering concerns not only the management of an unfolding process (the scheduling and tracking of the work), but also the effective co-ordination of very specific and highly differentiated knowledges and skills. Integration in this respect refers primarily to an ideal process of co-ordinated action that allows people to work across difference in such a way as

[4] We find intellectual support for this approach in anthropological work on exchange and circulation where it is clear that commensurability is not a necessary condition, even when monetary forms are active elements in exchange networks. The work of Jane Guyer (1997) exemplifies this approach.

[5] This argument is elaborated in more detail in our monograph *Roads: A Material Anthropology of Political Life in Peru* (currently under review). See also Harvey (2012).

to ensure maximum efficiency. The notion of integration here refers to the work of producing compatible knowledges. Integrated technical systems require that the elements that are incorporated into the system are formatted in such a way as to facilitate movement across difference. Science and technology studies (STS) has provided us with many rich descriptions of this work of co-ordination and the ways in which civil engineering, in particular, has deployed both technical instruments and social relations to achieve these ends.[6] Engineering in this respect is an art of ingenuity and contrivance in which the application of scientific ideas and social (or political) know-how come together in fashioning responses to specific material challenges. Historically, engineers have relied on the instruments of the 'engine sciences' (Carroll, 2006): the scopes, meters, graphs and chambers or proto-laboratories which afforded them a privileged understanding of the spaces that they set out to transform. Contemporary engineering continues to deploy these instruments, now enhanced and transformed by digital technologies that allow the rapid circulation of information and the possibilities of a distributed work force no longer required to be in physical proximity in order to work together on a problem. The challenges involved in achieving the integration of information and ensuring the compatibility of different knowledges produced by diverse specialisms are considerable and STS scholars have rightly drawn our attention to the translation devices (Callon, 1986), boundary objects (Star and Greisemer, 1989) and conscription devices (Henderson, 1991, 1998) that are deployed to this end.

A final way in which the engineers with whom we worked appealed to the notion and value of integration also takes 'discontinuous knowledge' as the problem, but in this case the discontinuity is associated with concerns over the disconnections between technical and social relations. In infrastructural projects that are funded with the explicit ambition to foster economic growth and to promote more widespread benefits of social 'development', lending institutions such as the World Bank routinely insist that engineering solutions manifest the grounds of their sustainability. The demand for projects to become autonomous of lender support requires the borrower (and ultimately the construction company that they contract) to produce evidence of widespread social investment in the enterprise. Construction companies are attuned to the need to address the open and contentious questions of social responsibility and to find ways to demonstrate social acceptance of the project. The social dimensions of business ventures are notoriously problematic. Nevertheless, the concept of integration has rhetorical purchase. Time and again in Peru we heard both engineers and politicians voice their commitment to the idea that technical solutions of steel and cement (*de fiero y cemento*) were no longer sufficient in and of themselves. It was always important to integrate the social into engineering development initiatives.

The commitment to integration is thus complex and signals the sense in which large-scale construction projects involve what Law refers to as 'heterogeneous engineering' (Law, 2002a, 2002b). That is, projects proceed via the simultaneous top-down imposition of the authoritative expertise of professional engineering knowledge, and a more negotiated or horizontal way of working in which the same engineers approach construction projects with a sense that material and conceptual integration has to be achieved through negotiation, and worked out on the ground, in order to ensure sustainability and social acceptance.[7] But the insistence on the need for integration also points to a recognition of the enduring dynamic between continuous and discontinuous relations. The idiom of integration attributes value to

[6] See, for example, Ash (2000), Carroll (2006), Mukerji (2009) and Suchman (2000), or alternatively, for an account of failed integration, Latour (1996).
[7] See Callon (2011) for extended treatment of these issues.

connectivity, but each new connection also reconfigures relational dynamics, and articulates new dynamics of inclusion and exclusion. As we analysed these processes, we became increasingly aware of the limits to thinking of roads as networks, and began to think more in terms of interface formations and processes of bordering (Knox, 2013; Harvey et al., 2013).

The network concept, whether we refer to the core trope of Actor Network Theory (ANT) or the infrastructural force of the internet as in Castells' account of the 'network society' (1996), privileges the notions of integration as territorial ordering or co-ordinated circulation, and tends to downplay the significance of the internal discontinuities or emergent difference to which the notion of the interface draws attention. Many critics of ANT approaches take issue with the ways in which the focus on continuity of flow or connectivity appears to flatten social process, and downplays the significance of power and conflict. This argument is not accepted by many advocates of ANT, who in turn question established understandings of political agency. For them, the political dimensions of ANT approaches reside in the ambition to identify the agencies and alliances through which the political unfolds. The concept of the interface (rather than the network) allows us to keep both these perspectives in play. Thus, we can take roads as the outcome of encounters between human intention and material potential, and between different social interests and political ambitions. At the same time, we can trace how these emerging material formations produce the grounds for new confrontations and disjunctures. We share the interest of ANT scholars in assuming the possibility of political agency beyond the actions and intentions of the liberal human subject, but we are equally committed to identifying disjunctive and conflictual relations, the "invisible trouble" inherent in infrastructural systems (Lampland and Star, 2009: 22). The concept of the interface keeps this sense of 'encounter' and of potential discontinuity more clearly in view.

In the road construction projects that we followed, difference and distance were marked in numerous ways: clothing, language, bodily comportment, the spatial arrangements of the construction camps, the modes of transport, the salaries, the levels of formal education. All such markers ensured that differences and discontinuities were reproduced and re-enacted on a day-by-day basis. However, we did not want to assume that such differences necessarily implied any kind of ontological rupture or condition of mutual incomprehension. We did not assume that the engineers necessarily lived in a different world to the local workers and residents. Nor did we assume that the engineers would approach the rationalising techniques and practices that are so central to their work as all-encompassing. On the contrary, our understanding of the histories of modernity led us to anticipate a more critical or ambiguous understanding of how difference aligns with both progress and risk in imaginaries of development. We were also aware that the ontological premises and environmental engagements that characterise Andean life-worlds cannot be distinguished from modernist engineering on the basis of their relational orientation. Awareness of environmental connectivity, and the open-endedness or inherent instability of form to which diverse social theorists refer in their analysis of dominant contemporary social formations, returns again and again to the central significance of relational thinking across the supposed western/non-western or modern/non-modern divide (Latour, 2005; Lury, Parisi and Terranova, 2012; Thrift, 2007). By attending to engineering as a practice of negotiation across a series of interfaces, however, we are led more directly to the differential qualities and effects of relational practices, and thereby to the space of the political in the transformative ambition of infrastructural form.

Approaching engineering through the metaphor of the interface invites a consideration of the hesitation, the sense of doubt or unease, and acknowledges the presence of concern in even the most gung-ho development projects. The civil engineers whom we worked with were not in a position to ignore the details of local engagement. They were required to attend to other knowledges, practices and possibilities on a daily basis. And their projects rarely simply fail or succeed, for they always carry multiple intentions and possibilities, and they always change things in unexpected ways. Contrary to the stereotype, we found that engineers know perfectly well that the data that they work with are provisional, and they know that they can only transform the environment by working with what is already there. In this sense we want to suggest that engineers only partially enact the modernist paradigm of approaching the environment as an external world of nature to be grasped and controlled, despite the fact that their expertise has commonly been described in this way.

Indeed, we suggest that the professional expertise of road construction engineers lies precisely in their ability to produce resilient structures out of the dynamic relational properties of the material and social worlds in which they find themselves. To achieve this task they concentrate their effort on material relations in full awareness that these relations are realised in dynamic engagement with social worlds. Aware of environmental relations and of the productivity of difference, of systemic interconnection and oscillating variation, they attend to the possibilities of framing; of provisional decontextualisation that allows relations to be stabilised for long enough for decisions to be taken and actions performed. Indeed, the central aspect of their work is the capacity to frame their own expertise as a particular quality of knowledge that enables controlled, ordered material transformation as a primary responsibility – undertaken, secondarily, with regard to the social implications of their work. This ability to carve out a specified domain of expertise is the key, we suggest, to appreciating both how social responsibility appears as a problematic issue for modernist projects of transformation, and how it is that the same expertise offers the best means available for responding to such problems. The point that we want to stress here is that the determination to identify and produce such framings is not founded on the distance of the person who fails to notice what is occurring on the ground, but in the distance taken by the person who is all too aware that local complexity has to be managed somehow if planned transformations are to be embarked upon. In this context, we suggest that it is helpful to think about engineers as both 'engineer' and '*bricoleur*' in Lévi-Strauss' terms; as 'recombinant scientists' working with what comes to hand to resolve the specific, localised problems that any infrastructural project produces in its articulation of the diverse interfaces that constitute the grand plan or overall scheme.

Engineering the social via acts of framing

Given the centrality of the logics of integration to engineering practice, how then do the civil engineers make space to act? How do they create and deploy framing devices in these complex spaces within which multiple knowledges and understandings compete for attention; and to what extent does this practice of framing help to produce the effect of the interface itself? Our approach here has been to follow the relational dynamics of the knowledge forms that engineers produce in the course of their work. Engineering projects generate all kinds of documents, plans and analytical forms, each representing particular kinds of abstraction, each enacting a particular framing as discussed above. These documents are themselves social forms; relational devices that are produced to serve a particular purpose.

One such purpose is the enactment of engineering expertise. Engineers, in common with the scientists that Latour and Woolgar (1979) famously described in *Laboratory Life*, produce inscriptions. In some respects these detailed specifications are understood to be the central product of engineering expertise. Civil engineers we have worked with in both Peru and the United Kingdom have stressed to us over the years that engineering and construction are two quite different things. 'Engineering' is the production of the technical solution, design or prototype that is subsequently realised in the practice of construction or manufacture. In this regard, the crucial engineering work is carried out prior to the construction phase of a project. However, even if we stick for the moment with the idea that engineering involves the production of a design, we find, in practice, that such designs are produced in a variety of social framings that subtly shift the referent of the design. A feasibility study for projects such as those we studied in Peru will include all kinds of technical details and specifications concerning the road surface, its foundations, materials, form, routing and its potential costs and benefits, including the calculated risks with respect to environmental and social impact. These studies are highly technical, but they serve a particular purpose: they sort and set out the relations between funders, politicians (and/or representatives of diverse public constituencies) and the construction company. The engineering in this framing combines social and technical knowledges in a specific way. The studies have to address questions such as: 'what kind of a road do we want and expect this to be?' and 'will this project be related to other concerns and policies with respect to public investment?' The studies are ultimately consolidated in the contractual agreements that are drawn up to allow a project to start through the release of funds.

Quite different knowledges are assembled in the laboratories of the construction companies once the works are underway. Here, the key relations to set and sort out are those between the available materials and the environmental forces that they will be expected to confront. The engineers measure and model the relational capacities of the materials with respect to things like their relative resistance to weight, plasticity, or porosity; they gauge the relative value of natural over man-made materials; and they work to find the best fit between what they have to work with and the agreed specification of their final product. These are still activities that move towards the production of an engineering design. The temporality has shifted, however. The design is still prior to the subsequent act of construction, but it is also recursive (Kelty, 2005). The problems and challenges that the construction process produces are continually referred back to the laboratory for modification and subsequent design refinement.

The notion that engineering work is always prior to, and separate from, construction is thus itself a somewhat abstract or ideal account of how construction proceeds in practice. Engineering design informs the construction process, and signals what it is that has to be built and how, but the design remains open to modification. The technical studies direct proceedings, but they do not in the end determine how to proceed. The realisation of the design is something that is worked out on the ground in the interactions between engineers (contractors and supervisors), foremen, labourers, materials and machines. The importance of the technical specifications lies in their capacity to clear the way for action by setting out the parameters of the material transformations that are to be undertaken. However, we suggest that they also serve another, equally important function in the ways that they simultaneously delimit the relational domain for which the engineers are responsible. We can see that the framings entailed in the drawing up of a technical specification are not predicated on the failure to address local conditions, but could perhaps be seen as attempts precisely to localise the space of intervention; to articulate its specificity and to limit responsibility for all that will, inevitably, overflow this space at some unspecified future date. In this respect, technical

knowledge works by closing down alternatives or rendering them outside the domain of action.

This formulation would, we imagine, be contested by many engineers who often articulated their point of departure as the specification of alternatives. These alternatives should always be explored at the stage of the feasibility study, to allow those in a position to decide what 'solution' best addresses which 'problem'. But this is not our point. There are many ways to build a road, but to the extent that any of these ways needs to pass through the framing devices of the feasibility study – the engineering specification, the laboratory analysis, etc. – they are subject to framings that create a meaningful distance and, thus, an interface between a sphere of expert practice and the everyday worlds of the surface dramas described earlier. These acts of framing produce social problems, and in fact 'frame' the social as a problem, not primarily because they distance the expert from local relations, nor because they cast the expert as governing subject able to impose a particular (erroneous) truth about reality. Rather, it is because their particular way of engaging the local generates a space of externality that appears, in retrospect, as problematic precisely because it is discontinuous and non-integrated (Callon, 1998). In the concern that technical projects should integrate the social, the 'social' appears, by default, as that which the technical has failed to carry forward, a relational space that is disengaged and left behind. It is in this way that expert knowledge practices produce 'knowledge gaps' and, in contexts where development and progress have widespread purchase as idioms of social improvement, such gaps signal both temporal and moral 'lag'. Engineers thus find themselves confronted with social and temporal otherness that must be incorporated somehow into current and future engineering solutions.

This interface effect was a cause of great concern for the engineers with whom we were doing research, although such effects were not generally understood as an effect of technical intervention. The engineers themselves remained caught up in a concern to bridge the gap between the technical and the social that often seemed to defy all (their) sense of logic. For example, one of the paradoxes that engineers are constantly battling with is their awareness that the same people who campaigned tirelessly to secure investment from governments for the roads that they believe will deliver them better lives, are also working against the realisation of this dream, even when the road is almost there, under construction and requiring only their co-operation for successful completion. Such dilemmas were vividly communicated to us by one of the engineers who had worked on the Iquitos/Nauta road. He told us, admittedly with a marked note of irony in his voice, that the road-workers and people living along the road that he was trying to complete were "total savages". He explained that this project was the very first in Peru to use a cutting-edge synthetic webbing, found to be highly effective in strengthening the road surface in sites (such as the Brazilian Amazon) where there was no stone. He and his colleagues had built a shelter to keep the webbing dry and had posted a guard to keep it safe, but the guard fell asleep and the webbing was stolen. The next thing he knew, the webbing started appearing as chicken-pen lining in the battery farms along the road. To make matters worse, when he did finally start to use the webbing for the job it was intended, his workers had managed to destroy it. A special machine had been brought in from Brazil to help lay the webbing on the ground, but the driver had not realised that the grooved wheels that facilitated the laying of the material in forward drive would destroy it in reverse. The engineer's complaint focused on how local people did not appreciate the value of the webbing, nor that they were damaging the very thing that they were supposed to be creating together. These failures to integrate people into a common project, as framed by the civil engineers, are widely seen as the kinds of 'social' issues that

the specialised 'social relations' departments of engineering companies are charged with handling.

The social relations officers are sent out to clear the way for the construction process, negotiating the minute details of routing, the sourcing of local materials, the negotiations of compensation, and of work opportunities. In the process they find themselves engaged in discussions of values and habits that are hard to reduce to the frames of developmentalist thinking. How, for example, do you compensate a family for a precarious, illegal roadside shack that is their only shelter and source of livelihood? How do you negotiate the value of land that has been painstakingly tended over many decades despite its poor productivity? How do you relocate a powerful shrine that indexes forces of regeneration and future possibility for those who attend to the powers of miraculous Christian saints? How indeed do you convince people that your inadequately guarded and clearly valuable material should not be taken and used to meet a spontaneous or pressing need? In all these cases the social 'problems' emerge as quite external to the technical framings, and are associated with a non-technical, recalcitrant and/or ignorant people who do not understand how their actions impede the progress for which they have campaigned. The possibility that such people might understand this perfectly and nevertheless choose to act otherwise tends not be examined. Integrating the social in the final analysis is about getting people 'on board' and signed up to a common project.

As others have pointed out with respect to the contemporary discussion of participatory methods in development projects (Green, 2010), technical framings are thus not primarily knowledge claims, but attempts to negotiate the ways in which a space of action (the construction project) becomes cut off from the everyday worlds of surface drama.[8] Where that distinction fails to hold the line, and signs of other activities, competing priorities and values emerge, they emerge as social problems. The problems might be articulated as either a failure to embrace the values of progress or to recognise risk. In either case 'education', or at least some kind of awareness raising, is nearly always produced as the answer; the means by which the integration of the social and the technical can be achieved or restored. In the process, 'social responsibility' remains securely bracketed off from the activities of the technical expert. Perhaps for this reason large-scale public works are widely thought (even by engineers themselves) to be steeped in corruption. With no secure identification of social responsibility, corruption stories flow freely around these projects. The nebulous force of 'interests', largely unspecified, is always thought to lie behind the decisions of who to employ, where to route a road, what materials to use, where to source them from, or where to dispose of them. Fears that the wrong kinds of integration are being effective are commonplace, and the question of who gets drawn into the projects and how occupies everybody's thoughts. Even spaces without roads can be configured in this paradigm as a space where a road might have been had somebody not run off with the money.[9]

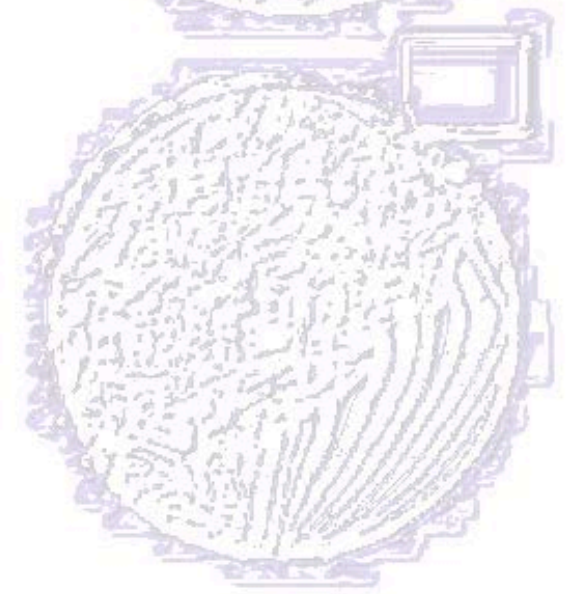
An engineer once explained to us: "A road is like a person – it is not static, it is dynamic – it grows. Every day you learn more about its problems". However grand the project in terms of design and control, and however invested a particular expert might be in specific modes of calculative reason, these road construction engineers display an open-ended orientation to the

[8] For a parallel argument concerning the training of surgeons, see McDonald (2013).

[9] Jokes about engineers stealing materials or siphoning off funds to build luxury lifestyles for themselves appear in more or less exactly the same form across Latin America, and possibly beyond. Diane Nelson, Professor of Cultural Anthropology, Latin American and Caribbean Studies, and Women's Studies at Duke University, told me jokes that she had heard in Guatemala which were exactly the same as those people had recounted in Peru.

worlds that they engage. They know that all entities constantly differentiate and transform, and they understand that the key question that they need to ask of any space of intervention is not what something is, "but what it is turning into, or might be capable of turning into" (Jensen and Rödje, 2010: 1). This orientation has many similarities with orientations to the world that might otherwise be classed as quite contrary to engineering practice. The engineers that we followed in Peru were working in spaces that were charged with the narratives, experiences and prior understandings of those who routinely attended to how things become otherwise. Andean worlds are notoriously unstable. You can never be sure what things might be turning into. Deception and disguise are commonplace. Evil spirits turn up in the guise of loved ones, and powerful forces – Christian saints, army personnel or corporate scouts – may appear unannounced to test you, and observe your reactions as they decide your fate. In the final analysis, all things and persons are known primarily through the engagements and exchanges that emerge in the process of social interaction.

Like the engineers, local people also watch the water, the soils and the weather; they watch who comes and goes; they keep an eye on each other's fortunes, and on the growth of animals and plants. Local people also understand that the forces that inflect their lives are not necessarily visible or accessible. Everyday lives are routinely affected by distant markets that move prices and commodities; by conflicts in other countries that lead people to migrate; by ecological and environmental changes that alter the possibilities for making a living. Drawing on the specificity of their experience, people analyse what is going on without necessarily even acknowledging that this is what they do. Engineering practice is oriented to projects of social and material transformation, and the need to create a space in which to act obliges the engineer to deploy techniques of framing that reinforce an apparent separation between the rational world of the technical expert and the non-coherent world of untamed material and social configurations. Our argument has been that this outcome also requires the engineer to engage the world as a pragmatic craft practitioner, deploying the open-ended analytical skills of the *bricoleur* and the wayfaring disposition of the traveller. A focus on these interfacing practices does not erase the political and moral hazards of engineering solutions. It does, however, keep in view how uncertainty and contingency shape the relations between technical knowledge, culture and social change.



References

Ash, E. H. 2000, '"A Perfect and Absolute Work": Expertise, Authority, and the Rebuilding of Dover Harbour, 1579–1583', *Technology and Culture*, 41(2): 239–68.

Beck, U. 1992, *Risk Society: Towards a New Modernity*, New Delhi: Sage.

Beck, U., Giddens, A. and Lash, S. 1994, *Reflexive Modernization: Politics, Tradition and Aesthetics in the Modern Social Order*, Stanford, CA: Stanford University Press.

Blaser, M. 2009, 'From Progress to Risk: Development, Participation, and Post-Disciplinary Techniques of Control', *Canadian Journal of Development Studies*, 28(3–4): 429–54.

Briggs, A. 2006, 'Introduction', in S. Smiles [1861–1905] 2006, *Lives of the Engineers*, London: The Folio Society, pp. ix–xiv.

Brighenti, A. 2010, 'On Territorology: Towards a General Science of Territory', *Theory, Culture and Society*, 27(1): 52–72.

Callon, M. 1986, 'Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of Saint Brieuc Bay', in, J. Law (ed.), *Power, Action and Belief: A New Sociology of Knowledge?*, London: Routledge and Kegan Paul, pp. 196–233.

——— 1998, 'An Essay on Framing and Overflowing: Economic Externalities Revisited by Sociology', in, M. Callon (ed.), *The Laws of the Markets*, Oxford: Blackwell, pp. 244–69.

——— 2011, *Acting in an Uncertain World: An Essay on Technical Democracy*, Cambridge, MA: MIT Press.

Carroll, P. 2006, *Science, Culture, and Modern State Formation*, Berkeley: University of California Press.

Castells, M. 1996, *The Rise of the Network Society*, Oxford: Blackwell.

Dumit, J. 2004, *Picturing Personhood: Brain Scans and Biomedical Identity*, Princeton, NJ: Princeton University Press.

Foucault, M. [1969] 1989, *The Archaeology of Knowledge*, London: Routledge.

——— 1971, The Order of Things: An Archaeology of the Human Sciences, New York: Pantheon Books.

——— 2007, *Security, Territory, Population: Lectures at the Collège De France*, 1977–1978, Houndmills, UK: Palgrave Macmillan.

Green, M. 2010, 'Making Development Agents: Participation as Boundary Object in International Development', *Journal of Development Studies*, 46(7): 1240–63.

Guyer, J. 1997, *Marginal Gains: Monetary Transactions in Atlantic Africa*, Chicago: University of Chicago Press.

Haraway, D. 1988, 'Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective', *Feminist Studies*, 14(3): 575–99.

Harvey, P. 2012, 'The Topological Quality of Infrastructural Relation: An Ethnographic Approach', *Theory, Culture and Society*, 29(4–5): 76–92.

Harvey, P., Casella, E., Evans, G., Knox, H., McLean, C., Silva, E., Thoburn, N. and Woodward, K. (eds) 2013, *Objects and Materials: A Routledge Companion*, London: Routledge.

Harvey, P. and Knox, H. 2011, 'Anticipating Harm: Regulation and Irregularity on a Road Construction Project in the Peruvian Andes', *Theory, Culture and Society*, 28(6): 142–63.

Harvey, P. and Venkatesan, S. 2010, 'Faith, Reason and the Ethic of Craftsmanship: Creating Contingently Stable Worlds', in, M. Candea (ed.), *The Social after Gabriel Tarde: Debates and Assessments*, Abingdon, UK: Routledge, pp. 129–42.

Henderson, K. 1991, 'Flexible Sketches and Inflexible Data Bases: Visual Communication, Conscription Devices, and Boundary Objects in Design Engineering', *Science, Technology and Human Values*, 16(4): 448–73.

——— 1998, 'The Role of Material Objects in the Design Process: A Comparison of Two Design Cultures and How They Contend with Automation', *Science, Technology and Human Values*, 23(2): 139–74.

Ingold, T. 2007, *Lines: A Brief History*, London: Routledge.

——— 2011, *Being Alive: Essays on Movement, Knowledge and Description*, London Routledge.

Jensen, C. and Rödje K. 2010, *Deleuzian Intersections: Science, Technology and Anthropology*, Oxford: Berghahn Books.

Kelty, C. 2005, 'Geeks, Internets, and Recursive Publics', *Cultural Anthropology*, 20(2): 185–214.

Knox, H. (in press), 'Real-ising the Virtual: Digital Simulation and the Politics of Future Making', in, P. Harvey, E. Casella, G. Evans, H. Knox, C. McLean, E. Silva, N. Thoburn and K. Woodward (eds), *Objects and Materials: A Routledge Companion*, London: Routledge.

Lampland, M. and Star, S. L. (eds) 2009, *Standards and Their Stories: How Quantifying, Classifying, and Formalizing Practices Shape Everyday Life*, Ithaca, NY: Cornell University Press.

Latour, B. 1996, *Aramis: Or the Love of Technology*, Cambridge, MA: Harvard University Press.

——— 2005, *Reassembling the Social: An Introduction to Actor–Network Theory*, Oxford, UK: Oxford University Press.

Latour, B. and Woolgar, S. 1979, *Laboratory Life: The Social Construction of Scientific Fact*, London: Sage.

Law, J. 2002a, *Aircraft Stories: Decentring the Object in Technoscience*, Durham, NC: Duke University Press.

——— 2002b, 'On Hidden Heterogeneities: Complexity, Formalism, and Aircraft Design', in, A. Mol and J. Law (eds), *Complexities: Social Studies of Knowledge Practices*, Durham, NC: Duke University Press, pp. 116–41.

——— 2004, After Method: Mess in Social Science Research, London: Routledge.
Lévi-Strauss, C. 1966, *The Savage Mind*, Chicago, IL: University of Chicago Press.

Lury, C., Parisi, L. and Terranova, T. 2012, 'Introduction: The Becoming Topological of Culture', *Theory Culture and Society*, 29(4–5): 3–35.

McDonald, M. 2013, 'Bodies and Cadavers', in, P. Harvey, E. Casella, G. Evans, H. Knox, C. McLean, E. Silva, N. Thoburn and K. Woodward (eds), *Objects and Materials: A Routledge Companion*, London: Routledge, pp. 128–43.

Mitchell, T. 2002, *Rule of Experts: Egypt, Techno-Politics, Modernity*, Berkeley: University of California Press.

Mukerji, C. 2009, *Impossible Engineering: Technology and Territoriality on the Canal Du Midi*, Princeton, NJ: Princeton University Press.

Pickering, A. 2011, *The Cybernetic Brain: Sketches of Another Future*, Chicago: University of Chicago Press.

Riles, A. 2011, *Collateral Knowledge: Legal Reasoning in the Global Financial Markets*, Chicago, IL: University of Chicago Press.

Scott, J. 1998, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*, New Haven, CT: Yale University Press.

Sloterdijk, P. 2009, *Terror from the Air*, Los Angeles, CA: Semiotext(e).

Star, S. L. and Griesemer, J. R. 1989, 'Institutional Ecology, "Translations" and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology', 1907–39', *Social Studies of Science*, 19(3): 387–420.

Suchman, L. 2000, 'Organizing Alignment: A Case of Bridge Building', *Organization*, 7(2): 311–27.

Thrift, N. 2007, *Non-Representational Theory: Space, Politics, Affect*, London: Routledge.