Virtuous Detachments in Engineering Practice – on the Ethics of (Not) Making a Difference

Abstract

Engineering is a discipline that works through the paradox of transforming some aspects of the world whilst ensuring other parts remain the same. Engineering practice involves a constant attention to the contingent relational effects of complex systems, a practice that depends on producing a specific, material outcome that can come to exist and operate quite separately from the relations through which it was brought into being. In this chapter, we suggest that engineers effect this separation through what we call 'virtuous detachments' that allow them to limit their impact on local populations (whilst providing infrastructures for desired economic development) and on the local environment (as they carefully lay asphalt concrete across the landscape). Specifically, the paper focuses on procedures of appropriate detachment and disposal through which persons and materials are disconnected from their prior relations, and ultimately disposed of, in ways that minimize the possibilities of 'toxic' aftershocks. Focusing on the way in which engineers deal with the social and material relationality of their actions through practices of detachment, we characterise contemporary engineering as a practice which is centrally concerned with the problem of how to navigate the tricky terrain of personal, social and corporate responsibility.

Introduction

Enrique Solari Swayne's play, Collacocha[1], first performed in Lima in 1956, tells the apocryphal tale of a Peruvian engineer and his encounter with the forces of nature and society. Echecopar is the charismatic, driven and single-minded head engineer of an Andean mineral mine. More at home underground in the oppressive heat of the mine, than in the cosmopolitan society life of Lima, he is defined by his incapacity for conventional norms of social attachment and his unswerving belief in the structural integrity of the mine that he oversees as he works to transform nature in the name of progress. However, Echecopar's world is literally shaken to its core when disaster befalls the mine and a cave collapses killing 180 workers. The play follows Echecopar's denial of the impending catastrophe that is foretold by the shuddering and shaking of the mountain walls and the exhortations of his colleagues, his response to the disaster as it unfolds and the subsequent transformation that the event brings about in Echecopar's character. Master of all he surveys (Burnett 2000), yet powerless in the face of disaster, working in the name of social transformation yet seemingly indifferent to the social world that surrounds him, Echecopar provides a caricature of the modernist engineer. His attitude to impending disaster exemplifies the detachment that is necessary to make action possible in a world of dangerous uncertainties. And yet as the story unfolds, his character transforms as he struggles to reconcile such detachment with the impulse to engage with the complex and unforeseen social effects of engineering practice.

In this paper we set out to explore how these dynamics of detachment and responsibility play out in contemporary engineering practice. Since Latour and

[1]Swayne, E. S. 1955. Collacocha in Teatro peruano contemporáneo J. Hesse Murga, Ed. Madrid, Aguilar**:**319-409.

Woolgar's groundbreaking study of Laboratory Life (Latour and Woolgar 1979), the epistemological practices of attachment and detachment through which contemporary forms of knowledge are enacted has become a concern of both anthropology and science and technology studies. Anthropologists have a long-standing interest in the relational basis of human being, exemplified by their very particular commitment to study of kinship, as the study of the ways in which human beings create (open) and limit (close) relational fields (Strathern 1995). As such anthropologists have often been critical of modern knowledge practices which are deemed reductive of the inherent complexity and richness of social and material life, and are thus violent in their bureacratic and administrative effects (e.g. Scott, 1998; Kirsch, 2014). This critique of modern knowledge making has also been extended to the production of academic knowledge, including established forms of ethnographic research. The descriptive techniques of traditional ethnography that worked to stabilise and delimit relations between people and things by focusing on local practice and specific situational encounters, were unsettled by approaches that demanded attention to more extended geographical, social and political relations (e.g. Ong and Collier, 2005). Crossing over with science and technology studies in their interest in material relations, other anthropologists have been at pains to demonstrate the intrinsic sociality of things, tracing how objects acquire relational biographies as they circulate and become entangled in the complex histories of those who produce and dispose of them (e.g. Appadurai, 1986; Thomas, 1991). Central to these approaches has been a focus on relational ontologies, that is an understanding of all entities as multiple and emergent (Brown, 2001, Law and Mol, 2002, Mol, 2002, Authors, 2013).

Despite disagreements between anthropologists and actor network theorists as to how the relation is best construed, (as network or meshwork (Ingold 2011) for example),

there is a general agreement between scholars working in these fields, that relational dynamics should be the focus of analytical attention. Bruno Latour, for example, recovers Gabriel Tarde as the ancestral influence for this approach, revisiting the historical conflict between Durkheim and Tarde and suggesting that the latter offers a more productive approach to the relational complexities of material life (Candea 2010; Latour 2002, 2005). Deleuzian approaches have also been very influential in provoking scholars to attend to those heterogeneous assemblages that combine the material, the symbolic, the technical and the political in complex ways (Bruun Jensen and Rödje 2010).

Like the potentiality of a relativist approach which always finds a way of responding to seemingly indisputable realist problems (Grint and Woolgar 1992), a sensitivity to connection produces a cascading panoply of lines of interconnectedness and complexity. Following these connections produces a rich and multifaceted account of social process, but even the most vociferous adherent to a philosophy of connection finds that they must stop somewhere (Strathern 1996). The description of social realities entails its own practices of detachment, its own choices over what is deemed important or relevant for inclusion. A sensitivity to connection produces the impetus for re-description, but description itself never ensues without acts of detachment as well.

This acceptance that people, places and things are often far more entangled than they might as first seem, has consquently prompted critical analysis of those modern knowledge practices, that assume particular categorical structures and divisions without acknowledging the role that these analytical devices have in shaping the worlds that they set out to understand and transform (e.g. Bowker and Star 1999, Hacking 1999, Lampland and Star 2008, Lury and Wakeford 2012). Latour (1987,

1993) for example, has explored science as the enactment of particular set of practices and technologies whose capacity for establishing boundaries and divisions lies at the heart of their generative potential. Similarly Callon (1998) has analysed economics through attention to practices of 'framing' which he has argued renders the world calculable, and in doing so has produced the conditions within which the figure of a rational calculative agency is born. The importance of detachment to modern forms of knowledge production has also been explored imaginatively by scholars of the history of science who have shown in some detail what it takes to isolate (i.e. to fully identify and define) an object of experimental concern or professional attention (Shapin and Schaffer 1985). They have shown us how the value accorded to objectivity, derives at least in part from the skill and effort required to achieve this act of identification, describing the massively complex arrangements of persons, things, ideas and practices involved (Latour and Woolgar 1979, Daston and Galison 2007). Moreover, they have shown us that despite the efforts and the struggles, scientific expertise is not only hard won, but also socially vulnerable and needs a further institutional apparatus to protect the standards and the standing of the skilled practitioner (Bensaude-Vincent and Stengers 1996, Latour 1988).

This chapter moves from the study of science and economics into the sphere of engineering to explore the practices of 'detachment' in which engineers engage in the course of their work. If science and economics provide models of how the world is supposed to work, engineering operationalises these models to bring about concrete transformations for specific social effects. Just as in science, detachment is central to engineering's capacity to deal with complex webs of relationality. Nonetheless, the circumstances within which these detachments are deployed raise important new insights into the work that detachment does in processes of material transformation.

To explore this, we attend to the way in which engineers deploy modern techniques of objectivity in ways that both mirror and yet also exceed the practices of scientists with which these literatures have enabled us to become so familiar. Specifically, we draw attention to the way in which the requirements of detachment that engineers share with scientists are coupled with an equally important need to make a direct social difference. Thus we argue that in place of a primary commitment to the stabilisation of epistemological truths, the road construction engineers with whom we worked deployed practices of detachment as a means of negotiating a contemporary politics of responsibility.

Engineering is founded on an explicit imperative to transform the world through procedures of stabilization. This is not a latent project of a hoped for transformation in some as yet undetermined future, but a pragmatic engagement with socio-material transformations in the here and now. Engineering is a pragmatic science. It involves devising technical interventions to bring about concrete and tangible social effects. In this respect it is a practice that both understands and attends to the intrinsic relationality of things (materials and persons) while holding to the possibility of shaping, and containing, this play of relations. In practice this double-take on the nature of reality requires engineering professionals to confront the problem of how to deal with the unexpected consequences of actions which take place in a world that exceeds the more familiar detachments and stabilizations that made action possible in the first place. The play of expected and unexpected consequences of intervention thus puts the question of responsibility – personal, corporate, or social - both at the very heart of engineering and, paradoxically, outside its remit. We take this dilemma as our starting point, and drawing on ethnographic fieldwork carried out with highway engineers in Peru, we focus on the specific work required to make choices about

which relations should be left alone and which need to be transformed. In focusing on a variety of practices of detachment, we aim to better understand both how the problematic question of responsibility comes to be posed for experts interested in social transformation, and the possibilities that lie open for its negotiation.

The ethics of (not) making a difference

The engineers who we describe in this chapter were the employees of a consortium that had been established to build the Interoceanic Highway in the South of Peru. This was a large construction project which formed a central part of an ethnographic study of Peruvian roads that we conducted between 2005 and 2009. The Interoceanic Highway construction project was a bilateral Peruvian-Brazilian initiative to build a widened and asphalted road across the southern Andean highlands of Peru and through the Amazonian lowlands to the border between Peru and Brazil. The aim of the project was to produce a paved road between the sea-ports on the Pacific coast of Peru and those on the Atlantic coast of Brazil, providing a new means of transporting goods across South America and out to international markets in Europe and Asia. For four years we followed the ratification and construction of this highway, conducting ethnographic research with the engineers, planners, designers, scientists, government officials, local politicians, communities, drivers and travelers who were concerned in one way or another with the appearance of this 700km stretch of widened highway. We spent time with the engineering consortium: living in the engineering camps, interviewing senior managers and shadowing technicians and engineers in their daily work of analysis, construction and community relations. We also travelled the road, speaking to local residents about their memories and experiences of the construction project, and, building on Penny's prior ethnographic research in this part of Peru, participating in the daily life of communities along the route. Further afield our

interest in the road led us to the documents of the world bank, the loan agreements of Credit Suisse and the environmental concerns of the World Wildlife Fund amongst others. We came across historical characters from Poland, Russia and Japan, whilst the engineers we met linked the construction to French engineering prowess, African road building experiences, American standards and Chinese markets.

Our interest in the Interoceanic Highway project was prompted in the first instance by the explicit ambition of politicians and engineers to mobilise a technical and material process as a means of bringing about large-scale social change. The huge effort and expenditure that goes into infrastructure projects is justified by the causal relationship that is promised between the material intervention (construction of a road) and a particular social effect (e.g. economic prosperity consequent on enhanced connectivity). Engineers often spoke to us of the great pride that they took from their involvement in such a project of social transformation, identifying themselves as agents who might be seen as in part responsible for social progress and improvement.

However the contours of this responsibility were far from straightforward, as we soon found out as we began to follow the construction process in more detail. As technologies whose very rationale is the planned connection of distant places, roads also produce all kinds of unplanned linkages. An attention to the road construction process led us to explore the licit and illicit movements of goods such as beer, coca and drugs, the migration of people into and out of the area through which the road was to pass, the extraction of gold and timber, trades infused with both promise and danger, and the histories of slavery and exploration through which this region had originally been revealed as a site of productive potential. It also took us to the construction camps, which were set up for the workers and built to house some 2000 people. We watched how the engineering company established themselves in local

towns: how the site of the engineering camp was identified and surveyed, and the earth flattened to accommodate the white prefab cabins that began to appear in lines along the contours of the field. Teams of men in yellow overcoats dug trenches which were filled with concrete, drainage was installed to collect run off water, systems of garbage disposal were put in place with different colored bins for different kinds of waste. A checkpoint was built at the entrance to the camp and cars and lorries were allocated their space. Electricity was connected, satellite dishes installed and the basic accoutrements of life were brought in – bedding and televisions, tables and chairs, wardrobes and wash basins. In the nearby town certain restaurants were certified as safe to eat in. The road into town was widened so that lorries could get through, and notices were put up calling people to public meetings.

Once established, the camps attracted many more in search of work and more again who were employed in the layers of sub-contraction that surrounded the activities of the core partners to the consortium. People came from far afield to work in often dangerous circumstances, leaving behind families and provoking fears of crime and disease in their new host populations. On signing a contract of employment some were provided with healthcare, some with accommodation of differing standards, producing new dynamics of social differentiation and hierarchical organisation. Engineers were proud of the generative potential of the roads that they were constructing, but they were also fully aware of the risks, realising that social change was an unpredictable business.

In addition to the unpredictability of the social consequences of road construction, the material process of building a road itself was also generative of extensive knock-on effects which the engineering consortium had to manage on a day-to-day basis. As well as laying asphalt on the land, road construction involves the establishment of

quarries and materials dumps to dispose of excess construction materials, and the building of drains, bridges and pavements. The construction process also mobilizes many thousands of trucks and heavy machines which require maintenance and fuel that leeches into the environment. It involves the quarrying, transport, processing and disposal of huge quantities of earth, stone, and asphalt concrete; it has implications for the water tables and for future land usage.

The question of how to operate responsibly in these fragile and vulnerable local environments is one of the key issues that engineering companies face and one which the engineers took very seriously. We were told by one senior engineer that the company was like a flock of migrating birds. "We come and we move on. While we are here we have to fit into local people's ways of living, not interfere or damage their customs in any way. It is our responsibility to make sure that we leave these places as we found them". He argued that the company's responsibility was to produce a road which they could hand over to the people who had campaigned for it, letting them work out how to use it to their best advantage.

Building a road without undue consequences is generally presented by engineering as a naturalized ideal and the requirement to deal with all kinds of polluting issues is a necessary aberration to this ideal. However in practice, we found engineers were constantly engaged with the question of how to police the relational effects of their work. When the construction company begins on a project they have to associate themselves with the places that they are intending to move through. They have to lease the land for the camps and expropriate land for construction, they have to locate, excavate and dispose of materials, and contract and provision a local workforce. At the same time they have to manage their connection to the local setting. Their relationship with the changes that they effect has to be carefully negotiated through a

series of technical, lgeal, affective and descriptive practices. Whilst engineering entails the making of new attachments to new places, the overwhelming demands they generate at times threaten to compromise the integrity of the vision of clean, responsible infrastructural transformation that engineers are working to effect. Thus pollution is not a trivial issue but lies at the very heart of the engineering practices we set out to study. It is in this respect that we suggest engineering is a practice that relies on a series of acts of what we call 'virtuous detachment' that engineers perform to extract themselves from the complex web of connections that are required to get the job done. We suggest that a focus on these practices of detachment have the potential to teach us not just about the limitations of modern epistemology but also about how and why engineering knowledge takes the form it does, and what its generative effects might be. In what follows we trace three examples of 'virtuous detachments' in engineering practice: the work of detachment involved in planning a road; the role of detachment in the construction process; and the practices of detachment that are deployed to deal with community relations. In each we explore how detachments in engineering are practices that are oriented to the problem of how to delimit the contours of social, technical and political responsibility (see also McCarthy and Kelty, 2010).

Detachments of Anticipation

Whilst it is impossible for engineers to predict precisely what kinds of challenges they will face in the course of construction, the anticipation of potential problems is a key aspect of engineering practice, and constitutes our first sphere of 'virtuous detachment'. In order to even begin the process of construction, the thorny issue of how to delimit and define the field of action has to be tackled. When we began our research into the construction of the Interoceanic Highway, a feasibility study was

underway which had to provide robust multi-disciplinary evidence that the routes proposed and the technical specification of the road itself, were appropriate for the needs identified in earlier studies. Such evidence had to be compiled across multiple scales and required an analysis of soils, water courses, geological formations, climate and data on the social and economic conditions of the regions through which the road would pass including settlement patterns, modes of land tenure, existing transportation plans, trading activities, all considered from international, national, regional and local perspectives. The descriptions that were produced in the feasibility study had to manage huge complexity. Even though the study finally amounted to seven hefty volumes, it is of course the case that the data presented was but a fragment of what could have been told about the 700km stretch of territory over which the road was to be built. The data was selected carefully and presented in a compact and standardized form in order to generate a sense of trust that what was accounted for did indeed encompass the important facts. Ironically however, whilst the engineering consortium worked to generate trust through this document, their integrity was being challenged from other quarters.

When we first interviewed the chief engineer of the Interoceanic Highway project, we began by asking the simple question of what the company was doing. We were surprised to get a defensive response to what seemed to us a benign question. At the very early stages of the project, prior to the commencement of the building phase, we were looking for possible sites for ethnographic participation and engagement. He, however, was concerned that in asking for an account of the company's activities we were alluding to claims that were raging in the local press which criticized the company for being in a state of paralysis.

In Peru, large infrastructure projects are often assumed to suffer from endemic corruption (see Authors, forthcoming). Following a series of scandals concerning the widespread embezzlements of infrastructure funds during the Fujimori government, the press and the public frequently see infrastructure projects as a front for the rich and powerful to make personal gains. Everybody knew, the stories went, that millions of dollars had been invested in this project, and they knew that engineering personnel were in the area but there was little evidence on the ground that anyone was actually working. People in hard hats would sometimes appear in the towns along the proposed route, hold a meeting, take some measurements or samples and then be gone, but where were the heavy machines, where were the jobs, and why was the land not being torn up and re-laid? The people who had campaigned tirelessly for the road to be built were nervous that the lack of action was connected to a change of political will, or worse still that the company was embezzling the funds.

From the perspective of the engineer however, they were in a very difficult position. Acknowledging people's fears, he argued that the public were misinterpreting a lack of visible construction as a lack of activity. He worried that people fundamentally misunderstood how the construction process works, exasperatedly asking us 'what do people want? It takes a woman nine months to have a child – you just can't do it in three months!... It might be possible for 1000 people to build 1000 houses in 1000 days but it is impossible for 1000 people to build one house in one day!". People wanted to see some tangible activity but in the eyes of this engineer they were far from inactive, involved as they were in the huge amount of definitional work that had to be carried out before construction could begin.

The definitional work of the feasibility study was necessary to produce the initial stabilizations that allow work to commence: the materialization of legal contracts; the

securing of funding sources and the determination of ideal routes for the planned highway. Many of the figures and descriptions produced for such documents are provisional and might never even be used in the actual process of road construction which was to follow. The remarkable production of such a complex future-oriented study of a social and material terrain that itself was in flux, was achieved in conversations with layers of legal and technical regulatory frameworks that delineated the contours of what should and what should not be included in such studies and what should and should not be measured. Taking place out of public view, engineers designing the project were engaged in a complex process of consulting regulations, norms and standards in order to enable the conversion of 'raw data' into data that would produce a road project that could fulfil its generic social and political ambitions.

This is not to say that these plans that resulted from these calculations were without contestation. The proposed routing that the engineers had developed in the feasibility study was the subject of great conflict amongst those communities who feared that the road would bypass their villages. Community members in some towns protested by setting up road blocks to publicise their desire that the engineers routings be altered, hoping that in later studies their protestations might be factored into the decision about where the road might go. However, at the feasibility stage, the engineers were not directly involved in debates with communities about routing. They were nonetheless aware that decisions about where the road would go would be interpreted politically.

Whilst these studies were produced through huge amounts of research and analysis, then, we suggest that what was being produced were not so much the 'facts' of scientists ideally separated from the 'values' of interested parties on the ground

(Latour 2004), but were rather 'factish' (Latour 2010) attempts at delineating the parameters and ownership of the relative forms of responsibility that would arise in the construction process. Far from sitting comfortably on one or other side of the facts/values divide, the necessity that engineers face of working within regulatory framings has, we suggest, a doubling effect. In one respect it immerses the civil engineer in a world of politics – for the legal regulations and the technical norms are themselves produced through prior political process – for example, the outcome of decisions taken in parliament about how to contain the intrinsic multiplicity and indeterminacy of the material and social world. In another respect the regulations act as a buffer between the engineer and the world of politics. Just as the requirement to adhere to regulatory requirement appears to render them inactive in the eyes of those who are not involved in the construction process, it also provides a legitimate response to accusations that delays or routings might be due to a failure of engineers to enact proper or adequate social responsibility[2].

The political formation of the regulatory frame points us to the ways in which standards are devices that allow the engineer to control without personal responsibility, without having to acknowledge their involvement and certainly without having to confront the issue of what gets left out of the picture once the regulations are applied. These are the 'locationless logics' that Timothy Mitchell

[2] In the production of predictive data, none of the engineers that we worked with saw their role as one of transforming the standards to which they worked. The engineer who acted correctly followed the letter of the law, and we found engineers to be very committed to the ideal of normative standards. However amongst engineers it was also common for them to acknowledge that standards are not always strictly adhered to. Indeed the obligation to find pragmatic solutions to unforeseen events was a necessary skill, albeit a dangerous one that made them vulnerable to the criticisms and rumors of malpractice that construction projects generate. However, such rumors served to reinforce the image of virtuous detachment expected of a professional engineer who is shielded by regulations and standards from individual fallibility, self-interest and personal opinion.

refers to in his book The Rule of Experts which describes the emergence of the modern economy in Egypt where the human cost of regulatory regimes and the implementation of 'rational procedures' dramatically undermines the narrative of progress and social transformation that the macro-economic evidence seems to support (Mitchell 2002). And so too with the engineers we worked with in Peru. Regulatory standards, norms and numerical standards helped the engineers to keep their distance – and to show that their designs had been arrived at rationally – unswayed by volatile circumstances on the ground such as local protests, floods or landslides. The key designers, based in Brazil, never even visited the site where the road was to be built but made their predictions on the basis of collated data sets provided by those in the field.

And yet, there is a twist here which we found interesting. While all the engineers we met understood the regulatory devices as providing the fundamental grounding of their expertise, these same people were the first to point out that social and material worlds are inherently unstable, that the anticipatory data they produce is therefore provisional and that the standards are not always fixed. This insistent acknowledgement of a volatile uncertain world led us to think about the design process in the terms that Annelise Riles coined in relation to her ethnography of Japanese financial traders – who acted in accordance with the subjunctive philosophy of the 'as if' (Riles 2011). The anticipatory work of defining a field of action, foregrounds practices of detachment whereby engineers use standards and regulations to act as if the world could be controlled, as if the data were stable. In Riles' terms the 'as if' abstractions are useful fictions, accounts that enable political terrain to be negotiated, decisions taken, funders and publics kept informed and on board, but only for so long.

Road construction parts with futures trading because at some point somebody starts to build a road. The work of detachment which generated data at the anticipatory stage of the construction process was itself detached from the actual construction of the road, through the chronograms and organizational charts of project management. If the work of anticipation appeared to allow the question of responsibility to be deflected away from the individual engineer, responsibility reappeared once the engineers turned their attention to the construction process itself. Here we find ourselves no longer in a pure realm of future-oriented facts determined by externally agreed standards, but in the muddy materiality of production.

Remarkably, the feasibility study literally disappeared from view once construction began, filed away behind cabinet doors. The final specification stipulated in the feasibility study remained important as it was integral to the contract that the state drew up with the construction company, but as other concerns took over, the subjunctive philosophy of 'as if', was supplemented and replaced by what we call a conditional philosophy of 'as long as' whose primary requirement was the functionality of the end-product – a road that works (Authors, forthcoming).

Responsive Detachments

Six months after we had worried the engineer by asking him what the company was doing, life on the road had transformed into a hive of activity. One site of intense work was the field laboratories where the detailed analytical work of construction takes place. These laboratories offer an interesting contrast to the data gathering directed to the completion of the feasibility study and, as we hope to show, reveal 'virtuous detachments' of a somewhat different order. Whilst still invoking

abstraction and still mediated by number, this time these calculations are overtly shaped by the engagement of the engineer and his technical assistants with the materials that they are looking to transform. Here politics is seemingly pushed right out of the picture as a concern with the relations between political actors and finance capital are excluded to allow relations between things to appear. Nonetheless, as we will see, the outcome of these practices of detachment are still somewhat different to the detachments of scientists in their pursuit and production of stable 'facts'.

Laboratory technicians work with soil samples that have been collected from along the length of the projected route. On arrival at the lab they are graded and sorted. The process of classification starts off with an ordering of matter, but it does so with the broader aim of determining not only abstract and continuous details about the soil – its weight, its volume or its particle size, but also the dynamic qualities that the material could potentially manifest. It is these potential qualities which the engineers seek to make visible under experimental conditions. We often heard engineers talking about the battles that they had with their materials as they struggled to build the road: mud that was like an undulating mattress; capricious water spouts which, however hard you tried to tap them would reappear in different places; the recalcitrant webbing that would not unfold and concrete that would not set. The job of the laboratories was to transform this site specific and embodied experiential knowledge of unruly matter into a mathematical description that would make the terms of its unstable qualities knowable and the possibilities for its stabilization calculable – clearly an exercise in virtuous detachment – but which, unlike the data gathering of the design process is carried out through intense, experimental engagement with the material qualities of things.

Watching a technician carry out the ‘plasticity’ test on a sample of soil, she explained to us that experimentation was a central part of the process of discovering the qualities of the soil she was working with. She explained that once they have been able to determine, through repeated testing, when the soil sample achieves what they referred to as the ‘limite liquido’ (liquid limit), the amount of water that has been added to achieve this level is written into a notebook thus stabilizing this piece of knowledge about the mud and allowing the second stage of the test to begin. However the process of testing does not take place in a relational void. As pointed out earlier, an awareness of the qualities of the materials under analysis precedes their appearance in the lab. Road projects were characterized by engineers in terms of the material challenges that they threw up – earth that was too muddy, a lack of sand, an abundance of rock, the presence of earthquakes. The tests that took place in the laboratories were conducted in relation to an already formed expectation of the qualities of the materials undergoing the test – these were the hypotheses built into the pre-determined measures and procedures of the experimental process. In the field labs engineers encouraged the materials to manifest their particular qualities in numerical form. The purpose of the analysis was to identify the suitability of the materials found along the road for use in the construction process, and to assess the stability of the current road surface so that a new surface could be successfully laid on top. The method of analysis incorporated all the histories of experimentation, and like a machine, operated by the engineer, appeared to become the conduit which is capable of transforming matter into number and back into matter. The engineer as operator, on the other hand, is the one responsible for encouraging the matter to pass through the machine of scientific method in the correct way, a skill which requires an embodied sensitivity to the process (Collins 1985). They find themselves engaged in the act of

coaxing the numbers out of the matter, with mathematics and experimental method providing a means of translating a relationship between engineers and the matter that they engage with on a day-to-day basis and that is already knowable in other ways.

The tendency to see scientific practice as a stripping out of certain social relations, prevents us from focusing on the productive aspects of such practices of detachment. Far from providing a reduced version of a relationship to the soil, in this case we can see that the experimental relations which stabilized matter into a numerical equivalent were the means through which engineers could become located within a nexus of relations of responsibility. In not only understanding materials, but also mobilising them for future effects, practices of detachment in the laboratories can be seen as provisional acts in a longer process whereby the engineer must take responsibility for future material relations (i.e. the performance of the road once constructed). Operators of a historically emergent method, custodians of data, it is in the laboratories and in their work with materials that engineers delimit the domain for which they can be responsible.

In the laboratories, we find that detachment does not deflect the problem of responsibility but rather defines those practices for which engineers might legitimately be held responsible. In the laboratories engineers take responsibility for the intimate relationship that they are able to develop with materials. Echoes of the etymology of the term 'responsibility' remind us of the communicative origins of the act of being responsible, the requirement to answer or to provide a reply[3]. Connected to everything but unable to respond, engineering would find itself without a language

[3] "Anglo-Norman responssable, ressponsable, Anglo-Norman and Middle French responsable answerable, entitled to an answer (13th cent. in Anglo-Norman in spec. legal use), answerable, required to answer (14th cent. in Anglo-Norman in spec. legal use), falling under a particular jurisdiction (14th cent.), accountable, standing surety for (15th cent.), that responds, that constitutes a reply (15th cent)." Oxford English Dictionary, 2011.

to communicate with matter, nor a means of judging the success or failure of its action. Through mathematically informed methodologies of analysis and experimentation however, numerical translations come to provide a language within which engineers can claim a limited domain of 'respons-ability[4]'. The actions of trial and error, in a constant conversation with materials which is mediated by numerical data is the action that produces a material object like a road.

Whilst mathematics enables materials to enter into a form of conversation with humans, it at the same time makes incommunicable other kinds of non-mathematical responses to the engineering process. If engineers have a language through which they can respond to matter, their status as engineers is challenged when they are asked to respond to other claims that are not capable of being translated into numerical form[5]. It is to ways in which the virtuous detachments of engineering are challenged by the slippery social claims of various different groups, and consequently the way in which the domain of the engineer is detached from other fields of action that we turn in the following section.

Incommunicable Dilemmas

A road block had been set up by one of the communities living alongside the road. People were upset by the removal of soil from their fields. Their protest was at first seen as a failure to 'let go' of their land in order to allow for the road, which was paradoxical given the strength of their campaign to get the road built. But as

[4] Donna Haraway also uses the formulation of respons-ability in her work on human-animal relations. Our use of the term differs from Haraways usage – whereas Haraway wishes to establish respons-ability as a manifesto for human-animal co-becoming, we use the term to describe the boundary making practices through which engineers demarcate who they can legitimately engage with in a professional capacity, and thus where the contours of their liability lies.

[5] See Callon, M. 1998. The Laws of the Markets Oxford, Blackwell. for an analysis of how economies are similarly constituted through the detachments of economic theory.

discussions ensued it transpired that their main concern was about the soil itself. They wanted it to be relocated for their future use but the company was insisting on taking it away. As we have seen, much of the engineers' work of detaching and reattaching materials takes place in the laboratories. One of their tasks is to identify the sites from which materials can be drawn (quarries, river beds etc) and sites where excess materials can be dumped. The laboratories assist in determining the compatibility of materials, and consideration is given to the effects on the water table and environmental stability. Soils are potentially toxic if misplaced. The company understood that the community might not want to see the soil carried away, but they only had the resources to test specific reception sites and could not carry out tests for ad-hoc relocations. The protest had arisen because the engineers could only respond to soil as either a chemical substance for which as we have seen they have a responsibility in mathematical analysis, or an economic resource for which they could refer people to the state compensation schemes, deferring responsibility onto another body with another set of standardizations and delimitations. The protesters however, had other claims that related more specifically to their sense of loss. The soil is a substance that they had cared for, that has its own vitality, and powerful relational connectivity to their community. It was part of them and its loss was painful despite their desire for the road (Author 2002, 2010).

This problem with the soil recurred in relation to the obligation of the company to return land that they had leased for the construction of the engineering camps, the dumps and the quarries. They are obliged by law to return these sites to the owners in the same state in which they were found. The task is tricky for various reasons – former owners are sometimes keen to strike deals for all kinds of modifications which suit their future ambitions. But there is a more intransigent problem of how to 'repair'

the land once it has been substantially transformed. The repair is in effect not a return to a prior state but the substitution of one piece of land for another – the substitute deemed equivalent by reference to a set of legally stipulated standards. Given that the transformational projects of civil engineering also require the engineers to leave places 'as they find them', the repair is in some respects a highly performative conjuring trick. A successful project is one where it appears by the end, that the new road has simply been laid down over the land which the engineer had no intention or right to change. Nature remains unified and unblemished whilst the technology of social progress is laid down upon it. Yet as we have seen, this sleight of hand is not an inevitable outcome but the result of considerable work, particularly with respect to the company's need and right to designate the relational qualities of the land prior to their interventions.

From the perspective of some landowners the repairs might be legal but the equivalence is clearly partial. People complain, for example, that the layer of top-soil provided is insufficient for agricultural purposes. Their complaints point to a sense that the company does not attend to their understandings and experience of what makes land viable. Meanwhile the production of legal equivalence allows the company to defer responsibility to those left to make something of their transformed world. The move effectively produces working limits to the company's remit of responsibility by separating the construction process from the complex and extensive social relations through which land sustains its productive vitality. From the perspective of the engineers the possibility for acting responsibly comes from an act of detachment rather than from following an ill-defined and unlimited engagement.

From these examples we can see that engineering companies are able to limit their engagement with respect to the potential effects of their transformational practice. In

the first case the land cannot be returned because there are no resources (or obligations) to ensure the compatibility of existing and newly introduced soils and so the soil is removed to the safety of the previously designated (and tested) dumping ground; in the second case where repairs have to be made the company mobilizes its resources with respect to a pre-specified set of relations. In both cases the cuts which they perform are highlighted as the ones that are crucial for the designation of relevant material qualities and capacities in the task of producing a road that is successful 'as long as' it's material coherence is not compromised.

We are of course, in familiar neo-liberal terrain where the ethics of corporate responsibility emerges in practice as a regulatory framework that works to limit corporate responsibility to a specific set of relations that corporations themselves produce as relevant. As private corporations take on the work of infrastructural development that used to be the domain of the state, the question of in whose interests such corporations are working become pertinent. Corporate Social Responsibility allows private corporations to demonstrate that they are both serving the interests of shareholders and the public, although, as studies of CSR have demonstrated inherent tensions regarding questions of responsibility remain (See Welker, 2009). On the Interoceanic Highway project, Corporate Social Responsibility was enacted in the form of specific legal negotiations like those described above, and in a number of discrete charitable projects: e.g. providing health advice and dental care to local communities. Beyond that the engineering company simply teach local people that the rest is up to them. Once the practice of expert detachment determines the conditions within which responsibility can be claimed, it leaves as a remainder, or externality, all of the other unforeseen consequences for which they cannot take responsibility. With the practices of detachment having produced the terms within which every action

must have a potential cause, every phenomena the potential to be associated with a prior action, the conditions are produced within which someone must ultimately step up to the mantle and take responsibility for the successes and failures of the road as technology of social progress. The message that local populations frequently hear is that it will be their fault if it all goes wrong. However to stop at this diagnosis would be to see the work of detachment as reaching a premature resolution. In actual fact, what we saw in the process of road building was the repeated unsettling of the forms of detachment which engineers were required to deploy in order to stabilize social and material environments. Working in defense of local populations and the natural environment, both of which are rendered as the passive subjects of state-led projects of material transformation, development organizations and ecological groups, work hard to re-articulate a language through which states and corporations might be forced to recognize a more extended sense of responsibility. Frequently this entails the attempted translation of previously incalculable qualities into numerical form, in an attempt to turn issues such as standard of living, healthcare, pollution and human rights into those which can be evaluated via material or economic calculations.

Responsibility thus appears to be not simply a moral imperative nor a stable position toward which one might aim, but the outcome of acts of contestation which work to draw out the qualities of things in order to make them elicit a response from a variety of different actors. Delimiting and detaching is more than just an epistemological position, or a form of ignorance or blindness to the interconnectedness of everything. In civil engineering it provides the conditions of possibility for action, for keeping some things in their place so that others can move, keeping some things stable so that others can change and for generating a language through which transformation will occur. A world without detachment would be a world without transformation, a world

where “we can no longer pass. We can no longer create. We can no longer live.” (Latour, 2010:28). Far from merely celebrating attachment in the face of its other, what the work of engineers teaches us is that detachment is productive and that part of its productivity comes from the challenge it poses to the consolidation of any particular form of change.

Conclusion

In this paper we have tracked the detachments upon which the modern project of engineering is reproduced. In doing so we have illustrated how the detachments of engineering practice are so much more than simple reductions of complexity that enable the reproduction of coventional contours of power and inequality. Instead we have demonstrated that detachment in engineering practice is primarily a matter of navigating a complex and uncertain terrain regarding the demarcation of political responsibility. We have described three related moments of what we have thus called ‘virtuous detachment’ to illustrate that the relationship between practices of detachment and enactments of responsibility is not settled, but an ongoing process of political negotiation. In the mode of detachment, the question of responsibility is both the impetus for engineering, but also its limit condition.

In Swayne's Collacocha, the protagonist Echecopar intrigues us for he is the very embodiment of the predicament of the engineer. With no corporation, state, or public upon whom to deflect the question of extended responsibility, we find a character who has internalized all the force of engineering and the possibilities and dangers that it holds for social transformation. Echecopar is passionate about the capacity of engineering to transform Peruvian society and equally devastated at the destruction of the social/natural edifice he inhabits in the form of his mine. The final act of the play

invites us to watch as Echecopar tries once again to generate through material intervention, a better future for his country, this time, having learnt that the detachment he exhibited from his fellow workers when he ignored their expertise and their warnings of impending disaster, placed him in a perilous position. The tale of Collacocha is not a call for connectedness, but an exhortation to be aware of both the dangers and the potential of detachment in engineering practice. Inspired by Swayne and his protagonist Echecopar, we have argued that an acknowledgement of the centrality of detachment allows for a reassessment of a theoretical position that privileges the ontological importance of attachment (everything is connected to everything else) and critiques those moments when attachments are curtailed. In contrast Echecopar and the engineers we worked with have have led us to consider the truly radical nature of a proposition that maintains the generative potential of detachment. By providing us with an archetype of the struggles of the modern engineer, Echecopar gives us a means of re-interpreting the particular struggles that infrastructural engineers face in bringing contemporary infrastructure projects into being. These struggles are not simply about the work of stablising knowledge but are rather ways of negotiating the relationship between personal, corporate and social responsibility that remain at the heart of contemporary projects of material transformation.

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