an infrastructure development as there is still a considerable amount of uncertainty about how the infrastructure will evolve. And this uncertainty cannot be settled up front; it has to unfold gradually. Gateways may prevent those in the position of making decisions from acting like 'blind giants'.

But it is not only during the early phases that sidestepping confrontation is vital. It is also important in a situation where there are already a number of alternatives, none of which is strong enough to 'conquer' the others. In the case of e-mail systems, for instance, many different proprietary systems and protocols were developed before the Internet or other standards were available. On this basis, it has been considered more convenient to develop the different protocols separately and link the networks together through gateways.

A more neglected role of gateways is the way they support modularization. The modularization of an information infrastructure is intimately linked to its heterogeneous character. The impossibility of developing an information infrastructure monolithically forces a more patchlike and dynamic approach. In terms of actual design, this entails decomposition and modularization. The role of a gateway, then, is to encourage this required decomposition by decoupling the efforts to develop the different elements of the infrastructure and coupling them tightly only at the end. This allows a maximum of independence and autonomy.

Modularization, primarily through black-boxing and interface specification, is, of course, an old and acknowledged design virtue for all kinds of information systems, including information infrastructures. But the modularization of an information infrastructure supported by gateways has another, essential driving force that is less obvious. As the development is more likely to take ten years than one, the contents are bound to evolve or 'drift'. As a result, previously unrelated features and functions are brought together and need to be aligned. The coupling of two (or more) of these require a highly contingent, techno-economical process, a process that is difficult to design and cater for. Cable TV and the telephone have a long-standing history of distinctly different networks. They were conceived of, designed, and appropriated in quite distinct ways. Only as a result of technological development and legislative deregulation has it become reasonable to link them. This has given rise to an *ecology of networks* that may be linked together later by gateways.

5

Actor-Network Theory and Information Infrastructure

ERIC MONTEIRO

The study of the economics of infrastructure has already begun to show how the development, introduction, and use of an information infrastructure are an involved socio-technical process of *negotiation*. The open-ended character of this process—the stumbling, the compromises, the way non-technical interests get dressed up in technical disguise—calls for an analytic vehicle that helps tease out interesting and relevant issues related to the 'management' of such processes.

This chapter introduces, outlines, and illustrates one such vehicle—namely, actor-network theory (ANT). We introduce ANT by briefly positioning it within the broader landscape of conceptualizations of technology and society. This exercise is intended to be neither comprehensive nor systematic. It is aimed at spelling out those underlying aspects of an information infrastructure towards which ANT makes us sensitive.

First and foremost, ANT, especially in the minimalistic version outlined here, offers an illuminating vocabulary to describe information infrastructure. It provides a language to describe how, where, and to what extent technology influences human behaviour. This is valuable when identifying the influence of seemingly grey and anonymous technical components such as standards or systems modules that are already installed. In particular, it allows ANT to zoom in and out of a situation as required.

This implies that the granularity (that is, the scope, depth, and level of detail) of the analysis is flexible. Sometimes a comprehensive set of interconnected modules and systems is collapsed into one node; sometimes the focus is on the relative contribution of each of the modules; sometimes a detailed analysis is needed of the design of one specific module. This kind of flexibility is indispensable in any analysis of information infrastructure.

The reason for outlining ANT in relation to the development and establishment of information infrastructure is the need critically to assess the descriptions of this issue provided by traditional management literature. This literature—as discussed in Chapter 2—is dominated by top-down, rational, decision making.

There are, of course, alternative perspectives on strategic information systems in general and information infrastructures in particular. For example, there exists an

interesting body of literature on critical management thinking related to information systems. This literature is sensitive to issues of power distribution (Knights *et al.* 1997), the lack of top-down control (Walsham 1993; Ciborra 1994), and rhetorical devices (Alvesson 1993). An ANT-influenced perspective on information infrastructure provides a fruitful supplement to such a body of literature. In particular, it provides a different insight into how information systems and business strategies are 'aligned' (see Chapter 2). Rather than portray 'alignment' as traditional management thinking, ANT offers a different account. Alignment in the sense of ANT, to be spelled out in greater detail below, differs along several, crucial dimensions, which turn the notion of alignment into something else. It is heterogeneous, meaning that there is an open-ended array of 'things' that need to be aligned, including work routines, incentive structures, training, information-systems modules, and organizational roles. It follows immediately that there can be no strict top-down control over such a collection of 'things'. Hence, ANT leans heavily towards a bottom-up concept of alignment and strategy formation. Furthermore, ANT emphasizes strongly the performative or process aspect of alignment. Alignment, according to ANT, is not the result of any top-down plan or decision. It is the achievement of a process of bottom-up mobilization of heterogeneous 'things', as Latour (1996: 86) underlines in his phrase 'every day is a working day'.

ANT belongs to the strand of thinking that questions given categories. It is accordingly more geared towards *performing* order through the establishment of facts, effects, beliefs, or technological solutions. Order is the effect of an achievement—it is not given a priori. The challenge is to develop an understanding of what this achievement is made up of, to unpack the dynamic, socio-technical process unfolding over time that as a net result constructs reality and order. This is an operationalization of the essence of social constructivism: it is waging war against essentialism and is devoted to 'understand[ing] how it is that durability is achieved' (Law 1999: 4).

The remainder of this chapter is structured into two parts. First, ANT is located within a broad strand of critical thinking around information systems and technology. We then turn to the core of this chapter, and outline a selection of key concepts and issues in ANT relevant to a grasp of the challenges of establishing a working information infrastructure. In so doing, we will draw upon illustrations from the cases described in greater detail in the case studies in Part Two of this volume.

ANT in Context

The non-technical in information systems research

The relationship between technology and society may be conceptualized in many ways. We embrace the fairly widespread belief that IT is a—perhaps the—crucial factor, as it simultaneously enables and amplifies the currently dominating trends for the restructuring of organizations (Orlikowski 1991; Applegate 1994). The problem, however, is that this belief does not carry us very far; indeed, it is close

to becoming a cliché. To be instructive in an enquiry concerning current organizational transformations, one has to supplement it with a grasp of the interplay between IT and organizations in more detail. We need to know more about how IT shapes, enables, and constrains organizational changes. A continuum of alternatives can be illustrated by two extreme end points. On the one hand, there is technological determinism, which holds that the development of technology follows its own logic and that the technology determines its use (Winner 1977); on the other hand, there is social reductionism or constructivism (which comes close to technological somnambulism (Winner 1977; Pfaffenberger 1988)), which holds that society and its actors develop the technology they 'want' and use it as they want, implying that technology in itself plays no role. A series of Braverman-inspired studies appeared in the late 1970s and early 1980s biased towards a technological-determinist position, arguing that the use of IT was but the latest way of promoting management's interests regarding deskilling and control of labour. Later, a number of studies nearer to the social-constructivist end of the continuum were produced, which focused on diversity of use among a group of users and displayed use far beyond what had been anticipated by the designers (Henderson and Kyng 1991).

A more satisfactory account of the interwoven relationship between IT and organizational transformations is lacking. More specifically, we need to learn, not just that this interplay exists, but how it works. This implies that it is vital to be more concrete with respect to the specifics of the technology. As an information system (IS) consists of a large number of modules and interconnections, it may be approached with a varying degree of granularity. We cannot refer to it indiscriminately as IS, IT, or computer systems. Kling (1991: 356) characterizes this lack of precision as a 'convenient fiction', which 'deletes nuances of technical differences'. It is accordingly less than prudent to discuss IS at the granularity of an artefact (Pfaffenberger 1988), the programming language (Orlikowski 1992), the overall architecture (Applegate 1994), or a medium for communication (Feldman 1987). To advance our understanding of the interplay it would be quite instructive to be as concrete about which aspects, modules, or functions of an IS enable or constrain which organizational changes—without collapsing this into a deterministic account (Hanseth *et al.* 1996).

The majority of scholars in the field adhere to an intermediate position somewhere between the two extreme positions outlined above. Their accounts end up with the very important, but all too crude, insight that 'information technology has both restricting and enabling implications' (Orlikowski and Robey 1991: 154). This insight—that IT enables and constrains—is reached using a rich variety of theoretical frameworks.

ANT represents one framework within this restricting/enabling regime outlined above. Given the interdisciplinary character of information systems research, there has never been a lack of candidates for theoretical frameworks. There has always been a steady import as indicated in the discussion above. ANT has been employed neither for a long time nor extensively within information systems research. It has

been used in a few interpretative case studies (such as Timmermans *et al.* 1995; Hanseth and Monteiro 1996; Walsham 1997; Jones 1998), but must still be said to remain on the margins.

In what follows, we argue that ANT is particularly relevant to developing information infrastructures, because of the way it lends itself to empirically underpinned studies (Monteiro and Hanseth 1995; Jones 1998).

Science and technology studies

ANT has not, of course, developed out of nowhere. To trace its roots in any detail would quickly take us beyond the scope of this chapter. Still, a brief look at the background will be useful.

ANT was born out of the interdisciplinary field of science and technology studies (STS). This field, which emerged in the 1970s, is grounded in a fairly simple observation. The way science is actually done—not how it is normatively supposed to be carried out—and the way technological artefacts are actually designed—not how textbooks in engineering instruct us—have largely been ignored by the social sciences and the humanities. The essence of STS, then, is to ask the following question: if we sideline all espoused theories about this realm and instead bring along the critical and empirically underpinned apparatus from sociology, history, and anthropology, what does the process of producing science and technology look like?

Looking back, a handful of approaches can be identified under the general label of STS (Bijker *et al.* 1987; Law 1991; Bijker and Law 1992; Williams and Edge 1996):

- the systems thinking developed by Hughes (1983, 1987, 1994), which describes the historical development of technological infrastructure by emphasizing the issues of inertia and heterogeneity;
- the social construction of technology (SCOT), which emphasizes the interpretative flexibility that the relevant actors have in ascribing meaning to a technological artefact (key contributors are Bijker, Pinch, and Woolgar);
- actor-network theory (ANT), as developed by Latour, Law, Callon, and Akrich, and as presented further below;
- the sociology of scientific knowledge (SSK), which is devoted to unravelling the infights and manoeuvring that go into the establishment of a scientific fact (key contributors include Collins, MacKenzie, and Traweek).

Related to STS, but largely decoupled from it, there is a strand of thinking that has been influential, not least within IS research—namely, socio-technical systems thinking. This approach has, however, seemed to fade away. Socio-technical systems thinking has lost its ground—and, ironically enough, its old abbreviation, STS. In fact, by the end of the 1990s the label STS was to an increasing degree associated with science and technology studies. From the point of view of ANT, Law (1991: 8) underscores the main problem with socio-technical systems thinking—

namely, that, 'despite the pioneering work on sociotechnical systems by the Tavistock group in the 1960s, *technology does not appear to be productively integrated into large parts of the sociological imagination*' (emphasis added).

Key Concepts (the Minimalistic Version)

What is an actor network, anyway?

The term 'actor network', the A and N in ANT, is not very illuminating. It is hardly obvious what the term implies. The idea, however, is fairly simple. When going about your business—driving your car or writing a document using a word processor—there are a lot of things that influence how you do it. For instance, when driving a car, you are influenced by traffic regulations, previous driving experience, and the car's manoeuvrability; the use of a word processor is influenced by earlier experience, the capabilities of the word processor, and so forth. All of these factors are related or connected to how you act. You go about your business not in a total vacuum but rather under the influence of a wide range of surrounding factors. The act you are carrying out and all of these influencing factors should be considered together. This is exactly what the term 'actor network' accomplishes. An actor network, then, is the act linked together with all of its influencing factors (which again are linked), producing a network.

An actor network consists of and links together both technical and non-technical elements. Not only the car's engine capacity, but also your driving training, influence your driving. Hence, ANT talks about the heterogeneous nature of actor networks. In line with its semiotic origin, actor-network theory is granting all entities of such a heterogeneous network the same explanatory status, as 'semiotics is the study of order building . . . and may be applied to settings, machines, bodies, and programming languages as well as text . . . [because] semiotics is not limited to signs' (Akrich and Latour 1992: 259). It is 'a ruthless application of semiotics' (Law 1999: 3).

It might perhaps seem a radical move to grant artefacts the same explanatory status as human actors: does not this reduce human actors to mere objects and social science to natural science? We do not intend to pursue this rather dogmatic issue and fully embrace Law (1992: 383) that this 'is an analytical stance, not an ethical position'. Interested readers should consult Callon and Latour (1992) and Collins and Yearley (1992).

For the present purposes, what is important is that this move has the potential to increase the level of detail and precision. More specifically, if we allow ourselves not to distinguish a priori between the social and technical elements of a socio-technical web, we are encouraged to undertake a detailed description of the concrete mechanisms that combine to glue the network together—without being distracted by the means, technical or non-technical, of actually achieving this. If we are really interested in discovering influential factors regarding the way we drive, we should focus on what turns out to be actually influential, be it technical (the engine's capacity) or non-technical (the driver's training).

In relation to the development of a working information infrastructure, how should we think about actor networks, where are they, and how should they be identified? A fruitful way of approaching this, which links up with the more general arguments that IS design and use have to be contextual and situated (Suchman 1987), is to view the actor network as the context. An actor network is literally the network of heterogeneous materials that make up the context. This can be illustrated from the IBM case study (see Chapter 7). The actor network related to the customer-relationship-management (CRM) effort includes: the contracts where middle managers pledge their commitment, the jungle of existing modules and systems, the hierarchical power structure, incentives, the habit embodied in employees of seeing organizational efforts come and go. Hence, the actor network is those elements in a context that shape action; 'the argument is that these various networks *participate* in the social. They *shape* it' (Law 1992: 382).

Equating an actor network with the specific characteristics—some technical, others not—of a context says something about what an actor network is. But it does not say what it is not or, more precisely, how to delineate one actor network from the next. The notion of an actor network, quite literally, instructs us to map out the set of elements (the network) that influence, shape, or determine an action. But each of these elements is in turn part of another actor network, and so forth. Hence, if you take this in too literal a sense, unpacking *any* actor network will cause an explosion in terms of complexity. You end up with the whole world in your lap every time. To illustrate this, tracing the actor network related to CRM would lead to the disciplinary regimes of structured methods, the political-economical manoeuvring to preserve IBM as a potent, US-based company, the processes by which IBM's portfolio of data communication protocols connect to external protocols such as the Internet, the military-industrial heritage of the Internet, and so on. In terms of methodology, this apparently makes the analytic tool of an actor network utterly unmanageable. This, however, is a distortion of ANT. It is rather the case, we argue, that it is overly ambitious (or naive) to expect ANT (or any other theoretical framework for that matter) to instruct you how to separate foreground from background (Bijker 1993). Employing ANT still requires a researcher to make critical judgements about how to delineate the context of study from the backdrop.

Inscription and translation

Two concepts from ANT are of particular relevance: inscription (Akrich 1992; Akrich and Latour 1992) and translation (Latour 1987; Callon 1991, 1994). The notion of inscription refers to the way technical artefacts embody patterns of use: 'Technical objects thus simultaneously embody and measure a set of relations between heterogeneous elements' (Akrich 1992: 205). The term 'inscription' might sound somewhat deterministic by suggesting that action is inscribed, grafted, or hard-wired into an artefact. This, however, is a misinterpretation. By balancing the tightrope between an objectivistic stance where artefacts determine their use and a

subjectivistic stance holding that an artefact is always interpreted and appropriated flexibly, the notion of an inscription may be used to describe how concrete anticipations and restrictions of future patterns of use are involved in the development and use of a technology. Akrich (1992: 208) explains the notion of inscription in the following way:

> Designers thus define actors with specific tastes, competencies, motives, aspirations, political prejudices, and the rest, and they assume that morality, technology, science, and economy will evolve in particular ways. *A large part of the work of innovators is that of 'inscribing' this vision of (or prediction about) the world in the technical content of the new object* . . . The technical realization of the innovator's beliefs about the relationship between an object and its surrounding actors is thus an attempt to predetermine the settings that users are asked to imagine . . . (emphasis added)

Stability and social order, according to ANT, are continually negotiated as a social process of aligning interests. This takes place in 'the process that is called translation, which generates ordering effects such as devices, agents, institutions, or organizations' (Law 1992: 366). As actors from the outset have a diverse set of interests, stability rests crucially on the ability to translate—that is, re-interpret, represent, or appropriate—others' interests to one's own. In other words, with a translation one and the same interest or anticipation may be presented in different ways, thereby mobilizing broader support. A translation presupposes a medium or a 'material into which it is inscribed'—that is, translations are 'embodied in texts, machines, bodily skills [which] become their support, their more or less faithful executive' (Callon 1991: 143).

In ANT terms, design is translation: users' and others' interests may, according to typical ideal models, be translated into specific 'needs'; the specific needs are further translated into more general and unified needs, so that these needs can be translated into one and the same solution. When the solution (system) is running, it will be adopted by the users, who translated the system into the context of their specific work tasks and situations.

In such a translation, or design, process, the designer works out a scenario for how the system will be used. This scenario is inscribed into the system. The inscription includes programmes of action for the users, and it defines roles to be played by users and the system. In doing this, the designer is also making implicit or explicit assumptions about the competencies required by the users as well as by the system. In ANT terminology, he or she delegates roles and competencies to the components of the socio-technical network, which includes the users as well as the components of the system (Latour 1991, 1999). When a program of action is inscribed into a piece of technology, the technology becomes an actor imposing its inscribed program of action on its users.

The inscribed patterns of use may not succeed because the actual use may deviate from it. Rather than following the assigned programme of action, a user may use the system in an unanticipated way; he or she may follow an anti-programme (Latour 1991). When studying the use of technical artefacts, it is necessary to shift

back and forth 'between the designer's projected user and the real user' in order to describe this dynamic negotiation of the process of design (Akrich 1992: 209).

Some technologies inscribe weak/flexible programmes of action; tools are typical of this, with the hammer a classic example. Other technologies inscribe strong/inflexible programmes, with the assembly line of Chaplin's *Modern Times* a standard illustration. Inscriptions are given a concrete content because they represent interests inscribed into a material. As Law (1992: 387) points out: 'Thus a good ordering strategy is to embody a set of relations in durable materials. Consequently, a relatively stable network is one embodied in and performed by a range of durable materials.'

The flexibility of inscriptions varies: some structure the pattern of use strongly, others weakly. The strength of inscriptions, whether they must be followed or whether they can be avoided, depends on the irreversibility of the actor network into which they are inscribed. It is never possible to know beforehand exactly what is needed, but by studying the sequence of attempted inscriptions we can learn more about exactly what inscriptions were needed, and how they had to be inscribed, to achieve a given aim. To exemplify, consider what is needed to establish a specific work routine. First, for example, the skills needed for the routine can be inscribed through training. If this proves to be too weak, the routine can be inscribed in a textual description in the form of a manual. If this is still too weak, the work routine can be inscribed by supporting it with an information system. Hence, through a process of translation, one and the same work routine can be inscribed into components of different materials, with the components linked together into a socio-technical network. As these inscriptions are added and superimposed, they accumulate strength (Latour 1999: 158).

Latour (1991) provides an illuminating illustration of this aspect of ANT. It is an example intended for pedagogic purposes. Hotel managers want to ensure that guests deposit their keys at the front desk when they leave. The way to accomplish this objective, according to ANT, is to inscribe the desired pattern of behaviour into an actor network. The question is, however, how to inscribe it and into what. This is impossible to know for certain beforehand, so the management has to make a sequence of trials to test the strength of different inscriptions. In Latour's story, the management first tried to inscribe the pattern of behaviour into an artefact, in the form of a sign behind the counter requesting all guests to return the key when leaving. This inscription, however, was not strong enough. The management then inscribed it into a key with a metal knob of some weight. By gradually increasing the weight of the knob, the desired behaviour was finally achieved. Hence, through a succession of translations, the hotel's interest was finally inscribed into a network strong enough to impose the desired behaviour on the guests.

Inscriptions invite us to talk about how various kinds of materials—artefacts, work routines, legal documents, prevailing norms and habits, written manuals, institutional and organizational arrangements and procedures—attempt to inscribe patterns of use (which may or may not succeed). Inscribing patterns of use is a way to confine the flexibility of use of an information infrastructure.

Inscriptions have many forms, quite a few of which are not easily spotted. We are accordingly particularly concerned with uncovering the different materials for inscriptions—that is, how and where patterns of use are inscribed. But first it is necessary to study how interests get translated—that is, how they are inscribed into one material before getting re-presented by inscription in a different material.

There are four aspects of the notions of inscription and translation to note:

- the identification of explicit anticipations (or scenarios) of use held by the various actors during design—that is, standardization;
- how these anticipations are translated and inscribed into the standards—that is, the materials of the inscriptions;
- who inscribes them;
- the strength of these inscriptions—that is, the effort it takes to oppose or work around them.

Consider an example drawn from the Statoil case (see Chapter 9), which deals with how the infrastructure based on Lotus Notes actually got 'diffused'. The IT department (SData), in an effort to gain greater organizational visibility, lobbied for the introduction and use of Notes. In terms of inscriptions, SData attempted to inscribe a scenario of extensive Notes use in Statoil. To achieve this, SData needed materials for the inscriptions. The pressure for quality improvement in the sense of ISO certification was exploited to this end. To spell it out in terms of inscriptions, the thrust behind ISO certification—initially spawned by the scandalous sinking of an oil platform belonging to Statoil—was translated and inscribed into a specific Notes application (called Elark) for electronic archiving. This was a viable strategy, as enhanced quality through the ISO certification had already been translated into stricter documentation procedures.

Irreversibility

A key feature of information infrastructure, as discussed in Chapter 3, is the difficulty of making changes. With the use and extension of the core ANT vocabulary developed above, this vital aspect may be lifted forward to occupy centre stage. An information infrastructure is an aligned actor network. The constitutive elements of an information infrastructure—the collection of standards and protocols, user expectations and experience, bureaucratic procedures for passing standards—inscribe patterns of use. But is it not possible to express this more precisely, somehow to 'measure' the net effects (a dangerous expression, but let it pass) to which these superimposed inscriptions actually succeed in shaping the pattern of use—in other words, to measure the strength of an inscription?

Callon's (1991, 1994) concept of the (possible) irreversibility of an aligned network captures the accumulated resistance against change quite nicely. It describes how translations between actor networks are made durable, how they can resist assaults from competing translations. Callon (1991: 159) states that the degree of irreversibility depends, first, on the extent to which it is subsequently impossible to

go back to a point where that translation was only one amongst others and, secondly, on the extent to which the network shapes and determines subsequent translations.

Hughes' (1983, 1987, 1994) historical studies of infrastructure technologies underscore the irreversibility of actor networks through his notion of 'momentum'. The crucial difference between Hughes and Callon is the way in which the dynamics of momentum unfolds. Hughes (1994: 108) describes momentum as very much a self-reinforcing process, which gains force as the technical system grows 'larger and more complex'. It is reasonable to take the rate of diffusion of the Internet during recent years as an indication of its considerable momentum. Major changes that seriously interfere with the momentum are, according to Hughes, conceivable only in extraordinary instances: 'Only a historic event of large proportions could deflect or break the momentum . . . the Great Depression being a case in point' (ibid. 108) or, in a different example, the 'oil crisis' (ibid. 112). This, however, is not the case with information infrastructure. Momentum and irreversibility are accordingly contradictory aspects of an information infrastructure in the sense that, if momentum results in actual—not only potential—irreversibility, then changes are impossible and it will collapse.

The issues of irreversibility and the alignment of actor networks provide an entry into the debate in the management literature on the (misleadingly similar sounding) notion of 'alignment' (see Chapter 2). An ANT perspective makes it strikingly clear that this 'alignment' is neither straightforward nor controllable in any strict sense. As ANT instructs us, it is not so much an exercise in juxtapositioning two neatly packaged entities as an attempted orchestration of all the elements of a truly extensive, heterogeneous actor network.

The degree of irreversibility of a network may be regarded as a process of institutionalization (Latour 1999: 155–6). This operates both ways: an increased degree of irreversibility is signalled by a firmer institutionalization, and, from the other point of view, the construction of institutions functions as a way to align the network and make it increasingly irreversible. The establishment of a new arena between Norsk Hydro and Statoil (see Chapters 8 and 9) to exchange experience, ideas, and worries related to Notes provides an example of this. The construction of an institutional cooperation aligns the initially independent efforts in the two companies and accordingly increases their irreversibility.

Black-boxing

The flexibility in the granularity of the analysis is essential in the description of information infrastructure. This is because information infrastructure, in a quite straightforward sense, is simultaneously a micro-phenomenon (detailed design, formats, protocols, patterns of local use) and a macro-phenomenon (the actual infrastructure, the collection in total, cutting across local contexts). There is a pressing need to curb the inclination that macro-oriented analyses are biased towards cause and effect of factors, whereas micro-oriented studies notoriously speak of contingency, interpretative flexibility, and social construction (Callon and Latour 1981; Misa 1994; Smith and Marx 1994).

In much the same way as ANT refuses to distinguish a priori between humans and non-humans, so it refuses to distinguish a priori between small and big networks. There is, in other words, no a priori distinction between the micro, meso, and macro level. ANT offers a uniform framework regardless of the unit of analysis.

The problem of information infrastructures, possibly global ones, seemingly inevitably leads to a macro-level analysis with relevant actors such as whole companies, even business sectors, governmental regulating bodies, and broad trends in consumption and production (see Chapter 4). This is important because, as Misa (1994: 119) points out:

> Besides taking a smaller unit of analysis, such micro studies tend to focus solely on case studies, to refute rationality or confute functionality, and to be disorder-respecting. Generally, macro studies make it easy for historical actors to appear rational, purposeful, and as key agents of change, whereas micro studies make it difficult or impossible for historical actors to have these same attributes.

The challenge, then, for any critical analysis of evolving, 'global' information infrastructure is to unpack the seemingly macro-elements down to their empirical constituents (see the argument for qualitative research methods in Chapter 2)—that is, their underlying actor network. In this way, ANT provides a uniform framework, in connecting the local and the global, to identify the local in the global, and vice versa.

To illustrate how this works when moving up and down in the analysis, consider the early phase of the introduction of Lotus Notes in Statoil (Chapter 9). A crucial element in the analysis is the way a macro-factor–falling oil prices–got translated into a need for uniformity and subsequently inscribed into a Lotus-based platform. In this way, there are empirical links between the macro and the micro. This link tends to be blurred when resorting to different framework for the micro and the macro: 'Too often sociologists . . . *change their framework of analysis* depending on whether they are tackling a macro-actor or a micro-actor' (Callon and Latour 1981: 280).

Law (1992: 380) also underlines the need to be critical of the unit of analysis. In ANT 'it is a good idea not to take it for granted that there is macro-social system on the one hand, and bits and pieces of derivative micro-social detail on the other', because, if we do so, 'we close off most of the interesting questions about the *origins* of power and organizations'. It is, accordingly, the result of an effort to construct oneself as a highly profiled organizational actor on behalf of others; it is not given beforehand.

The alternative to distinct frameworks that ANT represents is to make the notion of an actor network scalable. This implies that one actant of an actor network may be expanded into a new, complete actor network. Or, conversely, a whole actor network may be collapsed into a single actant. 'To summarize, macro-actors are micro-actors seated on top of many (leaky) black boxes' (Callon and

Latour 1981: 286).

What, then, does this imply in an analysis of information infrastructures, what does this zooming in and out of actor networks look like? It entails that the 'actor' of an analysis is of the 'size' that the researcher chooses as most convenient relative to the direction of the analysis. Hence, an actor may be a given person, a whole group or community of practice including its working technology, a whole organization, even a profession. Similarly, a researcher would vary between a focus on a technological platform as a whole, including the aligned, administrative routines, a focus on some of its applications and patterns of use, down to a focus on the details of integration mechanisms, functionality, and protocols.

Conclusion and Links to the Previous Theories

The way economical, strategic, social, and technical issues profoundly mesh in information infrastructure calls for a framework from which to launch a critical, empirically founded analysis. The ability of ANT to cut across these issues, zoom in and out and make sense of the unfolding process including how irreversibility is constructed, makes it a promising candidate. ANT provides an effective platform from which critically to assess and unravel a set of problematic explicit and implicit assumptions made from the management perspective on information infrastructures as outlined in Chapter 2.

The basic message of ANT related to management and strategy is a cautionary one. ANT is a strategy for unpacking the complexity of our everyday life. Abbreviations, short-circuits, and simplifications are always *produced*. They are the (up till now, successful) result of a mobilization process with black-boxing effects. The ordering these simplifications produce is neither neutral nor 'obvious'. They are *made* obvious or natural in order to achieve an effect—namely, to curb opposition or alternatives. For example, the utterly 'obvious' requirement for global information infrastructures to tidy up the existing mess, fragmentation, and local variety is not obvious at all; it is constructed as obvious.

Relationships with the Other Theories

We conclude by looking briefly at how the theories presented so far can be linked together. They have different origins and are developed to describe or explain different phenomena. However, they all point out important aspects of information infrastructures, and the difficulties and challenges related to the design and management—or control—of such infrastructures. And we also believe that the theories may be interpreted and used in ways so that they all fit together into a richer framework for understanding infrastructures.

One way to make them fit is to see actor-network theory (ANT) as a theory upon which reflexive modernization as well as information economics can be based. ANT can be used to describe in detail and in a coherent way how large heterogeneous networks are built through the ongoing modernization and global-

ization processes, and also how these networks can be interpreted as actors when side effects are propagated through the networks and new events—also having side effects—are triggered.

Network externalities can be looked at as side effects, and self-reinforcing mechanisms are specific patterns of side effects where one action creates them, and they further trigger new actions similar to the original ones, which again create the same side effects as the first, and so on. When a standard is adopted by one more user, a side effect is that the standard's value for its users increases, which leads to new adoptions, and so on.

Large systems, like the Internet, are built by many independent actors over time. Such systems appear as independent living actors for several reasons.

- The number of actors shaping the system/network is so high that it is impossible for any of them to overlook the actions of all others. This makes the network change in unpredictable ways.
- Side effects of known as well as unknown actions make the network change in unpredictable ways.
- One change—including its side effects—to the network triggers new changes.

Hughes (1983, 1987, 1994) has developed the concept of momentum to describe the development of large technical systems. This is a concept integrating the theories presented so far He describes momentum as close to a self-reinforcing mechanism as outlined by the economists; at the same time he defines large technical systems as heterogeneous networks in line with ANT (this similarity is pointed out by Hughes 1994 and Callon 1991, as well as by Latour 1999).

Finally, Giddens' image of contemporary phenomena (technology, organizations, institutions, personal careers, identities, and so on) as a juggernaut that is an independent actor partly shaping us and partly shaped by us seems to match perfectly the basic perspectives underlying ANT.