Automatic Vehicle Identification: A Test of Theories of Technology

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Two contrasting theories—actor-network theory and nondecision making—are separately applied to the same case study, namely, technologies for automatically identifying road vehicles. By this process, the strengths and weaknesses of each approach are highlighted: The actor-network approach is useful for understanding local processes but lacks tools for easily illuminating patterns across countries; by contrast, the concept of nondecision making is useful for explaining the general lack of implementation of technology for automatic vehicle identification but not for explaining variations between developments in different countries. This study highlights the importance of attempting to compare theories by using the same case study.

Traditional approaches to technology have distinguished between artifacts (the physical side of technology) and humans and their interactions (the social side of technology). Within this broad framework, many views of the nature and dynamics of technology have been explored: technology as neutral and the related use-abuse model (implicit in many works), technological determinism (Misa 1988; Winner 1977), technology as shaped by society (MacKenzie and Wajcman 1985), technology as determined by society (Dickson 1974), and technology as part of a labor process (Braverman 1974). (Of course, these approaches are not necessarily mutually exclusive or comprehensive.) These and other perspectives have been developed and applied in various ways. The important point here is that they treat society as something to be investigated separate from, or in addition to, artifacts.

This assumption has been challenged in the 1980s by what has been called the new sociology of technology. Growing out of the sociology of scientific

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knowledge, which challenged the traditional exemption of science from the sociology of knowledge, the new sociology of technology aims, in its most radical form, to reconstruct social theory by setting aside concepts of social structure and carrying out analysis by following actors. "Actors" in this theory can include a range of things including both people and artifacts.

The new sociology of technology has been criticized in a number of ways. For example, in a critique of Pinch and Bijker's (1984) social constructivist study of the development of the bicycle, Russell (1986) argued that a Marxist structural approach offered insights that were not accessible using Pinch and Bijker's conceptual tools. In reply, Pinch and Bijker (1986) reasserted the value of their approach and the limitations of the structural approach that they had set out to supersede.

There is one curious feature of this confrontation between those adhering to a structural approach and those adopting an actor-oriented approach: There are few, if any, common case studies. To illustrate and develop their ideas, the new sociologists of technology have analyzed a wide range of technologies such as the fluorescent light, the TSR2 aircraft, nuclear missile accuracy, and the bicycle. This list does not include any of the technologies, such as nuclear power, computer-aided manufacture, or genetic engineering (to give only a few contemporary examples), that have received intensive scrutiny by other analysts. It should also be said that critics have not tried to tackle the new sociologists of technology on the latter's chosen case studies.

Our aim in this article is to stimulate debate by applying two contrasting approaches to the study of technology to the same case study. For our case study, we use automatic vehicle identification (AVI), which we have been studying for some time.

Arguably, the most fundamental categorization of theories for studying society is between actor-oriented and structure-oriented perspectives (Galtung 1980).[1] On one hand, we have chosen to apply an actor-network model, representing one possible actor-oriented perspective. Actor-network theory seemed a good choice because we have carried out interviews with participants in the development of AVI in several countries, providing firsthand details about negotiations over the technology.

For comparison purposes, we have chosen the political theory associated with "nondecision making" in its version linked to a structural perspective: In this case, nondecision making refers to the influence of social structures on decision-making agendas independent of the conscious intentions of actors. Because AVI seems to be technically feasible but has not been widely introduced for road vehicles, we thought that nondecision making might offer a useful framework to explain its failure to be implemented on more than a very limited basis so far.

In undertaking such a comparison of approaches to studying technology, it soon becomes clear that the different approaches try to do different things. Inevitably we have had to modify the approaches in order to apply them and compare them. Our aim is not to carry out a definitive case study using either approach (or both together) but, rather, to gain insight into the strengths and limitations of two contrasting approaches to technology.

We begin with brief surveys of the actor-network approach and of nondecision making. Then turning to AVI, we first give a basic outline of information about the technology available through the literature and then offer two brief analyses in terms of an actor-network model and a nondecision-making model. We conclude with a comparison of the two approaches and a reflection on the debate between proponents and critics of the new sociology of technology.

The Actor-Network Approach

What has been called the new sociology of technology is a way of analyzing technology that tries to overcome the usual assumption that artifacts are objects outside the social world. There are several distinct strands within the new sociology of technology. One is the actor-network approach (Callon and Law 1989; Callon, Law, and Rip 1988; Latour 1983, 1987, 1988; Law 1986; Law and Callon 1988), in which analysts follow actors to discover how technologies are constituted and to reveal the constant negotiation and renegotiation among and between these actors. Latour's (1987) book *Science in Action: How to Follow Scientists and Engineers through Society* provides a blueprint on how to use this method.

Second is the social constructivist approach proposed by Pinch and Bijker (1984), which involves demonstrating the interpretive flexibility associated with technological design, then showing how an artifact is stabilized, and finally relating the form of the artifact to the wider social context. A third strand is the systems approach of Hughes (1983).[2]

For our comparison, we have chosen to use the actor-network approach. Our case study is contemporary and allows us access to actors in a way impossible for historical cases, an added dimension that is especially relevant for an actor-network analysis.

The importance of the actor-network approach is not so much that analysts follow the actors, since some sociologists and anthropologists have been doing that for years, but lies in the claim that this approach can erode the distinction between society and technology. Technologies, according to actor-network theorists, embody decisions and are the result of the mobili-

zation and combination of what are usually called the technical, social, economic, and political. These technologies or sociotechnical systems are, according to Law, the result of heterogeneous engineering (Law 1988; Law and Callon 1988). Law claims that heterogeneous engineers must first create a scenario that resolves a problem and appears attainable. Next they need to constitute, mobilize, and juxtapose the various actors, technical and otherwise, in order to create a network. Once the sociotechnical system is successfully located in the network, the seams of this web should be invisible.

According to this perspective, the failure of a technology cannot be explained as a mere technical failure but, rather, as a failure to engineer a network of all the elements in which each plays its designated role. These elements include artifacts, social groups, beliefs, finance, raw materials, and so on. Failure of a technology may be the result of faulty engineering (engineering in the wide, sociotechnical sense) or of the obduracy of some elements that because they are less malleable than others, resist engineering (Law 1988).

In order to engineer these heterogeneous elements successfully, actors must mobilize allies by "enrolling" them or, in other words, by enlisting their support (Callon and Latour 1981). Latour (1987) emphasizes that interests are not given but are constructed through enrollment and "translation." Actors can use various strategies to "translate" the interests of potential allies into the preferred course of action. These can include catering for their needs, inventing new needs and objectives, making oneself indispensable, inventing a new group, or convincing those involved that their present goals are unattainable unless a detour is made. Latour illustrates his arguments with the story of Pasteur and his success in enrolling and capturing health officials, veterinarians, farmers, and eventually all of French society. Pasteur so translated the interests of French farmers that if they wanted to solve their anthrax problem, they had to pass through his laboratory (Latour 1983, 1988).

There are a number of potential problems with this actor-network approach. It assumes that following actors, reading their texts, and listening to their conversations is a method that can efficiently reveal all that can be known about the sociotechnical world. Actor-network theorists claim that they can carry out their studies without prior conceptual theorizing involving the macrosocial context, but in practice many of their studies appear to draw on concepts of social structure to understand social behavior and to choose research strategies. Seldom is it clear where the categories used by the actor-network analyst come from. Furthermore, how can the concepts, or the studies based on them, be refuted or assessed? More specific to the theorists mentioned here is the problem of identifying the relevant actors. This is not unproblematic. As Russell (1986, 335) points out, groups may be omitted

"either because they had no voice in the process or because they were indifferent to the specific options on offer." It is also possible that certain actors may be invisible, serving or having their interests served without directly participating.

Another problem is that conceptual tools for analyzing actors and networks provide no way of determining why some actors succeed and others fail, other than tautologically saying that their alliances were strong enough or not strong enough (Amsterdamska 1990; Scott 1991).

Nondecision Making

The idea of nondecision making can be usefully delineated through the "three dimensions of power" as presented by Lukes (1974). According to Lukes, there are three ways to approach the concept of power in political science.[3] The one-dimensional view of power is the actor orientation: Power is exercised when one actor overtly influences another actor to do something. The interests of the actors are taken to be expressed by their subjective preferences, typically as revealed by their participation in the political process. This view focuses on behavior, overt decision making, and overt conflict.

The two-dimensional view of power is an attempt to deal with an exercise of power in which there is not necessarily any overt conflict or making of decisions. The focus is on both issues and potential issues, overt and covert conflict, and decision making and nondecision making. This view was raised most notably by Bachrach and Baratz (1962, 1963, 1970), who seem to use it in two distinct ways. In the first use, issues may be kept off the formal decision-making agenda by groups that manipulate agendas or divert attention to peripheral topics. This is an observable exercise of power designed to achieve a clearly understood end. In the second use, nondecision making occurs through issues never even being thought of enough to warrant formal attention. However, people may harbor grievances that can be uncovered, even if these grievances have never surfaced to affect decision-making agendas. Another way to describe nondecision making is the "mobilization of bias" (Schattschneider 1960): a bias in the structure of the political system, rather than an overt exercise of power in a neutral political system.

Crenson's (1971) *The Un-politics of Air Pollution* is a classic study in nondecision making. Crenson set out to show the defects of liberal pluralist political theory (Lukes's one-dimensional view) by arguing that powerful political interests could influence what things became issues, without any overt recognition that this agenda-setting was happening. Among other

things, he compared the development of policy concerning air pollution in the two cities of East Chicago and Gary, as well as other towns. Gary was dominated by a single employer and ratepayer, U.S. Steel; neighboring East Chicago had a more splintered political economy. Although U.S. Steel did not overtly intervene in city decision making in Gary on air pollution, much less action was taken there on this issue than in other cities. The reason, in nondecision-making terms, is that Gary politicians were so attuned to the interests and power of U.S. Steel that their beliefs and actions on air pollution were different from what they would have been had U.S. Steel not been there.

In addition to air pollution, nondecision making has been applied to topics such as British police authorities (Brogden 1977) and the Japanese automobile industry (Otake 1982). The concept of nondecision making offers the insights that there is more to policy than overt decisions, that it is useful to analyze what issues are left off the agenda or not even thought of by the actors, and that social structures can help to explain the formation of policy agendas.

The three-dimensional view of power, as described by Lukes, extends the concept of interests from subjective interests to include real interests. In other words, because of the structure of power, actors may have false beliefs about their own best interests. An example would be slaves who believed slavery was in their interest. This view overlaps with the second formulation of the two-dimensional view in which issues are not even considered because they are not thought of as significant.

Although the concept of nondecision making is usually associated with the two-dimensional concept of power, we use nondecision making here in a three-dimensional guise, looking for the impact of social structures on decision-making agendas independent of the conscious manipulations by actors.[4] This use of nondecision making provides a clear contrast with the actor-network approach.

A basic assumption of the three-dimensional view of power is that the concept of a social structure provides an insight into the dynamics of society not easily grasped using an actor orientation. Crenson (1971), for example, drew upon the concept of corporate power that he assumed could affect decision-making agendas. Without this concept, presumably it is unlikely that he would have considered comparing policy making in Gary and East Chicago.[5]

A second basic assumption of structure-oriented views is that the concept of interests provides a useful insight into society. If interests are simply determined by asking people about their views or observing their actions, then the one-dimensional view would be sufficient and the concept of interests would offer no special analytic value. The three-dimensional view

proposes that interests may be deeper than what is consciously perceived and expressed by actors. This inevitably entails a value commitment or evaluative element by the social analyst: Interests are attributed to actors, and the analyst proceeds to study the situation and test the usefulness of this attribution.

The actor-network approach, in direct contrast, rejects the attribution of interests. It fits into the one-dimensional actor orientation, preferring to avoid the a priori assumption of the usefulness of concepts of social structure (although, in principle, these concepts may be reconstructed from patterns of behavior).

For the purposes of our comparison of theories, we wanted a structure-oriented perspective that enabled some deductions to be made at the level of our case study. Many structural theories, such as those of some Marxists, are far too abstract to be of much use for this purpose.[6] Nondecision making is more readily applicable to policy making and also appeared potentially relevant to our case study.

AVI: The Technology

Automatic vehicle identification (AVI) refers to technology used to identify a particular vehicle when it passes a particular point. Automatic vehicle monitoring (AVM) involves the tracking of vehicles at all times. Developments in these two areas have been closely related, and for convenience we will usually refer only to AVI. This brief introduction to AVI is based on our reading of the literature and discussions and interviews with individuals from Australia, Britain, Germany, Hong Kong, the Netherlands, Norway, Sweden, and the United States.

Early development of AVI occurred in the United States (Hauslen 1977; Roth 1977), beginning with an optical scanning system in the 1960s to identify railroad box cars (Fenton 1980). Since then there have been enormous advances in microelectronics. Inductive loop, radio frequency, infrared, and microwave systems have all been developed and even satellites can be used to provide continuous monitoring of vehicles. These technological advances and increased accuracy and reliability, along with rapidly diminishing costs, have opened new options for use. Our focus here is on AVI applied to road vehicles (French 1989, 1990; *IEEE Transactions on Vehicular Technology* 1991; Jurgen 1991).

AVI can serve a range of purposes: to charge for road use, to suggest routes for drivers, to improve traffic management (such as traffic signal coordination), to detect stolen vehicles, and to monitor fleets of trucks, buses, and taxis. However, it should not be assumed that AVI was consciously developed

with all these purposes in mind. Another interpretation is that technologists look around for applications of a technology developed for other reasons (so-called technology push). In any case, one of the key uses of AVI, according to its proponents, is to deal with traffic congestion.

As cities became increasingly congested with road traffic in the 1950s and 1960s, the response from developed countries was to build vast freeways. The ultimate failure of that response to overcome traffic problems, along with growing environmental awareness, led to consideration of alternative ways of managing traffic. Traffic planners focused on ways of restraining traffic. If they could persuade, encourage, or force drivers to reduce their road use or change their patterns of use, then existing roads could be used more efficiently. This would reduce traveling time and fuel costs as well as air, noise, and visual pollution.

Planners and policymakers have considered a number of measures to achieve such restraint: taxes on ownership and registration of cars to reduce the number of people able to afford cars, physical barriers to prevent people from driving into congested city areas or parking controls to discourage them, and taxes on fuel as a means of indirectly charging for road use. Singapore introduced an area licensing system in 1975 based on manual collection of permit fees, which reduced peak hour traffic in the central business district by 40%, but few planners thought that this system could be easily applied to other countries with less authoritarian styles of government (Morrison 1986).

Developments in automatic vehicle identification and monitoring technology opened the possibility for a system of road pricing in which charges depend on the time of day, the road, and the vehicle. This would allow, for example, higher charges to be made for travel during rush hours and on specific congested roads. According to neoclassical economics, this would improve the efficiency with which the roads are used.

The first major trial of the technology for electronic road pricing was undertaken in Hong Kong between 1983 and 1985 (Dawson 1983). A volunteer vehicle fleet was fitted with electronic number plates. Loops beneath the road surface transmitted back to a control center the unique identification number of the passing vehicle. Vehicles that failed to respond with a valid or operative electronic number plate were photographed by closed-circuit television; this back-up system combined with the basic AVI system ensured a high degree of overall accuracy. The pilot study included the production of regular road-use statements (Dawson 1986). This trial was intended as a preliminary step toward a full-scale—and nonvoluntary—system of electronic road pricing, the main purpose of which was to restrain road use in congested areas by adopting the user-pays principle.

The Hong Kong government made every effort to emphasize the fairness of the system, including producing a video and booklet titled *A Fair Way to Go*. But opponents of electronic road pricing mobilized over the issues of high costs and privacy, and the Hong Kong government has not proceeded beyond the 1983-85 pilot scheme.[7] We will return to the Hong Kong experience later.

Research and development on AVI continues, especially in Europe and Japan (Catling and McQueen 1991). "Prometheus" is the name of an eight-year, $900 million industry-funded program involving six European countries. Its aim is to improve safety, economy, efficiency, and comfort and to reduce pollution through the development of an intelligent vehicle (Gillan 1988). A smaller program called DRIVE (Dedicated Road Infrastructures for Vehicle Safety in Europe) is jointly funded by governments and corporations. It is concerned with AVI technologies, computers in vehicles, "smart cars" (that can automatically register electronic transactions), and automatic enforcement systems, including cameras and license plate systems.

One use of AVI is "route guidance." Information about the distribution of traffic is transmitted to a computer on board a vehicle. When the driver keys in a destination, the computer—holding an electronic map—recommends an optimal route. As the journey proceeds, the computer gives detailed instructions about where to go, on a display or via synthesized voice (Organisation for Economic Co-operation and Development 1988). In Berlin, there is an $11 million test, involving 700 volunteers, of the Ali-Scout route guidance system, which uses Siemens technology involving infrared signals from roadside beacons (von Tomkewitsch 1991). A similar route guidance system, called Autoguide, is being tested in London (Belcher and Catling 1987; Jeffery, Russam, and Robertson 1987).

In Japan there is a large program organized under the Ministry of International Trade and Industry called the Intelligent Vehicle System, similar in size and orientation to Prometheus but with more emphasis on artificial intelligence and automatic chauffeuring. Another Japanese venture is AMTICS (Advanced Mobile Traffic Information and Communication System), an integrated traffic information and navigation system that combines CD-ROM technology with AVI (Tsuzawa and Okamoto 1988). Some Japanese cars on the market come with rudimentary autonomous route guidance systems. The Japanese government has halted the large programs and brought the project leaders together to decide future directions (Kawashima 1991).

In the Netherlands, there was an ambitious plan to introduce a national electronic road-pricing system by the early 1990s, in which each vehicle would hold a smart card whose balance would be electronically decremented

on passing beacons, with a back-up monitoring and enforcement system for vehicles without a valid card number or without sufficient funds (Stoelhurst and Zandbergen 1990). As we will describe later, this scheme has been postponed.

In Norway, several towns have adopted AVI toll systems. For example, in Alesund there is a programmable remote identification ("premid") system for toll collection on a recently completed island-linking tunnel and bridge system. Sensors in the road alert the system of an approaching car. Antennae send out a weak microwave signal that is reflected from an identifier plate on the car. This is analyzed by the premid computer to identify the car, confirm that it is a paying subscriber, and register the trip. This is recorded in 150 milliseconds. The information collected automatically on the site is then sent to a central computer. Cars that attempt to pass through without paying activate a video camera that records the registration number and the time and place (Waersted and Bogen 1989).

A different system has been introduced in Trondheim and Oslo following the success of a manual toll-ring in Bergen. The technology used in these cases is known as Kofri—translated as Queue-free—and is based on surface acoustic wave (SAW) technology. Drivers purchase a tag, or "brick," as it is known. Each passing of the toll site will check whether the vehicle has a valid seasonal pass or, in the case of a prepaid number of trips, will deduct one trip toll. If it registers a valid transaction, then the information is dumped. Unlike premid, which is an intelligent tag, Kofri is a passive tag. It requires no battery and has a longer life and a lower price than premid.

Compared to developments in Europe and Japan, the United States is far behind (Ervin and Chen 1988-89; Norman 1990). One prominent project in the United States is HELP (Heavy-Vehicle Electronic License Plate) that is investigating the feasibility of developing and implementing a system capable of collecting truck weight and classification data, as well as identifying individual vehicles for taxation and enforcement purposes (Walton 1991).

These are just a few examples of the tests, trials, and schemes being carried out around the world. They provide a background for our two contrasting analyses of AVI in the next two sections. The first is from the perspective of actor-network theory and the second from the perspective of nondecision-making theory.

AVI According to the Actor-Network Approach

An actor-network account is one that traces "sociotechnical networks that are put in place by actors whether these pertain to content or to context"

(Callon and Law 1989, 58). The focus is on actors—whether humans or artifacts—and how they *create* networks (rather than simply dealing with objects assumed to exist a priori). The investigator is supposed to use the same conceptual tools for dealing with human and nonhuman actors and is enjoined from taking sides in the controversy being studied. The application of this approach can best be illustrated through analysis of specific cases, such as those of Hong Kong and the Netherlands, introduced earlier.

One problem recognized by the Hong Kong government in 1982 was severe traffic congestion, with worse congestion predicted. The government acted by sharply increasing automobile registration charges and gasoline taxes. In addition, and especially relevant to our analysis, two British experts on electronic road pricing were asked to study the prospects for using this technology in Hong Kong. The experts recommended a pilot study, and the Hong Kong government agreed. The study commenced in 1983. Plessey was the main contractor for the hardware, while the consulting body Transpotech, owned by the British government, managed the project and analyzed the results. Thus the key actors in the early stages were the Hong Kong government (and its agencies), Transpotech, Plessey, and the two British experts.

In the two-year trial, the two firms mobilized the technology to their cause; it worked with high reliability, more than sufficient for an operational AVI system. Yet for AVI to be introduced throughout Hong Kong, its promoters had to enroll key interest groups in the territory. Their failure to achieve this meant that the AVI network could not be extended to all of Hong Kong. Only by consulting documents and talking to government planners, AVI consultants, and various interest groups is it possible to understand this failure.

The Hong Kong Automobile Association (HKAA) played a crucial role in the opposition to AVI. The HKAA was able to mobilize support through the district boards, which had been recently set up to provide an avenue for public participation in policy making. The HKAA questioned whether the technology would work and raised privacy issues. After the effective lobbying by the HKAA, the district boards overwhelmingly opposed or failed to endorse the AVI scheme. As well as the public arguments about privacy and reliability, another factor was the low credibility of the government: Board members did not believe that the high automobile and gasoline taxes imposed in 1982 would be reduced when revenues from electronic road pricing started flowing. In addition, the district boards may have wanted to show their independence of the government (Borins 1988; Scott 1990b). The campaign of the HKAA and district boards created an AVI-free network: Electronic road pricing is now so stigmatized that any government mention of considering it can cause "public disquiet" (Hau 1989, 195).

Another important case study is the Netherlands, which has the highest density highway network in Europe. Transport authorities would like to reduce the number of cars on the road in order to improve conditions for freight transport, which is vital to the Dutch economy. A special task force established in 1988 to investigate road pricing decided upon a sophisticated system involving two-way communication between vehicles and roadside processors. In order to win over groups concerned about surveillance, the technology was designed to protect privacy by using smart cards, encryption, and procedures to erase information about individuals immediately after valid transactions (Stoelhurst and Zandbergen 1990).

A public debate developed over the scheme, and opposition grew. The project might still have proceeded, given its strong political backing, but this ended with the election of a new government in November 1989, which provided an excuse to halt the project (Scott 1990a).

The actors in this case include transportation planners working on the AVI project, members of the government, representatives of the Dutch motorists organization, the privacy protection agency, technology assessment organizations, and the AVI technologies themselves. Following these actors is the means of determining what methods have been used to bring into being—or to block—this system.

The experiences in Hong Kong, Norway, Berlin, London, and elsewhere show that it is possible for system builders to enroll the technical components of AVI. Yet AVI has been installed only in pilot projects or in limited areas. On the whole, sociotechnical or heterogeneous engineers have so far been unsuccessful in gaining strong support from politicians and the public. Technical writers on AVI naively seem to expect that because the technology works and there are obvious pressing applications for it, it should be going ahead. Looking closely at actors and their attempts to create networks shows that promoters have failed to enroll the full complement of allies—humans as well as technical—to make AVI operational.

AVI According to Nondecision Making

The interesting thing about AVI technology is not the limited tests that have been done but, rather, the lack of a wide degree of implementation. The hardware has been available for quite a number of years and has been shown to be viable through the Hong Kong trial and other projects. Furthermore, there are a number of good reasons for implementing AVI, ranging from control over fleet operations, preventing theft, and controlling congestion

through road pricing. Yet widespread implementation of AVI does not seem likely in even the medium-term future.

It is possible to learn about the limited tests of AVI by reading articles, interviewing key figures, and observing the policy process at work. But this does not give much insight into why AVI has not been implemented. The key question is, Why has AVI had such a low profile that no proponents have arisen to push the technology to a prominent role on the political agenda? Why are European and Japanese planners pessimistic about the prospects for large-scale implementation in the near future (Scott 1990a)?

The concept of nondecision making is useful here. In only a few cases have governments made overt and conscious decisions to reject AVI. Rather, in most countries the issue has not been considered a serious enough prospect to be worthy of putting on the political agenda. AVI is still being developed and considered by many technologists and traffic planners but seldom has been raised to the policy level of serious consideration for implementation. To explain this pattern of nondecision making, it is necessary to examine social structures.

There are several structural factors that militate against AVI. One is that there are no immediately perceivable benefits from AVI for most road users. Reduced congestion is an indirect benefit, hard to measure. Fees paid as part of a road-pricing scheme, by contrast, are an immediately recognized cost to individual users.

Another factor is the ideology of freedom of the road (Flink 1975). Many motorists believe they have a right to drive virtually wherever they wish. External controls are resented. This ideology is probably most pronounced in the United States, where, for example, there has been enormous resistance to seat belt legislation (Kleinig 1984, 82-96). Seat belts provide an immediately documentable benefit, and there is no control (except for requirements for compliance) of the motorist inherent in the seat belt itself. AVI, by comparison, can readily be portrayed as an extreme intrusion, the ultimate control by "Big Brother" (Martin 1990).

The difficulty with any analysis using the concept of nondecision making is distinguishing between speculation about the effects of social structures and their real effects. One test is to see what happens when the technology is pushed further along toward implementation. If the preceding brief hypothesis about the likely resistance to AVI is correct, then we would predict that an effective opposition movement would arise should quick moves toward implementation occur. This seems to fit the Hong Kong and Netherlands cases.

Another way to test the analysis is to make comparisons with other technologies. CB radios are widely used in the United States by truck drivers.

One of their prime functions is for drivers to warn each other about police radar traps. Also available on the market are convenient units that car drivers can install that emit a signal whenever radar is detected, thus enabling the driver to slow down and avoid being booked. There are some similarities between CB radio and AVI. They are each electronic forms of communication, and they each provide a capacity to warn about theft, congestion, and location of fleet vehicles. But there are some strong contrasts. In the case of CB radio, the technology is actively used by drivers, at their initiative and sometimes to avoid control over their road behavior by government agents. AVI, on the other hand, provides information about vehicles to a small group of traffic managers.

Traffic planners and politicians are intuitively aware that some policies would be unworkable. In the United States, for example, it would be virtually unthinkable to put a freeway through the middle of a city's richest suburb, to use gasoline taxes exclusively to build bicycle paths and tram lines, or to close the central business district to all road traffic. In a similar fashion to these extreme examples, the key obstacles facing AVI—opposition to road pricing (W. Elliott 1986; Else 1986; Higgins 1986; Small, Winston, and Evans 1989, 87) and concern about surveillance, both linked to "freedom of the road" (Martin 1990)—are also understood intuitively. In some cases, as in Hong Kong, these issues come into the open during struggles over AVI. More commonly, no decision has to be made, since it is tacitly understood by traffic planners that to push AVI in a big way would be a losing proposition. In other words, their proposals to deal with transportation problems are comparable with prevailing power structures and social values. The decision-making agenda at the highest policy-making levels, as a result, seldom includes mention of AVI.

Assessment of the Theoretical Approaches

The case study of AVI shows a number of the limitations of the actor-network approach. It is quite difficult to gain certain types of insight into the development of AVI by following the actors. Basic researchers in optical scanning, microwaves, microchips, and so forth form one set of actors to follow. These researchers, for the most part, are not directly involved with AVI, and their actions would provide little insight, since their concerns arise elsewhere. A second set of actors is those doing applied research relevant to AVI, such as developing "electronic number plates." But there are no researchers in this set who are prominent in promoting the applications: The

field is divided by country, different organizations, and different technologies. Finally, there are the various consultants, traffic engineers, and others who are involved in mobilizing support, building alliances, and undertaking various networking and enrollment activities. But again the field is quite divided, and there is no particular individual or group to follow whose behavior can provide much generalizable insight. Unlike Latour's example of Pasteur, there is no one person, one group, or even one technology to follow. What seems to be occurring is a simultaneous development of various possibilities, with only sporadic interaction. Following the actors leaves out the possibility of using the concepts of social structure, including ideology, which favor or foster the independent introduction of similar types of technologies in different places.

In some individual cases, however, following the actors can provide valuable insights, as in the case of the overt opposition of the Hong Kong Automobile Association to AVI. But simply following the HKAA does not necessarily explain why they opposed it. For this, recourse to concepts of social structure, such as interests, can be more helpful.

Similar patterns of funding, similar organizational structures for carrying out research, and similar bureaucratic structures for policy making are likely to lead to similarities in the development and application of AVI technology around the world. These structural similarities can help to explain why certain groups, such as automobile associations, are more likely to be critical of AVI, whereas traffic engineers and electronics companies are more likely to support it.

The actor-network approach would explain why AVI has *not* been more widely taken up by saying, presumably, either that the sociotechnical engineering by the proponents was faulty or that the sociotechnical engineering by the opponents was superior. These explanations do not provide much insight into AVI, since most proposals lapse without opponents needing to mount a major campaign.

More generally, why are some groups better able to engineer their sociotechnical worlds more effectively? One explanation is that they have access to greater resources, such as a prior cohesive organization, adequate finances, technologies, or prevailing belief systems. But talking about resources in this sense is a structural approach. Assessment of such resources does not arise naturally from following the actors—and looking at resources used in a particular context does not say anything about those used elsewhere. It is trite to say that concepts of social structure are essentially generalizations about patterns of human interaction. It is precisely such generalizations that the actor-network approach ostensibly abjures. As a result, it is impossible to

generalize from detailed case studies such as Hong Kong to situations in which there have been no decisions about AVI and hence no actors to follow.

A study by Mangematin and Callon (1991) of competing route guidance systems in France was written after the preceding assessment was completed. Their study illustrates well the strengths and weaknesses of the actor-network approach. While Mangematin and Callon provide insights into the technical and social dynamics of the competition between two companies and their proposed systems, their study lacks any mention of the wider context of AVI developments, namely, events, influences, and networking in Hong Kong, Japan, the Netherlands, Norway, the United States, or elsewhere. In principle, following the actors should have led them to investigate actors and networks in these places, but in practice their examination is exceedingly narrow.

Actor-network researchers have made some useful contributions, especially in questioning the conventional dichotomy made between the social and the technical. But in pursuing their insights derived from the sociology of scientific knowledge, these researchers have jumped into the area of technology without giving credit to prior work and bodies of theory. From the point of view of researchers already in the area, they have also failed to deal with the difficult, complex issues such as nuclear power.

Critics would say that much of the work being done under the rubric of the new sociology of technology was already being done, de facto, by sensitive analysts using other theories. Even with a one-dimensional view of power and a social-technical dichotomy, it is possible to come up with sophisticated analyses that rival any explicitly actor-network study for attention to actors and negotiations.[8]

The strengths of structural approaches lie in their capacity to characterize processes that are not overt in the behavior of actors. Structural approaches provide a way to answer questions of "why?" Their weakness is the strength of actor-oriented methods, namely, an understanding of the particularities of individual cases. But in practice, structural analysis does not proceed in a data vacuum, but usually takes some account of concrete cases.

But if structural analysis relies on case study material, how reliable are its generalizations? Our structural analysis suggests that the interests associated with the ideology of freedom of the road militate against introduction of AVI. But is this only a post facto explanation? A structural analysis might also examine interests associated with the ideology of economic efficiency through electronic road pricing. How does the analysis explain why these interests seem to be far less powerful than those associated with freedom of the road?

Another problem with structural approaches is that they do not provide any way of examining the exceptions to their generalizations. The social

structures that have kept AVI off the main political agenda in most countries have not done so completely or uniformly. For example, the system in Alesund was only the first of a series of Norwegian AVI systems. An actor-oriented analysis seems much more useful for probing such discrepancies.

To undertake a structural analysis of such variations, we might look at factors such as traffic congestion, the organization of traffic planning, or the presence of electronics industries in order to explain differences in interest in AVI. But such a prescription points to the open-ended nature of the analysis, since there are many possible political, economic, and social factors on which to base a structural analysis.

As indicated at the beginning of this article, actor- and structure-oriented theories set out to achieve different things, and hence comparing them on a common case study is problematic. Our use of the AVI case study was dictated in part by our own familiarity with it, a familiarity that may contaminate our model stories according to the two approaches, since we, as authors, are aware of the insights to be gained from each approach. We look forward to seeing other comparisons of theory in which proponents of one approach tackle a case study pioneered by users of a contrasting approach.

NOTES

1. For an ambitious attempt to reconcile and go beyond these perspectives, see Giddens (1979).

2. See also Bijker, Hughes, and Pinch (1987); B. Elliott (1988); and MacKenzie (1990).

3. Other treatments of power include Barnes (1988), Boulding (1989), Galbraith (1983), and Wrong (1979). See also Russell (1991).

4. For discussion of the pros and cons of nondecision making as a concept, see Abell (1977), Frey (1971), McEachern (1980), van der Eijk and Kok (1975), and Wolfinger (1971).

5. Crenson assessed nondecision making by comparing policies of cities with different political economies. Such a comparison of policies to investigate nondecision making is compatible with a structure-oriented three-dimensional view, whereas the investigation of conscious manipulation of agendas fits into an actor-oriented two-dimensional view.

6. The Lukes framework of three dimensions of power has itself been criticized. Although Lukes goes beyond the simple actor-decision orientation, even in his three-dimensional view the focus is on actors in the sense of discussing their interests (subjective or real), the existence of potential issues (involving actors), and control over the political agenda. This is inadequate from the point of view of some of those favoring a more thoroughgoing structure-oriented perspective. Marxists using the concepts of capitalism and hegemony, for example, conceive power as a relationship structured by ownership of the means of production, the sale of labor power on the market, and so forth. See, for example, the structural frameworks of Althusser (1977) and Poulantzas (1978). Miliband (1969), by contrast, presents a Marxist picture that pays more attention to actors. The differences between these perspectives are highlighted in the debate between Poulantzas (1969) and Miliband (1970).

7. On the Hong Kong project, see Catling and Harbord (1985), Dawson (1983, 1986), Dawson and Brown (1985), Dawson and Catling (1986), B. Harrison (1986), and W. Harrison et al. (1986).

8. See, among many other examples, Ellis (1975), Herken (1981), and Morison (1966) on military technologies and Pringle and Spigelman (1981) on nuclear power. Some of the best accounts in terms of following actors are by journalists, who are unlikely to be given appropriate credit by academics.

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