Incidental Paper

"Infrastructure" and the Telephone Network: Defining the Problem

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Executive Summary

Many participants in recent public policy debates about telecommunications have focused on the "infrastructure," yet there is considerable disagreement about the policy implications resulting from that focus, even among those whose concerns are expressed in similar terms. One possible explanation for the lack of unanimity is that a number of quite different analyses underlie this shared terminology, each with its own assumptions, dynamics, and corresponding policy prescriptions.

This paper develops three different conceptions of "infrastructure" based on those debates – infrastructure as inventory, the industry as a public good, the industry as a ubiquitous input – highlights the assumptions and hypotheses inherent in each conception, and illustrates some of the resulting policy disagreements. It concludes by suggesting some empirical or factual tests to help determine how well each conception – and the conclusions about public policy associated with it – actually fits today's telecommunications industry and its customers.

Contents

The "Problem" of Infrastructure

In 1990-92 a great deal has been said about telecommunications "infrastructure." Industry executives, public officials, and policy analysts expressed concern about it, concern that in many cases has led to public policy recommendations related to its perceived condition or importance.[1] Although many recommendations conflict or appear based on vague principles, and in spite of unheeded calls for the development of a broad national consensus about telecommunications infrastructure, commentators unanimously attribute great importance to the issue, even when their views on appropriate policy initiatives differ.

My hypothesis is that several distinct, coherent views of "infrastructure" exist under the single common term. When participants in disputes on the problem of infrastructure often seem to talk at cross purposes, they may be doing just that, and shared interests may mask essentially different views. The different conceptions of infrastructure implicitly convey different policy prescriptions determined by initial formulations of the meaning. In other words, I think that "infrastructure" has come to be used as shorthand for a number of quite different analyses of the telecommunications industry, each starting from different assumptions or relevant facts. The "problem" is understanding what public policy consequences follow from a given analysis of the industry's present status. If such genuinely different conceptions exist, then factual questions could be posed that would clarify which view might by a particular measure be "right" or from a particular standpoint most useful. The following discussion is an attempt to identify some of these questions.

Conceptions of Infrastructure

I call the three predominant conceptions involved in the tele-communications debate the infrastructure inventory, the industry as public good, and the ubiquitous input.

The Infrastructure Inventory

A simple inquiry can begin with the capacity, age, and characteristics of cost and performance of the fixed capital investment available to serve the demands of an industry. For example, the stock of planes in use by the airline industry is growing older, perhaps less safe, and may require replacement at a more accelerated rate than in the past. A related inquiry into the capital stock or production capacity of major aircraft manufacturers asks whether the manufacturer can build new planes quickly enough. These examples typify an analysis by infrastructure inventory.

An infrastructure inventory has many uses in thinking about corporate or public policy. An individual firm's relative competitive position may depend on the age, size, and health of its productive capacity. Forecasts of replacement needs and timing help determine capital budgets. Public policies that may impose new demands on an entire industry should be formulated with knowledge of whether or how the industry can produce the required output or of the probable effects on various vintages of plant. Generally, the main issue is how the firm or industry will find funds to support replacement, modernization, or upgrading of its productive capacity. The same kind of review can be used for productive assets owned by the government.

An infrastructure inventory analysis need not include "oughts" or "shoulds." The facts involved are reasonably objective – how many productive assets of which type are owned by whom, of what age and in what state of repair, the operating costs of these assets, whether different enterprises have different relative mixes of inputs,[2] and so on. This information can be difficult to obtain in some cases, for competitive reasons, and the implications of the analysis are apparent only when illuminated by a decision-maker's desires or concerns.

For example, the infrastructure of the airline industry is aging. Not long ago, many airline executives believed that passenger demand would continue to grow steadily and that economies of scale greatly

favor a growing air carrier. This belief, coupled with the aging infrastructure, led to concern for sources of funds to replace a large number of aircraft relatively soon. The related infrastructure inventory of aircraft producers showed high rates of capacity utilization and long lead times for orders of many new models; this secondary infrastructure inventory therefore provided cause for concern. These results might not have had implications for corporate policy if the airlines were a declining industry with falling demand.

My purpose here is not to comment on the airline industry (indeed, the foregoing "facts" are stylized to some extent) but to illustrate how the policy implications of an infrastructure inventory depend on concerns outside the analysis. For example, does it matter if the inventory reveals that aircraft are aging? Given that the industry is concerned with expansion to meet growing demand and achieve economies of scale, the answer is yes. Interestingly, the current economic slowdown may have reduced these concerns: despite a continuing substantial backlog of orders for new passenger aircraft, current market conditions have led to parking more than a hundred jets and taking them out of service.[3] A changing market can lead to very different corporate policy conclusions, even given a little-changed infrastructure inventory.

An infrastructure inventory can catalog and detail the productive capacity of an industry, but whether the results are seen as indicating a problem depends on how well they match views of the probable demands or challenges the industry will face. An infrastructure inventory does not prescribe a particular remedy, should a mismatch occur.

An infrastructure inventory of telecommunications is performed similarly. Items are cataloged, such as switches, transmission capacity, and outside plant for local telephone companies and interexchange carriers; depending on the interests of the analyst, private networks and customer-owned equipment, such as customer premises equipment (CPE), may be included. Until placed in a broader context, such statements as "the switches are aging" or "the outside plant is modern and low-maintenance" convey no policy implications. Aging

switches, for example, might represent degrading service and high maintenance costs or the laudable extension of the life span of a still useful technology.

The Industry as a Public Good

Observers who find an analogy between telecommunications networks and highways or even mass transit systems are speaking of telecommunications as a public good, which is the second conception of "infrastructure." In economics, a public good is unique in that, if the good is supplied at all, excluding potential customers from using it is either impossible or impractical. Further, consumption of the good has a quality of "non-rivalry," that is, one person's consumption does not reduce the quantity or quality of the good available for anyone else. By this definition, national defense is a classic public good. An aspect of externality may also help define a public good if one person's consumption also benefits another person or the society at large.[4] Sewers, vaccinations, or education provide examples of goods where it is in the collective interest to assure that everyone consumes a minimum amount.

Market failure can occur for all public goods. Because private producers of such goods face consumer or market demands that do not aggregate to the full public value the good creates, they will underinvest in and underproduce the goods. In other words, what individuals are willing to pay directly to use (or benefit from) public goods adds up, in total, to less than what the goods are worth to the public. In this case, the sellers of the public good will not be persuaded to produce as much of it as the public actually needs or could use; hence, the failure of the market, as society ends up having less of the public good than it would make sense, collectively, to buy. A generally accepted alternative is for government to decide on the quantity of public goods that should be produced and to pay the cost by levying taxes on the entire group of beneficiaries.

Fixed investments in public goods are often referred to as "infrastructure." In the cases of highways, which like sewers and education have a public good quality, the political process seems to have accepted that observable market demands for the goods will understate their genuine economic importance to society; the implication is public responsibility for assuring an appropriate level of investment.

For telecommunication networks, the clearest formulation of the argument of public good may be based on an externality argument, that the value of the network as a whole increases the more subscribers can be reached. Given that virtually all households and businesses in the United States now have telephones, the public good perspective has shifted from the basic supply of telephone service to the potential for upgrading the capacity or capabilities of a network and to whether coordinating enhancements to give most subscribers access to these at about the same time has a public good character.

A related argument often cited by advocates of the public good view of telecommunications infrastructure is the "supply-push" scenario for the development of applications for a new technology. These advocates suggest that all uses for a new technology can never be foreseen prior to its widespread availability. Accordingly, only after a technology (e.g., broad-band switched communication) is widely deployed will technologists and entrepreneurs quickly develop products that more than justify the investment cost of upgrading the network.

The supply-push view may issue in part from beliefs about the nature of the new information-based industries that will come to use the new network: for example, that they feature a significant minimum efficient scale[5] or a steep learning curve,[6] or that the ability to reach a mass market is essential for other reasons.[7] Any of these characteristics of the industries that might use the upgraded network to reach customers would argue for universal or near-universal deployment of network enhancements over a relatively short time.

Borrowing from the recent movie *Field of Dreams*, one might call the supply-push scenario the "network of dreams" scenario – "If you build it, they will come" – a scenario complementary to the perspective of network infrastructure as a public good.

The Industry as Ubiquitous Input

The third conception of infrastructure in telecommunications involves its economic linkages to other industries as a ubiquitous input. In the late twentieth century every industry of any significance relies to some degree on telecommunications, and many that are intensive users have benefited from continuing technological advances. According to this conception, public policy concern about the telecommunications industry should be linked primarily to its importance to the rest of the economy. Telecommunications is, so to speak, the universal raw material; high-quality, cheap telecommunications facilitates widespread economic success.

A ubiquitous input need not have a public good quality nor any unusual economic characteristics. Industries that demand a ubiquitous input can do so in proportion to their need for it and to the overall value it creates, with no gap between private demand and overall economic welfare. As providers, telecommunications firms might well have the appropriate incentive to produce the full measure of what society needs, so no systematic shortage would occur, as occurs in the market with a public good.

The policy implication of this conception of infrastructure is that telecommunications should be supplied as cheaply as possible. As with any market good, consumers should be permitted to demand varying levels of quality (and corresponding prices); a public policy mandate requiring high standards of minimum quality could force consumers to pay more for more quality than they need. Measures that increase the price of telecommunications reverberate throughout the economy by increasing the cost of all goods whose production is dependent on the ubiquitous input.

The telecommunications industry is hardly unique in this respect; many industries have pronounced economic linkages to many other industries. What sets telecommunications apart is the intensity of its use in many high-value-added sectors and its rapid pace of innovation and technological change.

The metaphor related to the conception of telecommunications infrastructure as ubiquitous input, corresponding to "supply-push," is "demand-pull." Demand-pull advocates say that investment will logically follow demand when a consumer market finds applications of sufficient value to justify the investment expense. Personal computers, for example, are a compellingly useful technology, but until wordprocessing and electronic spreadsheets were developed and marketed few were purchased except by hobbyists. The usefulness of those applications justified the creation of a vast installed base of personal computers available now for use with other applications. The economies of scale in producing computers and marketing software are available, even though no effort was made to subsidize the availability of personal computers. Thus, what supply-push advocates seek was achieved in this industry through the operations of market supply and demand.

Conflicting Perspectives

Conflicts among the three conceptions of infrastructure are, as stated at the outset, apparent, and, similarly, the implications of policy perspectives adhering to each conception, and the concomitant arguments, also conflict, particularly for the industry as public good versus the industry as ubiquitous input. As suggested, the implications for public policy of an infrastructure inventory may depend on the goals involved in evaluating the results of the inventory, although such implications are more closely tied to the conceptions of infrastructure as public good or ubiquitous input than to an infrastructure inventory.

In the case of the public good, external funding of investment or production is needed to assure that output reaches appropriate levels;

for the ubiquitous input, market demands will motivate the production of an adequate supply. In the case of telecommunications, cross-subsidies for various social purposes have almost always been generated within the industry by the equivalent of taxation through pricing: some products are given a higher mark-up so that others may be offered more cheaply.[8] Cross-subsidies for telecommunications stand in contrast to examples of public goods (highways, sewers, education), public financing for which often is provided from an external source. If telecommunications is viewed as a public good, then raising the price to existing customers in order to fund new investment in the network (i.e., investment not otherwise cost effective) might create a public benefit. Alternatively, in keeping with this perspective, breaking with precedent to use general tax revenues to help fund widespread investment in telecommunications networks might be appropriate.

Viewing telecommunications as a ubiquitous input argues against non-cost-effective investment, which would raise the price to all users, because this would result in direct harm to the economy without an offsetting benefit. Consumers would pay to support deliberate excess capacity for a market good; the resultant higher prices would act like a tax on the economy as a whole (because of the ubiquity of telecommunications as an input), which might hit the most innovative sectors hardest if these use telecommunications intensively. According to the view of telecommunications as ubiquitous input, systematic stimulation of network investment would not be necessary, beyond what investors in the telecommunications industry found profitable.

Challenging Advocates of the Three Conceptions

The issues raised here are to some degree empirical and should provide the bases for hypotheses which, when tested, will indicate that one approach rather than another will appear appropriate for a given circumstance.

In this regard the National Telecommunications and Information Administration (NTIA) Notice of Inquiry into the telecommunications

infrastructure[9] is helpful, posing numerous questions about the "infrastructure" from which various useful hypotheses can be picked out. In addition, I offer further questions that might be posed to advocates of the views of telecommunications as a public good or as a ubiquitous input.

Challenging Advocates of Telecommunications as a Public Good

One issue for public good advocates to respond to is the historical pace of deployment or development of other public goods infrastructures – highway and rail networks, water and sewer systems, and public education. In most or all of these cases, the current extent of the infrastructure was reached gradually, often over several decades. Advocates of simultaneous and universal deployment of fiber loops (or other technologies) need to address why, even if the view of telecommunications as public good is valid, telecommunications is different from the other cases. The most relevant example might be the telephone network itself: decades passed between the widespread availability of telephone service and the achievement of universal service, a pace of deployment that has not been shown to have caused either harm or substantial loss of opportunities.

Another issue for public good advocates is market definition, in the terms of both supplier and product. On the product side, given that universal connectivity has been achieved, to what extent do potential enhancements relate to broader markets, such as entertainment or information processing? The public good character of telephone network enhancements would seem doubtful if their result was simply one more means of offering an existing competitive product. For example, because cable TV and a range of information services already exist in well-developed markets, any need for public infrastructure to permit competition in the existing market, rather than to initiate the supply of a vital service, is difficult to imagine. Similarly, the increasingly competitive nature of telecommunications supply can create doubts about what to subsidize: beyond the complete or partial

substitution competitive networks offer for one another (e.g., interexchange carriers), many large customers also have their own private networks which perform similar functions. A general policy of, for example, tax credits could benefit all builders or buyers of infrastructure, but would that be the right focus? In my view, the following questions arise: What elements of the network are essential, why are they likely to remain so, and what risks does the public run in subsidizing the further development of any particular group of providers (e.g., local exchange carriers)? Can public-spirited advocates of subsidizing a particular aspect of the infrastructure avoid becoming co-opted by the firms that own it?

The most successful consumer products of the information age have been decentralized and come under the control of individual consumers. Fax machines, personal computers and modems, videocassette recorders (VCRs), and answering machines are examples of the notable commercial successes of this technology. These products do some of what an enhanced telephone network could, and, indeed, many proposals for subsidized network enhancements are based on these specific capabilities (e.g., fiber loops for video transport). It is a truism that what can be done by a smart network can be done by a dumb one with smart peripherals at either end, although the relative costs of these extremes and of any mixed strategy fluctuate with changing technology.[10] In time, the net subsidy needed for universal deployment of this technology will decline and probably disappear; the upgrade will become cost effective on its own. If so, then the question arises whether this (or any particular) year is the right time to pay the needed net subsidy. Even for advocates of telecommunications as a public good, the trade-offs of timing deserve careful consideration: the longer the wait, the cheaper and more evidently useful the upgrade. If the wait is long enough, the upgrade will happen on its own.

Challenging Advocates of Telecommunications as a Ubiquitous Input

Advocates of the view of telecommunications as ubiquitous input also need to consider certain questions. There is evidence to support the "network of dreams" argument; for example, the uses for personal computers have far exceeded most people's initial vision, and the public might have benefited had the industry's present scale been achieved earlier. Yet in relation to personal computers the issue of timing may be trivial, because the industry has developed rapidly; for telephone networks, the lead time for the universal deployment of anything is considerable. Should such deployment start sooner rather than later?

Certain social problems are considered particularly susceptible to technological assistance, such as the need for greater productivity in education in a time of limited funds or the need to make a depressed rural area attractive to economic development. Many developing countries have attracted significant outside investment in part by localized investments in state-of-the-art telecommunications networks for business use. These examples suggest (*i*) that modern communications will act as a catalyst for growth and economic activity in an almost multiplicative way and (*ii*) that certain institutions (e.g., education) simply cannot afford what they need and ought to be subsidized indirectly by being given the telecommunications capabilities they would buy if they could. The first point, if true, would provide real evidence in support of the conception of telecommunications as public good. The second is an argument that might deserve consideration for the use of public money. Can advocates of telecommunications as a ubiquitous input rebut both points?

The effects of regulation may matter. For example if poor regulation has impeded investment in new technology and resulted in an antiquated telecommunications infrastructure, then a catch-up program of modernization might be appropriate. Logically, such a conclusion would imply a need to reform regulation. Put another way, advocates who call for a program of immediate telecommunications investment because they believe that important networks have run down should be willing to

recognize that something about the overall structure of regulation may have contributed to the development of the situation.

Conclusions

I hope this analysis may help encourage participants in the debate on telecommunications infrastructure to clarify and carefully construct their arguments. They are debating an issue of substantial importance, and their clarity might help a broader audience participate in resolving it. No side may be entirely right. For example, the local exchange price caps set by the reform decision[11] of the California Public Utilities Commission (CPUC) strongly favored the ubiquitous input view: the CPUC found that, absent retrospective "prudency" review by regulators, market-like incentives for telephone company management would lead to appropriate levels of network investment. The same decision authorized a small rate increase for Pacific Bell to support the cost[12] of modernizing all its remaining step-by-step and crossbar central offices. The CPUC embraced the first view yet allowed for facts that justified a small exception for the second. Other opportunities may well exist for similar compromises in the national debate.

Glossary

CPE	customer premises equipment
CPUC	California Public Utility Commission
NTIA	National Telecommunications and Information Administration
VCRs	videocassette recorders

Notes

1. Andrew C. Barrett, "Public Policy and the Advanced Intelligent Network," *Federal Communications Law Journal*, 42:3, Federal Communications Bar Association, UCLA School of Law: Washington, D.C., July 1990. William H. Davidson and Ronald Hubert, *A Comparative Assessment of National Public Telecommunications Infrastructures*, MESA, Inc., 04/09/90. Deloitte and Touche, State of New Jersey Public Utilities, *New Jersey Telecommunications Infrastructure Study: Volumes 1, 2, and 3*, New Jersey Public Utilities: Newark, N.J., January 1991. National Telecommunications and Information Administration, United States Department of Commerce, *Comprehensive Study of the Domestic Telecommunications Infrastructure: Notice of Inquiry; Request for Comments*, Docket No. 91296-9296, NTIA: Washington, D.C., January 1990. National Telecommunications and Information Administration, United States Department of Commerce, *The National Telecommunications and Information Administration (NTIA) Infrastructure Report: Telecommunications in the Age of Information*, NTIA Special Publication 91-26, United States Government Printing Office: Washington, D.C., October 1991.

2. For example, some use more labor but less energy, or perhaps use raw materials in different proportions to create a product.

3. "Will They Ever Fly Again?" *The Economist*, 7 March 1992, 67-68.

4. In economics, an externality occurs when one person's activity causes a cost or benefit to another, where the first person would not ordinarily face the cost (or see the benefit) of that "spillover." Pollution is a classic negative externality: the widget-maker spews out soot that causes cleaning bills for the neighbors but (absent intervening laws or regulations) does not cost the widget-maker anything. Painting one's house can create a positive externality if as a result the whole block gains in appearance, and other houses on it become more attractive or valuable.

5. Unit costs are high until volumes are substantial, so a large market opportunity is needed for the financial success of firms that would use such a technology; this might be the case for selling information costly to produce but, once in hand, cheap to distribute.

6. The unit cost of delivering the initial product is high, but unit costs decline as, cumulatively, more units are produced (the firm learns how to produce more cheaply with experience).

7. Such as economies of scale in advertising.

8. A notable exception is low-cost loans to small telephone companies from the Rural Electrification Administration (REA).

9. National Telecommunications and Information Administration (NTIA) Notice of Inquiry 91296-9296, released January 9, 1990.

10. Anthony G. Oettinger, personal communication.

11. CPUC Decision 89-10-031.

12. Strictly speaking, the dollar amount allowed was the incremental cost of the upgrade, net of resulting operational savings and revenue from new products the switch upgrades would permit to be offered.