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ABSTRACT

This sociotechnical analysis assesses the effects on the educational environment of migrating from the currently fragmented analog system to an environment dominated by integrated digital telecommunications systems. An integrated telecommunications channel is at the heart of the design for an ISDN (integrated services digital network). ISDN is a set of technical standards and a network architecture that describe a digital telecommunications channel able to carry voice, data, and compressed video on the same telecommunications network. Two central issues are how an integrated telecommunications system will differentially affect voice, data, and video users, and whether ISDN inherently favors large or small "customers" for telecommunications services. The conceptual discussion is followed by a case study of a large university (Ohio State) in the process of developing an integrated telecommunications system. (26 references) (Author/EW)

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Introduction

Whether an organization is a commercial or educational enterprise, technology-based communication systems are central to the organization's ability to accomplish its mission. As learning and work become de-centralized, the configuration of electronic networks and the organizational functions they facilitate and inhibit grow in importance. In commerce, the clearest evidence of the role of telecommunications can be seen through an analysis of costs. For example in the finance industry, Citibank reports that telecommunications, following only payroll and real estate disbursements, is the third largest expense it incurs in providing its services (Noam, 1987). In education, usage may be a better measure than costs for describing telecommunication's increasing role. Today, many researchers rely daily on electronic mail networks such as ARPAnet, NSFNET and BITNET to accomplish their research goals. Recognizing the growing importance of electronic communication to scholarship, EDUCOM, a cooperative of educational institutions, has set the establishment of a fully interconnected national computer network as one of its principal goals (King, 1988).

Telecommunications serves to link individuals within and across organizations. On average, large organizations report that about 60 percent of their telecommunication needs are internal with the remaining 40 percent external to the organization (Lera, 1986). Since individual rates of adoption differ within organizations, and because shared technical features of the available communication links vary among different organizations, the enhancements available in individual work environments create preferred networks among persons and simultaneously interfere with the construction of other social patterns. Technological conformity and nonconformity are influencing the social organization of work which in turn affects which jobs are accomplished and which are marginalized because of the difficulty in accomplishing particular tasks.

An important goal of an institution's strategic planning process is to avoid a technological distortion of what work should be completed. In other words, technology concerns (costs, availability, usability) should not determine the goals an institution sets for itself. One tool useful for grounding the strategic planning function in personnel rather than technology is *sociotechnical analysis* (STS). In addition, STS offers an approach to maximizing the benefits available from the technological work environment.

Sociotechnical Analysis

Sociotechnical analysis is an intervention-oriented methodology with the purpose of integrating technological change into a work environment (Huse, 1980). STS assumes that a system's output is an interaction between people and the technology they apply to their jobs. Traditional sociotechnical analysis advocates a process of scanning the technological environment, scanning the social environment and consulting with workers to address the problems introduced by the shift to a new technology and the implied change in how work is accomplished (Pava, 1983). Through this process of defining technical problems within the purview of the affected user population, the researcher allows the community to construct its own appropriate responses rather than imposing exogenous solutions. Consequently, STS begins by defining the organizational problem at the level of the individual or organizational subunit prior to defining the organizational solution.

STS has proved most successful in organizations in which operations could be unitized and brought under the control of small work groups that share well-defined, common interests. STS is more difficult to use in large organizations in which individuals perceive their self interests as only loosely coupled (Pava, 1986). Often, individuals perceive decisions made at the higher organizational levels to have outcomes that create competition rather than collaboration among subunits. Telecommunications provides an arena in which the partitioning of resources (e.g., bandwidth, terminal equipment, connect time) can be viewed as win/lose trade-offs among various users.

Traditionally, users of telecommunication services have been identified by the mode of information transmitted: voice, data, and video. Voice and data traffic usually are an aggregate of many relatively small individual needs (although the emergence of supercomputers is changing this in the data field), while video represents fewer users who require large chunks of network capacity at irregular intervals. As long as these services had been kept segregated into telephone (voice) data processing (DP) and "television" (video), user groups and decisionmakers were rather successful at ignoring their interdependence. However, as telecommunication costs have grown very large, and as more and more users find access to such systems essential for their work, organizations have been forced to centralize the telecommunication responsibilities, often under individuals with titles such as Vice-President of Information Services. Under this re-organization of voice, data and video into a united information service, the technologies are being examined for their complementary aspects rather than perceived as independent needs.

Telecommunication planning committees are finding it is difficult to apportion costs across a network configured to serve voice, data and video users because pricing models by which to provide these services can be construed in radically different ways. In an integrated network environment, optimizing network utilization requires a value judgment above and beyond an economic rationale. For example, a *full cost recovery model*, in which services are priced such that each technology pays for itself, will be perceived by video users as discriminatory because the cost of video (at this stage of its development as a telecommunications service) when isolated under this model is quite high. An alternate pricing strategy known as *Ramsey pricing*, in which a technology which users need the most is priced above its actual cost, would generate a rate structure in which the cost of voice circuits could be set above their true cost to subsidize other telecommunication services. Because the demand for voice is relatively inelastic, voice users (by paying the higher prices) will encourage the growth of video. The choice of pricing model has much more to do with the institution's perceived goals, than it does with a purely economic solution. The various users of the network must concur early on with respect to those goals if the organization is to reach a satisfactory pricing decision. Otherwise, when the issue of paying for the system surfaces, as it inevitably must, the debate will be disruptive to the migration of the community to the new technology.

From the perspective of the designer of the telecommunication network, sociotechnical analysis advocates that the voice, data and video users be drawn together and their various needs made explicit *prior* to the construction of the network. This *social scan* allows the planners and designers of the technological environment to foreground the anticipated trade-offs among the members of the organization. Determining the organization's members' expectations about how their organization functions (called their theories *of action)* will influence how the technological change can be implemented. The designer must anticipate the set of possible responses (or actions) toward the technology from the organization's members based on their theories of action. Often, these action theories will differ from what the agent *espouses* in a planning session. Nor will the espoused theories stay stable as technology introduces unexpected problems and issues. When users' theories in action differ from their espoused theories, the initial goal of STS is to delineate apparent contradictions in each individual group's actions and the explanation they present for their actions. Once this level of self-reflection has been obtained and made public, it is possible for the organization to try to manage the change process to more successfully achieve its aggregate goals. (Argyris & Schon, 1978).

Sociotechnical analysis traces its origin to the Tavistok group in England and co-founder Eric Trist's work with introducing new technology to the tradition-bound coal mining industry (Trist, Higgens, Murray and Pollack, 1963). The problem they faced was that coal output fell when new production equipment was introduced, even though the new methods were clearly technologically superior to the old mining techniques. By involving the miners in re-designing their approach to their work, the promise of the new design was realized and led to a substantial rise in output. The STS process and outcomes have been replicated in many diverse industries with long histories, including automobiles (Guest, 1979) and dog food (Walton, 1977). With respect to the new telecommunication environment, the issues revolve around how to represent the needs of the diverse set of telecommunication system users which are more emergent than historical in nature and to then design networks and price their utilization flexibly to accommodate these volatile and diverse needs. Sociotechnical analysis advocates generating a description of both the social and technological environments as the baseline for the needed collaborative decision making.

Technological Scan

Five years ago, a technological scan of the telecommunications environment would have uncovered a myriad set of network options. Typically, the voice and data networks would be dedicated to these functions and leased from public common carriers. When special needs arose (e.g. expanded long distance capacity or the introduction of a supercomputer), the local telephone company would be contacted and a series of leased high capacity or long distance circuits would be negotiated. Video needs, such as for videoconferences, would be purchased on an ad hoc basis from one of several value added suppliers, typically using portable satellite dishes to provide the temporary communication links (Elton, 1982).

Today, and partially propelled by the 1984 breakup of AT&T, the set of possible network options has actually increased in number. However, as the various user needs have continued to grow, more and more large organizations are pursuing internal solutions in which they build and manage their own integrated network rather than contracting individual external vendors. This unification of telecommunication functions in organizations generally inexperienced in the management of large scale networks has raised the profile (and anxiety levels) of those charged with meeting an organization's telecommunication needs. One outcome has been that the longstanding call for more standardization in the telecommunication industry has been accelerated and joined by many new voices.

Another significant event initiated by the breakup of AT&T is the furthering of competition between the computer industry, oligopolistically structured and dominated by IBM, and the telephone industry, dominated by AT&T with its monopolistic form and personnel raised in an environment insulated from competition. One of the assumed benefits of challenging IBM with an equally well-capitalized opponent, and challenging AT&T's corporate culture of complacency, was that the many different telecommunication system users would benefit from greater choice, more responsive service, and lower costs. However, how this environment unfolds is heavily dependent on whether the telecommunication or computer model that traditionally has defined the innovation process dominates the merged services.

To date, innovation is being driven by the competitive models historically-based in *both* the computer and telecommunication spheres. The computer model has emphasized custom features responsive to unique needs of an industry or user, over-and-above the virtues of having the system compatible with other systems. The telecommunication model has emphasized interconnectivity at the expense of the absolute "best fit" for a particular client.

As the once separate industries continue on the path toward overlap and merger, the aftermath of divestiture has been increased chaos and uncertainty in the telecommunication world (Datamation, 1988). Users, manufacturers and vendors all want more stability, but all for different reasons. Users want to have various technologies "plug compatible" to streamline purchasing, maintenance and personnel needs. Vendors would like to offer "turnkey" solutions to users, and manufacturers prefer large markets in which to recover the costs of innovation rather than multiple small markets all of which have heavy costs associated with sales. At issue is the form that this standardization should take since this will influence whether the computer industry's model or the telecommunication industry's model of the increasingly merged market will drive the market's growth and development.

Standards Organizations

The International Telecommunications Union (ITU) through its CCITT (International Telegraph and Telephone Consultative Committee) plays an important role in establishing standards for the telecommunications industry. The ITU is heavily populated by the PTTs (post, telephone and telegraph authorities) of most of the countries in the world and also includes AT&T and other free market enterprises in the United States. Because of its overall representational skew toward businesses built on central planning, the ITU's standards and regulations are oriented toward central control. Helmont Schoen, head of Telecommunications at the German Federal Ministry of Post and Telecommunications, presents a persuasive view of the role of standards from the perspective of the PTTs when he explicitly links the role of standards to the welfare of the entire German economy. He observes that a standardized international market must be available for German industry to be able to compete outside of its own comparatively small domestic market (Schoen 1984, cf Noam, 1986). With an emphasis on central control, software complexity and CPE (customer premise equipment) interconnectivity are less at issue than are system integrity and security. The view of standards has the effect of favoring one of several "break points" for defining where the central network begins and the customer's on-site equipment begins (Noam, 1986).

Another organization heavily involved in setting world standards is the International Standards Organization (ISO), whose membership reflects manufacturers of both computers and telecommunications equipment as well as national standards setting committees such as *ANSI* (American National Standards Institute). While the ITU and ISO share the goal of complete end-to-end interconnectivity, it is fair to say that ITU concentrates on transmission "plant" issues and ISO emphasizes the standard setting functions which benefit those who create terminal equipment (Noam, 1987).

OSI

The ISO's approach to the issue of standards is to divide the communication session into seven hierarchically arranged layers called the *Open Systems Interconnection Reference Model* (OSI) (Miller and Ahamed, 1987). Conceptually, the seven layers can be divided into three functional layers. The top three OSI layers are called *application* layers (e.g. electronic mail, file transfer, remote login procedures), the middle layer is called the *transport* layer (error detected and corrected transmission), and the bottom three are called the *communication layers* (routers, local area networks, etc.) (Arms, 1988). Equipment that conforms to the OSI standards (where fully implemented) is interchangeable with similarly standardized technology and will function within the compatible communications environment. However, since the seven layer OSI model is not fully described (i.e everyone has not agreed to its totality), there continues to be a substantial problem with full interconnectivity among technological components.

ISDN

Because of its membership makeup favoring PTTs, the CCITT has particular concerns with the communications layers of the OSI model. One of the recent, and potentially most significant activities of the CCITT, was th . 1984 formulation of proposed standards for ISDN (integrated services digital network). ISDN is a set of technical standards and a network architecture which describe a digital telecommunications channel able to carry voice, data and compressed video on the same telecommunication network. It is a standard that is in the process of being integrated into the OSI model at the lower three layers (Melindo and Valbonesi, 1986). Fully implemented, ISDN standards will have world-wide compliance. Decina writes that ISDN's key feature is that the user-network interface will be standardized such that the working of the network will be transparent to end-users (p. 20, 1982). Noam (1986) points out that ISDN can be implemented at various points some conceptually closer to the user's customer premise equipment (favored by the network philosophy) and others further from the CPE-connect point (which favors manufacturers of terminal equipment).

Regardless of the cut-off point for standardization, a basic ISDN channel provides the capacity to carry 144 kilobits-per-second (kbs) of digital information. This channel capacity is divided into three subchannels. Two of the subchannels are designated as **information** channels and can carry 64 kbs of information. The remaining 16 kbs of information are dedicated to the third subchannel called the **signaling** channel (Rutkowski, 1985). Since ISDN is a digital network, many communication services can be delivered over the same channel, including voice, facsimile, videotex and slow-scan videoconferencing. The European Economic Community proposes to have a standard basic ISDN service linking its twelve member countries by the end of 1988 (Arms, 1988). Somewhat further in the future, At&T is working on a primary-rate service which can provide ISDN compatible service up to 1.5Mbs.

By dedicating the **information** subchannels of ISDN to various communication services, the **signaling** subchannel permits such enhancements as indicating the identity of a station placing an incoming phone call or running a "clock" that ticks off the charges-per-minute associated with a given communication service. In short, the ISDN technology promises remarkable flexibility through dynamic reconfiguration of the telecommunication channel, and, in the minds of many observers, the vehicle by which multichannel, international communication will someday become commonplace and affordable. Nonetheless, to support ISDN implies a support of a standard with some costs to some members of the user environment.

Social Scan

In spite of the great potential of ISDN, a question that should early jump to mind is: "Why should we expect ISDN to be different than videotex, consumer videodisc and a host of other new communication technologies that debuted with much optimism but very limited early market acceptance? The potential of every technology is only realized within an interdependent arena of its design, the policy governing the technology, and the social context of the user community into which the communication services are to be introduced. Consistently, technologies are oversold on their design potential with too little regard to how national policy and user needs may impact on the technological promise. In the case of ISDN, the importance of policy is heightened because the expressed goal of a "world standard" implies coordinated agreement among many different politics and the need for ISDN stations to develop comparably in many different countries. Of no less importance is the requirement for users to settle the issue of integrating the management and control of telecommunication services in the new unified environment.

In understanding the social environment for telecommunication, it is important to realize that in all countries, the telephone network developed as a social service that used cross subsidy from heavy users (typically business and institutional customers) to support a universal network linking light users (individual households) (Pool, 1983). Lera (1986) points out that ISDN's appeal from a technological perspective is that it allows available bandwidth to be used efficiently. He reports that voice traffic represents 80 percent of the required bandwidth of telecommunication networks and that around 70 percent of the voice traffic is generated from residential users who are inefficient users of bandwidth. The other sector of customers is the commercial/institutional cohort who more routinely fully utilize their available circuits and would like to be able to reapportion their needs by splitting ISDN's bandwidth. Noam (1987; p. 34) reports that 3 percent of the users generate 50 percent of the telephone revenues for the network providers. While a shift to ISDN would facilitate a pricing structure sensitive to large user needs, it is unlikely that the political process will allow the residential subsidy to be eradicated. This re-allocation capacity is important for ISDN to realize any major benefits for its large users and directly casts the issue of maximizing network efficiency along major pathways (i.e. among several large users) versus the.design goal of maximizing reach among many pathways (i.e the concept of universal service overriding issues of efficiency).

While none can argue against serving major customers, if this service implies discrimination against small users, it becomes a different issue. Kench (1986) points out that a survey of rural users of telecommunications in his native Australia indicated a need for three things: (1) a telephone, (2) a telephone that worked; and (3) a telephone that worked all of the time. Notably absent was a hue and cry for enhanced data or video services. Similar reasoning and needs identification have historically underscored the PTTs philosophy that developed and still governs network management (Noam, 1987).

This same social demography applies at the organizational level. In a university context, all departments and colleges have well-defined needs for reliable telephone services (Marks, 1988). And, although there continues to be a skew toward engineering and professional schools, data requirements are generally acknowledged as essential to university work (Solomon, 1988). At the periphery is video, a service of considerable expense that has not yet been routinized into the university's daily activities (Selby, 1988). In the next section, a large organization trying to integrate these telecommunication services across subunits with different needs is examined.

Case Study

To meet rapidly expanding telecommunication needs, the Ohio State University began an installation of a fiber optics network in 1983. In the process, the University took over the responsibility of managing the university's telephone service from Ohio Bell which continues as one of the vendors who interconnects the university with outside constituencies. The Ohio State system relies on a fiber optics backbone with copper twisted pairs to provide internal building wiring. At least six fibers terminate in most office, classroom and research buildings. Some buildings with known heavy needs (e.g. the university's public television station and supercomputer facility) have additional fiber optic cables. Depending on the interface equipment attached to the fiber optic backbone, voice, data and video (with additional intemal wiring) services can be provided.

When OSU chose to have voice, data and video share the fiber backbone, it created a centralized telecommunications management structure. This structure provided a logical fit for many of the university's centralized telecommunication needs. For example, the university recently has moved to a telephone-based registration system for students that ultimately will serve over 50,000 students per quarter. In addition, the library's holdings can be searched from faculty offices and any other location equipped with a modem (there are no charges attached to this service). The university also manages four campus electronic mail networks and interconnects with several national networks including BITNET and ARPAnet. Also, a supercomputer facility has located on the university campus and must be accessible to researchers from other institutions as well as from a de-centralized set of academic departments on campus. Coordinating and funding these uses of telecommunications centrally is seen as furthering the university's overall mission in an efficient way.

Besides these centrally-defined services, the academic departments on campus have locally determined telecommunication needs. The several hundred individual departments have substantially different requirements with respect to voice, data and video. Originally, when the university-managed phone system replaced Ohio Bell's service, a method of apportioning costs was chosen that resulted in substantial increases in the charges to all departments for telephone services . At the same time, data needs remained centrally funded so that departments received encouragement to use electronic mail and remote access to mainframe computers. This "encouragement" directly reflects the fact that individual department operating budgets do not reflect actual usage for data paths. Video has remained a problem with the few experimental applications being addressed in an ad hoc manner. Since the university has access to both satellite downlink and uplink facilities, a small but vocal component of the campus community is seeking university level subsidy for video to encourage its use. The university's concern is that the charges for voice already are seen as too high by many departments (Levitt, 1988) and the original model for retiring the bond issue that paid for the system has had usage assumptions changed by unexpected needs which have emerged.

The issues facing OSU grow at least partly from the decision to centralize telecommunications. In many respects the OSU experience with an integrated network parallels the concerns raised with respect to ISDN, many small users whose needs are concentrated in the voice area are finding their telecommunication costs increased. And, although the spectrum of services is wider, more flexible, and of higher technical quality at the organizational level, the individual user environment focus on only a subset of these capabilities. As a result, many departments feel they are forced to pay for capabilities that they actually do not need. Now recognizing this, Ohio State is enlarging representation of departments across campus and is examining other pricing/support options

Arms (1988) has edited a valuable book on the construction of campus networks. It includes case studies from 10 universities that differ with respect to size and emphasis on research and teaching. Not surprisingly, the solutions created within these differing social environments themselves differed substantially.

Stanford University's SUNet, was one case study included and describes a network built in the early 1980s premised on an alternate cost-recovery method than OSU's. Like OSU, Stanford attracts substantial external funds that provide operating revenues for departments, particularly those in the physical sciences and engineering. While these departments can employ strategies to pass their telecommunication costs to outside funders, the humanities and social sciences often find themselves more confined to internal budgets to meet operating expenses. Recognizing this, Stanford elected to provide a university-wide subsidy for the use of the network, requiring departments to pay for the network wiring and connectors within their own buildings. Of equal importance, Stanford chose not to integrate voice, data and video but rather to operate a voice network and a separate high-speed computer and video network (Siegman and Yundt, 1988). In essence, Stanford's emphasis on department-configured systems has traded-off central standardization and management for flexible resource allocation. Not surprisingly, this technological solution and concomitant management structure poses different social issues for Stanford. For example, central administration must encourage departments to undertake some of the long range planning that OSU more easily can pursue with its centralized structure.

Summary and Conclusions

The potential of any technological innovation must reflect both technical and social considerations. In the case of ISDN, its technical strengths stem from its potential to bring order in the chaotic telecommunications marketplace. Its weaknesses follow those common to all efforts at standardization: it is never easy to decide when the rate of technological progress has slowed to the point where standardization makes sense. In the case of ISDN, the 64/kbs channel originally was chosen to reflect the needs of voice, the largest user class for telecommunication services. However, further technological advances already have made it possible to reduce the voice bandwidth to 32/kbs bringing into question the need for a 64/kbs information channel. At the same time, other users feel that the basic ISDN channel capacity of 144/kbs is too low a bandwidth to meet the communication needs already on the horizon (Newstead, 1986).

In the social sphere, the attraction of ISDN reflects the desire of a centralized organizational management to be served by a centralized telecommunications network (Noam, 1987). While this centralization facilitates planning for the organization's overall needs, whether the integrated solution is viewed as equitable by the organization's sub-units depends on whether the sub-units feel that the pricing and operation of the system interfere with their individual objectives rather than facilitates their attainment.

While most ISDN experiments have occurred in other countries, many large U.S. organizations have been involved with implementing large scale telecommunication networks. One lesson that has been learned is that an important goal of an institution's strategic planning process is to avoid a technological distortion of its mission. To avoid technology concerns (costs, availability, usability) inappropriately determining the goals an institution pursues, sub-units representing different mixes of voice, data and video needs must be part of the collaborative planning process during the shift to an integrated telecommunication network. Technical decisions must be sensitive to the social ramifications if the organization is to be well served. Sociotechnical analysis can foreground the tradeoffs from the perspective of these sub-units as the overall needs of the organization are pursued.

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