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Expected Impacts from
TeleKansas II Fiber Optic Links:
Channels of Influence
Construction Impacts
Tele-education

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

Tables:

Figures:

EXECUTIVE SUMMARY

PURPOSE

This report was prepared by researchers at the Institute for Public Policy and Business Research at the request of Southwestern Bell Telephone Company, in connection with its proposed TeleKansas II Project. The report focuses on the expected socio-economic impacts of the proposed investments in fiber optic transmission lines, especially in rural areas. The purpose of the report is to provide a scholarly appraisal of the benefits of the services that fiber optics may be able to provide to the state of Kansas.

This report is *not* a benefit-cost analysis; in particular we do not appraise the economic effects or reasonableness of any changes in rates, tariffs, or regulations proposed or implemented in connection with the TeleKansas projects.

THE INFLUENCE OF NEW SERVICES: A QUALITATIVE REVIEW

Based on a review of the literature, fiber optic transmission services are expected to have a variety of positive effects on rural Kansas.

Essential Effects

Rural fiber optics is expected to be both an essential prerequisite and a triggering stimulus for several types of consumer and business services:

• In medicine, fiber optic technology is essential for remote emergency care and for remote imaging and diagnosis. Both techniques will allow urban specialists to assist rural patients without the time and expense of transporting doctors or patients.

• In education, fiber optic technology is essential for two-way full-motion video distance education. This technique will allow rural high schools to increase the scope of class offerings and reduce costs by sharing teachers across high schools.

• In consumer services, fiber optic technology opens up the possibility of on-demand video.

• In business communications, fiber optic technology is essential for two-way high-volume digital data transmission and for heading off private bypass strategies. In other words, in the absence of fiber optic cables, some individual businesses will meet their private needs via private satellite transmission strategies, while other businesses will have to make do without.

Facilitating Effects

Rural fiber optics will also facilitate many other consumer and business services functions, although these could also be implemented (at a higher cost) using satellite or copper transmission:

- In medicine, fiber optic technology will facilitate home-provider links such as remote monitoring and remote triage; rural-rural provider links, such as centralized records and remote consultation/diagnosis; rural-urban provider links, such as remote expert systems and remote literature searching; and provider-insurer links for billing and referral authorization systems.

- In education, fiber optic technology will facilitate partial courses (modules or units that are integrated into the curriculum); enrichment materials (one-time only presentations); training and staff development; student and professional communication (individualized access of outside resources); college and graduate courses; and adult continuing education courses.

- In consumer services, fiber optic technology will facilitate services such as call forwarding, call waiting, and 911 emergency numbers.

- In business communications, fiber optic technology will facilitate value-added services (like caller ID); high resolution fax; and high speed modem transmission. It will also improve data security and reduce error rates.

QUANTITATIVE ESTIMATES OF IMPACTS

This study provides numerical estimates of the impacts of TeleKansas II through two channels of influence: construction and education.

Construction

The construction phase of TeleKansas I and TeleKansas II started in 1989 and, as proposed, would extend through 1999. TeleKansas construction over both phases is estimated to generate roughly ten million dollars per year in direct wages and salaries in Kansas. It is estimated to generate on average around 200 jobs directly in the construction sector. After allowing for multiplier effects, the project will generate a total of around $20 million in personal income, and around 500 jobs per year.

These numbers are conservative. They include only the results of the physical construction associated with these projects, not the increased service capability provided by the completed projects. And they do not include the direct and indirect effects due to the purchase of supplies, materials, equipment, and services other than construction.

Two-way Tele-education

Kansas rural and small town high schools are significantly smaller on average than urban high schools. As a result, rural high schools tend to have significantly narrower course offerings. The cost of adding more rural teachers and classrooms to provide course offerings throughout Kansas equivalent to the best urban high schools was estimated at $250 million per year.

Fiber optic telecommunications can bridge the gap in course offerings at less expense by supporting two-way interactive video teaching. In particular, a single teacher can reach students in several high schools simultaneously using equipment that allows the teacher and all the students to see and hear each other. This method of teaching is sometimes called "distance education." Southwestern Bell's proposed investments in TeleKansas II would make this technology available to about one-half of the high schools in Kansas.

Rural high schools served by Southwestern Bell could potentially provide urban-quality course offerings at a cost of $25 million per year. The net saving from using distance learning rather than adding teachers would be about $40 million per year.

PROPOSED QUANTITATIVE IMPACT METHODS

For two additional channels of influence, health care and price-quality changes, we have outlined methodologies which, if implemented, would provide quantitative estimates of the magnitude of impacts.

Health Care

Our proposed research on the applications of telecommunications to health care includes four phases:

- First, we propose to identify the specific applications through which advanced telecommunications can influence health care.

- Next, we would define indicators by which to measure improvements in health care delivery.

- Next, we would gather data and modeling ideas, both from pilot projects making use of advanced telecommunications and from published sources.

- Finally, we would estimate the impact of telecommunications for each of the previously defined applications.

This proposed study would spell out the impacts of telemedicine in Kansas, not only in terms of cost, but also in terms of quality and access to health care. We believe that this would be the most comprehensive study of telemedicine to date.

Economy-wide effects of Improved Service

To explore the long run impacts of TeleKansas II, we propose to implement an general equilibrium model of the rural Kansas economy. Such a general equilibrium model would take account of the structural interdependence of the economy by incorporating features such as:

- producer-supplier linkages;
- producer-consumer linkages; and
- producer and consumer responsiveness to qualitative improvements.

Implementing the general equilibrium study of long-run impacts would require three research phases:

- modeling of quality enhancements to telecommunications infrastructure in terms of price changes;
- collecting data specific to rural Kansas and incorporating the data into a general equilibrium framework; and
- calculating changes in output, prices, employment, and income in all other sectors.

The model, once constructed, could be used to analyze not only the TeleKansas II plan but also related issues.

CONCLUSIONS

TeleKansas II investments in fiber optic telecommunications cables are likely to have a substantial positive influence on the rural Kansas economy and rural life over the next decade. Fiber optic technology provides new capabilities through four main channels: improved medical care; improved education; improved consumer services; and improved business communications.

Further work is needed in order to place an overall social value on TeleKansas II. However, we know enough now to predict that the benefits in the long run may exceed $50 million per year, and may exceed 1% of rural income in Kansas.

1 | INTRODUCTION

PURPOSE

This report was prepared by researchers at the Institute for Public Policy and Business Research at the request of Southwestern Bell Telephone Company, in connection with its proposed TeleKansas II Project. The purpose of the report is to provide a scholarly appraisal of the services which that project may be able to provide to the state of Kansas. This report is *not* a benefit-cost analysis; in particular we do not appraise the economic effects or reasonableness of any changed rates, tariffs, or regulations proposed in connection with the TeleKansas projects. The authors of this report do not take a position either for or against TeleKansas II or any portion thereof.

This report describes the anticipated effects of improvements in Kansas telecommunication technology being planned by Southwestern Bell Telephone Company. In particular we attempt to predict the qualitative socio-economic impacts that new fiber optic transmission lines will have on nonmetropolitan areas of Kansas, paying special attention to the areas of Kansas served by Southwestern Bell.

This report also makes some selected quantitative predictions. We will estimate the economic effects on Kansas likely to result from the construction phase of Southwestern Bell's fiber optic project. We also estimate the potential value to the local school districts in Kansas of using two-way video "distance education" to expand course offerings in the high schools.

In addition, this report proposes methods for making other quantitative predictions, which we hope to implement in future work. We propose methods to estimate the potential value to rural areas in Kansas of "telemedicine" made possible by fiber optics. And we propose methods for measuring the overall boost to the nonmetropolitan economy in Kansas that will follow from the lowered price and increased speed of massive data transfers.

THE TELEKANSAS PROJECTS[1]

This report provides some analysis that applies in general to rural fiber optics in Kansas. Most of the analysis, however, is restricted to the specific fiber optic links being

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[1] This material is based on statements by a spokesperson for Southwestern Bell [private communication].

planned under Southwestern Bell's TeleKansas II project. TeleKansas II is a proposed successor to the TeleKansas I project. Chapter 3 of this report describes some construction impacts of TeleKansas I.

TeleKansas I

TeleKansas I (originally called just "TeleKansas") is an investment and alternative telephone regulatory plan that governed Southwestern Bell's activities in Kansas from 1989 through 1994. The goals of the project have included network modernization throughout Kansas, rate stability for basic local service, pricing flexibility for additional services, and greater incentives for efficiency for Southwestern Bell. Outcomes of the project in the area of network modernization have included replacement of electromechanical with digital switches, replacement of 1,000 miles of N-Carrier facilities with digital facilities, replacement of party lines with single lines, and many other network services. There has been no increase in local rates during TeleKansas I. During the same time period, the percentage of Kansas households with telephone service has increased from 94.4 to 95.2 percent. Southwestern Bell has also offered a more diverse range of services (such as Plexar®) at competitive rates.

TeleKansas II

TeleKansas II is a proposed successor of TeleKansas I. The features of TeleKansas II include $138 million of new investment in Kansas, continued rate stability for local service, and more regulatory changes. As part of its investment in modernization, TeleKansas II would provide fiber optic networks which would have the capacity to support services such as Distance Learning, Telemedicine, and Public Switched Video Service. Additionally, TeleKansas II would include regulatory changes allowing Southwestern Bell to offer new services and compete in new markets while being subject to the same regulations as its competitors.

Southwestern Bell's Kansas Territory

Southwestern Bell serves about 1.16 million customers in Kansas through 133 telephone exchanges. Another .22 million customers are served by independent telephone companies in Kansas through 413 exchanges. Hence, Southwestern Bell serves about 84% of the customers and 24% of the exchanges in Kansas. Southwestern Bell serves about 97% of the Kansas customers in SMSAs and cities over 10,000 persons; about 68% of customers outside SMSAs; and about 42% of the customers in places of under 2,500 persons. In terms of geographical area, Southwestern Bell serves somewhat less than half of the square miles in Kansas. These statistics imply that (depending on definitions) roughly one-half of the rural people and businesses in Kansas are directly affected by the TeleKansas projects.

SOCIO-ECONOMIC CONDITIONS IN NONMETROPOLITAN KANSAS

The impact of fiber optic investments in a region depends partly on the existing situation in that region. In metropolitan Kansas, fiber optic transmission lines are already becoming widely available for business use. In nonmetropolitan Kansas, fiber optics will be needed just to keep up, by providing equivalent communications services.

But in the future, fiber optic technology may be even more important for nonmetro areas than it is for metro areas. Life in rural areas and isolated towns in Kansas entails a number of disadvantages in comparison to life in areas near Wichita and Topeka-Kansas City. Of course there are also many comparative advantages of life in nonmetro areas (e.g. lower crime rates). Fiber optic communications may be able to offset some of the disadvantages without reducing the advantages.

For example, nonmetro areas tend to have fewer resources than metro areas devoted to basic services such as health care and education. Partly because of these and other limitations on the quality of life, nonmetro Kansas has been much less successful than metropolitan Kansas in economic development. Consequently, income is lower and job opportunities are scarcer in nonmetro Kansas, leading to a loss of population and relatively high rates of property taxation. These factors feed back in a vicious circle by impeding economic development and reducing the resources available for maintaining the quality of life.

As we will argue in later chapters of this report, fiber optics can potentially reduce costs and augment resources available for rural medicine and rural education. At the same time, fiber optic business communications will help level the economic development playing field. In these ways, as we will argue, advanced communications can potentially help to short-circuit the vicious circle.

But first we need to document the existence of this vicious circle in the economic development of rural Kansas. Unfortunately, the concept of "rural" has no single accepted definition. In the discussion that follows, we will focus on nonmetropolitan counties in Kansas, a concept which is clearly defined. Nonmetropolitan refers to areas not included in a Standard Metropolitan Statistical Area (SMSA). We will use SMSAs defined as of 1990.[2] A rural county under any reasonable definition will be nonmetropolitan; however some nonmetropolitan counties (such as Reno, Saline, and Riley) are not very rural. Moreover, most metropolitan counties in Kansas do contain some areas that are rather rural in character.

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[2] The standard definition of metropolitan Kansas includes the following nine counties: Butler, Douglas, Harvey, Johnson, Leavenworth, Miami, Sedgwick, Shawnee, and Wyandotte. The remaining 96 counties of Kansas are considered nonmetropolitan Kansas.

Population

Over the last century, the most obvious trend in nonmetropolitan Kansas has been its relative and absolute loss of population. In 1890, the 96 nonmetropolitan counties accounted for 80 percent of Kansas's population. By 1990, this figure had dropped to 46 percent. Of these 96 counties, 57 had greater population in 1890 than in 1990. Not only has the relative size of nonmetropolitan Kansas changed, the age structure of nonmetropolitan Kansas is different from the age structure of the metropolitan area. The median age in Kansas is 32.9 years. The median ages in two nonmetropolitan counties exceed 45, and another 14 counties have a median age that exceeds 40. For more details on the age structure of metropolitan and nonmetropolitan counties, see Table 1-1. This age structure implies that young workers are migrating out of the nonmetro areas.

Household Income

In 1989, median household income in Kansas was $27,291. Only 13 Kansas counties had a median income above that figure, and 7 of these were among the 8 metropolitan counties. Only 6 out of 96 nonmetropolitan counties had a median income equal to or greater than the state median income. The percentages of nonmetropolitan and metropolitan households earning less than $30,000 were 63 percent and 46 percent respectively. A fuller description of the income distributions of metropolitan and nonmetropolitan Kansas is given in Table 1-2.

Health Care

In terms of the supply of health care, nonmetro Kansas is in somewhat worse shape than metro Kansas. Metropolitan and nonmetropolitan Kansas have roughly the same ratio of population to hospital beds. However, metropolitan Kansas has a much more favorable ratio of population to primary care physicians; and when the ratio of population to doctors is considered, nonmetropolitan Kansas appears in even worse shape (see Table 1-3). On the other hand, when all health care professionals are considered, nonmetropolitan Kansas does not fare as poorly; it has roughly its proportionate share of less-skilled health care workers.

In terms of the demand for health care, nonmetro Kansas probably has substantially more. Nonmetropolitan Kansas is the region with the larger share of the population over 65: 17 percent to 12 percent. This difference in age structure implies there is a greater relative demand for health services in nonmetropolitan Kansas than in metropolitan Kansas.

Table 1-1
Kansas Age Structure: Percent of Population by Age Group

Age Groups	Kansas	Metro	Nonmetro
0 to 15	24%	24%	24%
16 to 34	30%	31%	28%
35 to 49	20%	21%	18%
50 to 64	13%	12%	13%
65 to 79	10%	9%	12%
80 and over	4%	3%	5%
Total Population	2,477,574	1,332,928	1,144,646

Source: U.S. Bureau of the Census, STF 3, Table P13, 1990.
Percentages may not add to 100% due to rounding errors.

Table 1-2
Kansas Household Income: Percent of Population by Income Class

Income Class	Kansas	Metro	Nonmetro
Less than $9,999	16%	13%	19%
$10,000 to $19,999	20%	16%	24%
$20,000 to $29,999	19%	17%	20%
$30,000 to $39,999	16%	16%	15%
$40,000 to $49,999	11%	12%	9%
$50,000 to $74,999	13%	17%	9%
$75,000 to $99,999	4%	5%	2%
$100,000 to $149,999	2%	3%	1%
$150,000 and above	1%	2%	1%
Total Population	946,253	507,048	439,205

Source: U.S. Bureau of the Census, STF 3, Table P80, 1990
Percentages may not add to 100% due to rounding errors.

Table 1-3
Kansas Health Care Indicators

Category	Kansas	Metro	Nonmetro
People/Hospital Bed	169.8	167.9	172.1
People/MD	768.0	559.1	1327.4
People/Primary Care Physician	1875.5	1677.4	2163.8

Source: KU Medical Center, 1992 Kansas Medically Underserved Areas Report

Education

Since both metropolitan and nonmetropolitan Kansas have approximately the same percentage of their populations under 15 years of age, one would expect proportionately the same demand for educational services. However, as we will show in Chapter 4, the smaller schools serving nonmetro Kansas are more expensive than metropolitan schools, yet deliver a smaller choice of course offerings.

At the adult stage, the metropolitan population tends to be more educated than the nonmetropolitan population. Metropolitan Kansas has almost twice the proportion of people with bachelor's degrees as nonmetropolitan Kansas. The same statement is also true of graduate and professional degrees. Using a broader category of education, 55 percent of the metropolitan population over 25 has some college education while only 42 percent of the nonmetropolitan population has any college education. For more details on educational attainment, see Table 1-4. There is evidence to suggest that ultimate educational attainment tends to be quite similar for persons born and raised in metro and nonmetro areas. The difference in educational attainment of the work force, therefore, should be seen as the result of a net migration of well-educated persons from the nonmetro areas to the metro areas, in search of better jobs and opportunities.

Table 1-4
Kansas Educational Attainment
Age 25 and Over

Educational Achievement	Kansas	Metro	Nonmetro
9th Grade or Less	8%	5%	10%
9th to 12th Grade, No Degree	11%	10%	12%
High School Graduate	33%	30%	36%
Some College, No Degree	22%	23%	21%
Associate Degree	5%	5%	6%
Bachelor's Degree	14%	18%	10%
Graduate or Professional Degree	7%	9%	5%
Total Population	1,565,936	840,479	725,457

Source: U.S. Bureau of the Census, STF 3, Table P57, 1990

Economic Development

The basic working population, age 16 to 65, makes up 64 percent of the metropolitan population while it makes up only 59 percent of the nonmetropolitan population. Nonmetropolitan Kansas has the bulk of the agricultural industry while metropolitan Kansas has nearly twice the share of professionals outside of the fields of education and health care. Metropolitan Kansas also has slightly more than twice the share of employed persons in the executive, administrative and managerial occupations. This pattern implies that the highest paying jobs are disproportionately found in the metro areas. For more information about the labor market in metropolitan and nonmetropolitan Kansas, see Table 1-5. Note that the total employments for metro and nonmetro areas are similar; therefore, large absolute differences between employments by category imply that there are also large differences by share.

CONCLUSION

In many respects, the comparisons given above understate the disparities between Kansas communities. "Nonmetropolitan Kansas" includes several counties such as Riley, Finney, McPherson, Saline, and Ford that are situated on major highways, have populations over 20,000, and are doing reasonably well; it also includes many counties of similar or smaller size that are doing worse or much worse than average. Both kinds of counties need fiber optic transmission facilities; but, in the long run, the counties now doing the worst may benefit the most.

The remainder of this report seeks to specify some of these potential benefits. Chapter 2 describes the effects of fiber optics in qualitative terms. Chapter 3 predicts quantitative effects of the construction phase of the TeleKansas II project. Chapter 4 predicts the potential quantitative value of two-way video in Kansas high schools. Chapter 5 proposes (but does not implement) methods for estimating the quantitative value of rural Kansas telemedicine, and also the quantitative value of lowered communication prices for the rural Kansas economy. Chapter 6 makes concluding remarks.

Table 1-5
Kansas Employed Persons 16 Years and Over by Industry and Occupation

Industry	Kansas	Metro	Nonmetro
Agriculture, Forestry, and Fisheries	61,324	9,952	51,372
Mining	11,554	3,098	8,456
Construction	61,897	33,619	28,278
Manufacturing			
Nondurable Goods	78,559	43,830	34,729
Durable Goods	117,926	75,613	42,313
Transportation	51,596	30,224	21,372
Communications and other Public Utilities	35,959	22,116	13,843
Wholesale Trade	50,637	31,555	19,082
Retail Trade	193,262	106,924	86,338
Finance, Insurance, and Real Estate	73,632	50,306	23,326
Business and Repair Services	45,879	29,705	16,174
Personal Services	30,694	16,515	14,179
Entertainment and Recreational Services	12,892	8,214	4,678
Professional Services			
Health Services	105,744	61,138	44,606
Educational Services	110,191	55,581	54,610
Other Professional and Related Services	78,595	51,113	27,482
Public Administration	51,873	29,663	22,210
Occupation			
Managerial and Professional Specialty Occupations			
Executive, Administrative, and Managerial	132,736	88,793	43,943
Professional Specialty	164,867	104,854	60,013
Technical, Sales, and Administrative Support Occupations			
Technicians and Related Support	39,255	25,976	13,279
Sales Occupations	133,978	83,214	50,764
Administrative Support Including Clerical	188,610	117,690	70,920
Service Occupations			
Private Household	4,129	1,865	2,264
Protective Service	15,991	9,807	6,184
Other Service	137,680	67,634	70,046
Farming, Forestry, and Fishing Occupations	54,139	8,770	45,369
Precision Production, Craft, and Repair	134,400	69,349	65,051
Operators, Fabricators, and Laborers			
Machine Operators, Assemblers, and Inspectors	73,246	38,313	34,933
Transportation and Material Moving	48,001	20,761	27,240
Handlers, Equipment Cleaners, Helpers, and Laborers	45,182	22,140	23,042
Total Employment	1,172,214	659,166	513,048

Source: U.S. Bureau of the Census, STF 3, Table P78, 1990

2 | CHANNELS OF IMPACT

INTRODUCTION

Investments such as those planned for TeleKansas II provide several channels for social and economic impacts. During the construction phase, such investments bring new money into the rural Kansas economy and create jobs and income. Chapter 3 details these benefits. Continuing benefits to Kansas households and businesses flow from the investments once they are in place—benefits in terms of improved quality of life and increased competitiveness. The present chapter catalogs the potential channels of influence of TeleKansas II in the realms of health care, education, consumer services, and economic development in nonmetropolitan Kansas.

TELEMEDICINE AND THE PROSPECTS FOR IMPROVING RURAL HEALTH CARE

Telemedicine has two definitions, one broad and one narrow. Broadly speaking, telemedicine refers to any use of telecommunications technology in the health care field. A narrower definition refers to the use of telecommunications technology in the direct diagnosis and treatment of patients. But regardless of definition, the area of telemedicine is a rapidly emerging one. To illustrate this fact, the computerized databank Medline Express contains 55 citations to journal articles related to the topic in 1993, in contrast with only 18 for the entire four year period 1989-1992.

Telemedicine includes a number of applications, each with its own specific requirements in terms of equipment and infrastructure. Many applications require (or are at least facilitated by) the enhanced capacity provided by a fiber optic network. Not all of telemedicine is confined to rural applications: some uses are of equal value to rural and urban health care delivery.

However, the development of telemedicine holds particular promise for rural areas. Rural health care delivery systems lag behind urban systems with respect to two types of economic efficiencies. The first of these is called economies of scale. Larger health care systems are able to support the services of specialists such as neurosurgeons and cardiologists because of their relatively large patient load. Similarly, these health care systems are able to support the use of expensive medical equipment and to justify the installation of information management hardware and software. The second efficiency is called economies of agglomeration. Where health care services are geographically

concentrated, all providers are able to benefit from the availability of secondary services such as specialized laboratories and educational opportunities.

The lack of these two important economic efficiencies helps to explain some of the symptoms of inadequate health care in rural areas: the closure of rural hospitals, the difficulty of physician recruitment and retention, and the deficiency of specialist services. The problem is accentuated by an increasing demand for rural health care due to an aging population. The shortage of specialized and sometimes of basic services in rural areas means that patients may need to travel long distances for care. To the extent that telemedicine can fill some of the gaps in rural health care, it can improve the quality of rural care and stem the further erosion of services.

We discuss a number of telemedicine applications in this section. For each application, we discuss examples of its actual use, particularly in rural health care settings.

Networking

Health care support services can, to some degree, be provided with the simple kind of networking available using a computer and a modem. As an example, a doctor in a rural location might download a journal article in electronic form from a medical database. A more interactive example is provided by an electronic support group designed to benefit the care-givers of patients with Alzheimer's disease [Smythe and Harris 1993]. The care-givers, typically family members, found it difficult to find and/or attend traditional support groups. The Alzheimer's Disease Support Center established a bulletin board with up-to-date information about the disease, and instructions for effective care-giving. In addition, the Center started an open electronic question and answer forum through which care-givers can discuss their individual needs and concerns.

Home-health Monitoring

Simple monitoring devices can allow patients to self-administer tests that would otherwise require a trip to a health care facility. Examples include a fetal monitoring device developed by Tokos Medical Corporation and a vital signs monitoring system developed by Buddy Systems Inc. [Arthur D. Little 1992]. Data from the devices are transmitted via telephone to a medical center. The use of such devices would be particularly important in rural areas, where trips to a doctor's office are often long and stressful for patients.

Home-health Systems

A few hospitals have started to experiment with in-home "intelligent" diagnostic terminals for patients [Arthur D. Little 1992]. The terminals direct patients to the appropriate level of care based on their personal health histories and their reported symptoms. A test of this type of system is underway in Burlington, MA. The system downloads patient records, asks the patient questions about his or her condition, and makes recommendations—for example, to use self-care or to call the physician. When self-care is recommended, the system gives step-by-step instructions. Given the high cost (in terms of travel time) for many rural residents to visit a physician, these systems would seem to be more cost-effective in rural than in urban areas.

Advanced Networking

Several regional systems have been developed to integrate the flow of information among and between patients, nurses, physicians, hospitals, third-party payers, and pharmacies.

KARENET, one of three telemedicine programs provided by Texas Tech University, addresses, among other things, the administrative and record-keeping needs of rural health care providers [Dymond and Randkin 1992; Arthur D. Little 1992]. Health care providers use the system to:

1. create automated health care records that can be accessed by community hospitals, clinics, physicians, and nursing homes.

2. access patient management protocols. These are computerized descriptions of procedural steps that must be followed in emergency and other diagnostic situations.

3. participate in menu-driven continuing education courses, some of which can be accessed using only a computer and modem.

Another example of advanced networking is the Colorado Medical Information Network, a system that includes over 500 physicians, 20 rural hospitals, and several pharmacies and laboratories. The system transmits bills and authorization forms from doctors to managed care organizations, sends radiographic images between hospitals, transmits prescriptions to pharmacies, and directs emergency care reports to primary care physicians [Brunner 1993].

The Wisconsin Health Information Network, a joint venture between two hospitals and Ameritech, has, as its goal, the creation of a standardized public network for the transmission of patient clinical and financial data. Objectives include the provision of telecommunications linkages to health care providers, transmission of claims submissions, utilization reviews, and funds transfers [Brunner 1993].

Interactive Education for Health Care Practitioners

Interactive tele-education allows physicians, nurses, and other health care professionals in rural areas to keep up to date with advances in their professions. One of the most extensive of such systems is Mednet, a system that links medical facilities at Texas Tech University with hospitals in rural Texas and New Mexico [Dymond and Rankin 1992]. The network makes use of several transmissions media: satellite, telephone, and microwave. Among its many uses is to provide interactive continuing medical education programs.

Although the Texas program is probably the most ambitious in the country, Texas is not alone in its educational outreach programs. The Kansas University Medical Center makes use of compressed video technology to provide continuing medical education at sites throughout the state.

Diagnostics and Treatment

Advances in telecommunications technology now allow access to the services of specialists such as radiologists and pathologists from off-site locations. Several types of telecommunications interactions are possible, including teleradiology, telepathology, and interactive consultations.

Teleradiology

The use of telephone lines to transmit x-ray and other radiographic data was one of the first forms of telemedicine to develop. As discussed by Gardner [1990], severe technical challenges were faced in overcoming the limitations of existing telephone systems. But fiber optic capacity now allows transmission of a diagnostic quality x-ray in a few seconds, critical when series of x-rays must be evaluated in an emergency situation. X-rays can also be sent over conventional lines in as little as five minutes. The benefits of teleradiology go beyond providing rural areas with access to radiologists' skills on a 24 hour per day basis. According to the experience of several Nevada communities, the availability of radiology support also aids in the retention and recruitment of physicians, and it allows patients who otherwise would have been transported to urban hospitals to be cared for in a rural setting closer to their homes [Gardner 1990].

Telepathology

The concept of telepathology and its applications to rural locations are similar to those discussed for teleradiology. Images of tissue samples are sent over telephone lines and are interpreted by a pathologist at an off-site location.

Consultation and examination

Through the use of interactive video, a specialist can "see" a patient from hundreds of miles away. According to Allen [1993], there are currently ten programs in North America that use interactive video to examine significant numbers of patients. Of these, the KU Medical Center ranks third, with 180 interactive video consultations in 1993.

The KU Medical Center has implemented a program whereby a specialist in Kansas City sees live video coverage of patient examinations in rural Kansas. A pilot project in Hays is described by Allen, Cox, and Thomas [1992]. The specialist receives inputs from specially adapted stethoscopes and other examining devices. The video camera has an endoscopic attachment that allows close-up examination. Simultaneous with the visual images are normal two-way conversations.

The system was developed to be usable over commercial common-carrier telephone lines available in Kansas in 1990. But the use of fiber optic cable has lowered the cost of transmission on the system to the range of $10 to $35 per hour [Allen, Cox, Thomas 1992].

In a recent issue of *Kansas Medicine*, physicians who had been involved in the use of telemedicine in Kansas outreach clinics evaluated their experiences [Chaves-Carballo 1992; Mattioli et. al 1992; Hubble 1992]. All reported that the system delivered a sufficient degree of accuracy to be of great use in rural health care.

As Allen [1993] points out, only a relatively small number of patients have been seen by means of telemedicine consultations to date. This makes it difficult to evaluate cost-effectiveness and impact.

Telemedicine: Future Research

Our overview of the literature has left us with three unanswered (or only partially answered) questions: What specific types of telecommunications technology and infrastructure are currently employed in ongoing applications; what are the cost and capacity advantages that fiber optic cable provides to these applications; and how can we provide quantitative measures of the welfare impacts of telemedicine on rural communities. We discuss a methodology for answering these questions in Section 5 of this report.

DISTANCE LEARNING AND IMPROVING RURAL EDUCATION

The methods and results of our current system of education are now open to question and re-examination. The impact of technology on the educational delivery

system is an emerging issue of great importance. There are two general ways in which technology can affect the delivery of education: equity and quality. New technology can appreciably increase access to education by underserved populations and it can provide a vehicle for revising or revamping parts of the educational system. Indeed, the most profound long-run effects of technology may be in the area of revision of the curriculum and of how it is delivered to students [Steadman and Bransford 1992]. Nevertheless, technology has already had significant effects in the area of providing access, and, particularly for rural areas of Kansas, these possible equity effects would appear to be the most immediate and predictable.

Distance Learning

A useful way of looking at some of the more immediate effects of technology on education is to consider them under the umbrella of "distance learning." A fairly strict definition of distance learning incudes three criteria: (1) students and teachers are geographically separated; (2) it involves a formal course of study or training, and there is some formal evaluation of students' work; (3) there is real-time live communication between students and teachers [Clover and Weinstein 1993]. In our discussion of the effects of technology on education, we will occasionally broaden the definition; in particular, we will relax the second requirement so that we can include some more informal kinds of learning.

In general, there is a broad range of technologies that can be used to implement distance learning, but the choice of the technology significantly influences the nature of the distance learning that can be implemented. Distance learning technologies can be classified into six types according to the speed and type of interactivity [American Legislative Research Council 1993]:

1. Voice teleconferencing involves two or more sites connected into a teleconference. Although teleconferencing provides real-time voice communications, there is no video and the mailing or faxing of visual aids is required.

2. In audio-graphics teleconferencing two or more sites are connected into a teleconference as in (1). In addition, graphic information is transmitted to each site's personal computer over telephone lines. Although this method enhances courses based on static visual aids, there is no live video of the instructor.

3. One-way satellite/cable networks and microwave networks provide high quality video of an instructor, but often do not allow interaction between student and instructor during class. Teachers cannot see students, and students cannot see each other.

4. In compensated-motion (compressed) video, two or more sites are connected into a video teleconference. Teachers can see and hear students and the students can see

and hear each other. However, because the bandwidth (amount of information that can be transferred per second) is limited, the quality of the video signal can be quite poor. The video is not full motion, and the method may not be appropriate for courses requiring action or high levels of observation.

5. Full-motion video using analog fiber allows two or more sites to be connected into a full motion video conference. The high quality of the video and audio allow the possibility of easy interaction between students and instructor. This method is not well-suited for data transmission or multimedia applications.

6. Full-motion video using digital fiber provides a full-motion video conference in which the teacher can see and hear the students, and the students can hear and see both the teacher and other students. This two-way full-motion video is the technology that most closely duplicates the teacher classroom environment associated with traditional kindergarten through twelfth grade education in the U.S. In addition, this technology is well suited to applications that require data transmission and multimedia, since it also allows for easy two-way communications between teachers' and students' computers. [Clover and Weinstein 1993]

All of these except (3) differ from the traditional mode of learning at a distance, i.e., correspondence courses, in that, to differing degrees, they allow real-time interaction between students and teachers as well as between one student and another. Thus, they avoid the lack of interaction and the long delays in feedback associated with traditional correspondence courses.

Educators who are experienced in the field of distance education tend to feel that there is no single "right" technology to employ in distance learning; the choice of technology should be determined by the nature of the particular educational goals and objectives in a particular case [Steadman and Bransford 1992]. Furthermore, it is generally agreed that in the past the choice of mode of distance learning has often been driven by the type of technology that was available, and that in such cases the quality of the distance learning suffers [Moore 1989]. To as great an extent as possible, the educational design should influence the choice of technology.

Enhancing the Rural Curriculum

There are two salient features of the educational landscape in Kansas that suggest significant benefits to education from having a digital fiber optic network linking schools throughout the state. The first is that Kansas is a very rural state, and that the vast majority of Kansas school districts are in rural areas. The second is that there is a movement toward increasing graduation requirements and raising college entrance standards, with an emphasis on mathematics, science, and foreign languages [Parker and Hudson 1992].

The rural nature of many Kansas school districts, and the recognition of the necessity of making more advanced course offerings available, come together in a particularly telling way. Since the economies of many rural Kansas communities are stagnant or declining, the fiscal pressure is for reduced expenditures on education at a time when the educational pressures are for an expansion of educational services. This situation is made worse by high per-pupil costs in rural districts: the area served by a local high school may be so small that the enrollment in advanced courses is only one or two students, making the cost per student in the rural school district much higher than for a comparable course in an urban high school [Parker and Hudson 1992]. In addition, in fields for which there may be a shortage of teachers of advanced courses, it may be difficult for a rural school district to offer such a course even at a very high cost per student [Barker 1989].

The considerations in the previous paragraph point to a serious issue of access for students in rural school districts. It seems natural to conclude that this equity issue can be addressed directly through the use of distance learning. If small school districts have too few students to provide cost-effective advanced courses on-site, then an alternative may be to substitute courses delivered through some kind of a distance learning technology. For example, several rural school districts could band together to provide a bundle of such courses (curriculum sharing) [Parker and Hudson 1992]. Each district might hire at most one teacher, who would provide courses for all of the districts in the group. Alternatively, such courses might at some point be provided by some private provider, who contracts independently with school districts (imported curriculum) [Parker and Hudson 1992]. Since the main consideration here is access to courses that are more frequently provided in urban school settings, the emphasis is not so much on new instructional technology (the course itself might look quite traditional) but on the delivery technology. Thus, because full-motion video using fiber optics allows distance learning to be structured much like the traditional classroom, it would likely be the technology of choice for addressing access problems in rural schools through distance learning [Parker and Hudson 1992].

An Example

An example of just such a use of fiber optic technology is the Panhandle Share-Ed Video Network in Beaver County, Oklahoma [Barker 1989]. Beginning in the Fall of 1988, four small school districts in Beaver County joined together to supplement their high school curricula by providing courses through a two way full-motion fiber optics television network. The county's four school districts exemplify the kinds of conditions faced by rural school districts in many areas. The districts are geographically large; the smallest is over 300 square miles in area. Yet the student populations are small; the largest kindergarten through twelve population was 519 students and the smallest was 159 students. The districts are remote and isolated, and before the establishment of the

network, many advanced and special courses were either not offered or were provided only in alternate years. In many courses the cost of employing a full-time certified instructor was prohibitive because of low student enrollment. In some cases, even when funds were available, it was difficult to find a qualified instructor willing to move permanently to the area.

The history of cooperation among the four districts dates back to the 1960s, when they began sharing traveling teachers for selected courses. As the pool of qualified teachers shrank, however, such an option became less viable. In the mid 1980s the four districts began to look at two-way TV systems as a means of providing courses in which there was a low level of enrollment. Because of flat terrain and cost factors, consultants recommended a microwave network; however, the final choice of technology was a fiber optics network. Three factors influenced this choice: (1) violent weather conditions in the panhandle meant that fiber optic cables, which would be laid underground, would be cost competitive with microwave towers; (2) the establishment of a microwave system required FCC licensing; and (3) fiber optics had a greater potential for transmitting signal quality, and thus allowed a greater range of technological options in the future.

The Panhandle system links a TV classroom in each of the districts' four high schools, and allows both video and audio interaction between the host teacher and students at each site. Students can see and hear the teacher, and they can hear and see other students in the class at other sites. In addition, the teacher can hear and see each student at each remote site. Microphones are on an open line so that audio communication is immediate. The system has been used not only to enable the districts to share teachers electronically and thereby expand high school credit course offerings, it has also been used to provide in-service training to teachers, to provide community education programs for local residents, and to allow conference meetings of teachers and administrators among schools. The response to the system has been positive on the part of administrators, teachers, and students.

Other Applications of Distance Learning

As the above example suggests, addressing the access issue for rural high school students through the use of a two-way video fiber optic system is not the only application of distance learning that is possible. Below is a partial listing of other uses of video based distance learning.

Partial courses: Students receive modules or units that are integrated into the curriculum. Although most current activity in this area is not interactive, it is a promising area for innovation.

Enrichment materials: These activities are usually one-time only presentations designed to inform students and teachers on a particular topic. Some such activities could benefit from being conducted within an interactive format. For example, students might talk to an author or a scientist.

Training and staff development: Teachers and educators could also use the distance learning systems in their schools for seminars, college level courses, workshops, and certification classes.

Student and professional communications: Students can use the telecommunications technology to reach outside information and resources on their own. Examples are retrieving large amounts of information from data bases, accessing homework hotlines, and conducting electronic teleconferences with their peers. Teachers can increase their professional contact with their peers, exchange curriculum materials and classroom ideas, and access databases and information sources [Linking for Learning 1989].

College, graduate, and adult continuing education courses: The use of two-way interactive video to teach complete courses is not limited to high schools. Such a technology would allow many types of post-secondary courses to be offered in rural areas [Kansas Regents Telecommunications Task Force 1993].

Cost-Effectiveness

The choice of whether to use distance learning as a substitute for some traditional classroom instruction and, if so, the choice of whether to employ a two-way video fiber optic technology or some other technology must depend not only on the appropriateness of the technology for the educational task, but also on the cost-effectiveness of the technology. Assessing the costs of applying a technology is a difficult task, and should be done relative to the costs of providing the same educational service in some alternative way. In Chapter 4 of this report, we attempt such a comparison of the costs of providing courses using two-way video fiber optic technology to the cost of providing courses in a more traditional manner .

TELECOMMUNICATIONS AND NEW CONSUMER SERVICES

Southwestern Bell's original TeleKansas plan has already made substantial improvements in consumer services in rural Kansas. Among these are 911 universal emergency number service, call waiting, call forwarding, and single-party lines [Southwestern Bell 1994]. Continued infrastructure improvements in rural Kansas would position consumers to take advantage of new services as they emerge. As an example, developments in the entertainment arena make the provision of on-demand video an exciting prospect for the near future. Companies such as Microsoft and Novell are

prototyping software to distribute movies and other video as requested by consumers [Clark 1994].

TELECOMMUNICATIONS AND THE GROWTH OF RURAL BUSINESSES

Telecommunications has been used as a business input since its inception. Over the years 1963-1987, telecommunications use by businesses grew faster than the use of any other input [Cronin 1993]. Has the increased use of telecommunications as an input been accompanied by increases in worker productivity? Difficulties in measuring productivity gains are cited by Egan and Wildman [1992]. However, a recent study [Cronin 1993] documents productivity changes in terms of labor and capital savings: 1991 savings for the U.S. economy due to telecommunications were estimated at $102 billion. Another study specifically addresses whether *rural* telecommunications improvements have enhanced rural growth. Parker and Hudson [1992] look at data from Oregon and Washington State, and find strong correlations between improved telecommunications infrastructure and economic growth in rural counties.

Two factors may increase the future importance of telecommunications in rural areas. The first of these is the growth of the service sector, the fastest growing sector of both the national and the Kansas economies. During the period 1980-1990, service sector employment grew by 44.5 percent nationally and by 35.3 percent in Kansas. This contrasts with growth in other sectors of 12.0 percent for the U.S. and 5.6 percent in Kansas [Oslund 1992]. The service sector is a heavy user of telecommunications inputs, and hence is positioned to gain from improvements in technology.

The second factor is the ability of telecommunications to change the comparative advantage of rural versus urban production locations. In particular, telecommunications can overcome some of the well-known obstacles to development in rural locations. Rowley and Porterfield [1993] cite several obstacles to business development, and point out ways in which telecommunications might overcome these obstacles (see Table 2-1).

Telecommunications alone will not solve the income and employment problems of rural areas. An adequate and well-trained labor force, adequate public infrastructure, available local finance capital, entrepreneurialism, and a good quality of life are all factors that influence a firm's decision to locate or expand in a rural area. But enhanced telecommunications can improve the competitive environment for rural firms. The remainder of our discussion looks at channels connecting telecommunications and business, citing several specific examples. A number of additional examples (partly from Kansas) are given in Davidson, Dibble, and Hom [1990].

Table 2-1
Telecommunications and Obstacles to Rural Business Growth

Rural Development Obstacle	Benefits from Telecommunications	Drawbacks of Telecommunications
geographic isolation.	reduces time for information transfer. reduces need for travel.	does not reduce time for transfer of physical goods or personnel.
declining job opportunities.	may decentralize jobs to rural areas. opens urban markets.	jobs that decentralize often low-wage. opens rural markets to urban businesses. makes it easier for firms to locate in developing countries.
lack of human capital.	provides access to training and education.	may not reach those most in need. quality of remote learning may be inadequate.
lack of institutional capacity.	access to information and advice.	must overcome lack of familiarity and hesitancy to adopt.

Adopted from Rowley and Porterfield, 1993

Channels Through Which Telecommunications Affect Business

Preserving existing advantages

Enhanced telecommunications are necessary for rural areas to preserve their existing competitive advantages. Enhanced telecommunications are becoming an entry requirement for firms to locate or even remain in an area. At a minimum, enhanced telecommunications mean the ability to send and receive faxes and to transmit and receive data over a modem. Value-added services such as dynamic call routing, call forwarding, and call queuing are starting to be expected. Illustrations from Parker et. al. [1989] point out the necessity of enhanced services to retain existing businesses. They point out the cases of a hardware chain that requires franchises to have on-line capacity, and of a small Montana business that was forced to relocate because of inadequate fax reception.

Increasing sales and lowering costs

Enhanced communications can help firms increase their sales and lower their costs. Davidson, Dibble, and Hom [1990] point out two examples from agribusiness. The Superior Livestock Auction in Texas makes use of satellite transmissions along with a

computerized ordering system to expand its cattle sales. The American Farm Bureau Federation sponsors the ACRES system, an agriculturally-oriented video text service. The service offers timely information about commodity markets and other agricultural conditions, in order to help farmers make better decisions.

Creating telemarketing centers

Enhanced telecommunications allow rural communities to capitalize on their abundant labor supplies (particularly of part-time workers) and low labor costs. Several telemarketing centers have developed throughout the Midwest to take advantage of the opportunities offered in small Midwest communities.

In Kearney, Nebraska, two firms, ERMG and Cabela's, have found profitable locations [Bernal, Stuller, Sung 1991]. The firms make use of an automated voice response system and an automated call distribution system. In some cases, the firms have had to work around the existing telephone infrastructure by purchasing their own systems. Some systems are shared among telemarketers in the area. But despite their successes, these firms could use more capacity. To date, they have been unable to connect to a nearby Sprint high capacity fiber optic line. The absence of a fiber optic connection caused one of the firms to pass up bidding on a large federal contract.

In North Dakota, economic diversification is taking place as new telemarketing and data processing businesses make use of telecommunications advances [Leistritz 1993]. Digital switching and data-quality lines are minimum requirements for these operations.

Avoiding bypass strategies

If local telecommunications service is inadequate or too expensive, firms may develop bypass strategies. This is socially inefficient because it limits the possible externalities associated with high capacity service. As an example, Wal-Mart makes use of a satellite system that connects each of its stores with the central office in Bentonville, Arkansas [Bernal, Stuller, Sung 1991]. On one hand, the development of bypass strategies demonstrates the importance of communications to rural firms. Firms are willing to undertake costly investments in order to transmit data, voice, and video. On the other hand, the development of private systems may limit the economic feasibility of public access to high capacity systems that could aid small businesses and consumers. Difficulties in recovering costs of high capacity systems arise when large customers are siphoned off into private systems.

Digital fiber optic networks offer some unique advantages. They offer high quality, high speed communications which offer security and low maintenance costs, which are immune to electro-magnetic disturbances, and which are flexible in their applications [Egan 1991]. These systems can transmit video, voice and business data. Fiber is particularly suited for two-way communication.

Fiber also enhances wide area networks for the transmission of large volumes of data. Increasingly, local area networks allow the sharing of information and computer hardware throughout a building or small geographic area. Wide area networks allow the same kind of sharing across multiple establishments widely separated by hundreds of miles. The capacity to form wide area networks is essential for establishments such as the back-office data processing and billing operations of national firms.

Telecommunications and Business: Summary and Further Research

Telecommunications serves as a critical input in the production of goods and services. Telecommunications allows rapid transfers of information among consumers, producers, and suppliers. Telecommunications has special significance for rural areas, since it removes some of the barriers otherwise imposed by distance. As an example, a retail outlet must be located close to a large population center, but a mail-order operation can be set up anywhere, given the appropriate infrastructure.

The deployment of advanced telecommunications has repercussions that spread throughout the economy. Jobs attracted to rural Kansas create income that, when spent, creates yet another round of jobs. Cost savings due to more efficient telecommunications potentially reduce prices and make rural firms more competitive. Chapter 5 proposes a methodology to explore these issues more thoroughly.

CONCLUSION

This section has discussed several channels through which telecommunications can improve the quality of life and enhance the business climate in rural areas. Fiber optic capacity is essential for some of the applications we have discussed, for example, high resolution interactive video applications in telemedicine and education. For other applications, fiber optic capacity improves the quality of service and potentially lowers the cost of transmission. In many cases, fiber optic capacity makes advanced applications economically feasible.

3 | CONSTRUCTION IMPACTS

INTRODUCTION

This chapter gives our estimates of the economic benefits of the construction phases of TeleKansas I and TeleKansas II and provides an explanation of how we arrived at these results. We have considered only the benefits of the physical construction used in these projects, not the increased service capability provided by the completed projects. Our results are presented in two parts. First, the direct effect of these two projects is described along with the important assumptions we made concerning the data we have. The data for the direct effect are provided in Tables 3-1 to 3-3. Second, the process we used to estimate the indirect effects of these projects is briefly explained. The aggregated results of our estimation process are provided in Tables 3-4 to 3-5. In the two appendixes to this chapter, we provide more detailed explanations of the methodology used to estimate the indirect effects. Appendix 3-1 is a less technical explanation while Appendix 3-2 provides a more formal explanation.

THE DIRECT EFFECTS OF TELEKANSAS I AND II

The data used to estimate the direct effect of TeleKansas I and II were provided by Southwestern Bell and consisted of annual expenditures for materials and labor. The data through 1993 are actual figures while the numbers used for 1994 and later years are estimates. Although some of the material used in these projects has been or will be bought in Kansas, Southwestern Bell expects that most of the materials will be purchased from out-of-state sources. Since no cost-effective way has been devised to estimate the split between out-of-state and in-state purchases of materials, we will assume that all materials have been or will be purchased from out-of-state sources. This assumption eliminates consideration of material purchases directly influencing the Kansas economy, and hence leads to somewhat understating the total impact of TeleKansas on Kansas.

Therefore, the only direct influence on the Kansas economy under consideration is the labor expenditures during each year. We will assume that all of these expenditures take place inside Kansas. The data given us for TeleKansas II are in 1993 dollars. However, the data for TeleKansas I are in current dollars. We revised these data using the United States Consumer Price Index for all urban consumers so that they were also in 1993 dollars. The columns labeled labor in Tables 3-1 to 3-3 detail the direct effect of these two projects. Expenditure on labor are treated as an exogenous (i.e. independent) increase in Kansas household income.

THE INDIRECT EFFECTS OF TELEKANSAS I AND II

The KSSAM2 (Kansas Social Accounting Matrix) model of the Kansas economy developed by the Institute for Public Policy and Business Research was used to estimate the indirect effects of TeleKansas I and II. A social accounting framework is an elaboration of a standard input-output model for a region. For the purposes of estimating the benefits of TeleKansas I and II, the major difference between KSSAM and an ordinary input-output model is that household and government behavior are exogenous in an input-output model, while they are endogenous (i.e. taken into account) within the social accounting framework.

For the purposes of estimating economic benefits, the KSSAM2 model is solved for a 52 by 52 matrix of multipliers. These multipliers show the total effect that results in each of 52 sectors, from a given direct effect in each of 52 sectors. In technical terms, matrix multiplication on the vector of direct effects leads to a vector of total effects. Each element in the vector of total effects represents the total effect of the TeleKansas projects on each of the 52 sectors in the model. Our results are provided in aggregate form in Tables 3-4 and 3-5. First, we have provided the annual estimated direct, indirect and total effects on Kansas income. Then we have estimated the direct, indirect and total effect on Kansas private sector employment.

THE TOTAL EFFECTS OF TELEKANSAS I AND II

The numbers in Tables 3-4 and 3-5 were calculated using a complete matrix of multipliers. However, the key aggregate multipliers can be summarized as 1.88 for income to income and 2.06 for job to job. The income to income multiplier means that a one unit exogenous increase in income to Kansas households results in an additional indirect increase in Kansas household income of 88 percent of a unit of income. Thus, combining the direct effect and the indirect effect shows the total effect to be an increase of 1.88 in Kansas household income due to an initial increase in Kansas household income of 1.

The job to job multiplier is similar to the income to income multiplier. An increase of 1 job by Southwestern Bell stimulates slightly more than 1 additional job in the rest of the Kansas economy. An income to income multiplier of 1.88 and a job to job multiplier of 2.06 might appear inconsistent; however, consideration of the nature of the original jobs created by Southwestern Bell should remove any confusion. The jobs created by both of these projects, for the most part, require skilled and highly skilled labor which will earn more than the average income in Kansas. Thus, the ratio of jobs to income for the TeleKansas projects is going to be lower than the average for the rest of the Kansas economy. This is the reason the job to job multiplier is larger than the income to income multiplier.

Table 3-1
TeleKansas I Expenditures by Year in Current Dollars

	Material	Labor	Total
1989	$18,244,490	$ 5,615,510	$23,860,000
1990	20,485,170	5,874,830	26,360,000
1991	27,995,690	13,804,310	41,800,000
1992	17,890,380	10,917,620	28,808,000
1993	8,176,680	6,251,320	14,428,000
1994	2,143,370	1,334,630	3,478,000

Source: Southwestern Bell

Table 3-2
TeleKansas I Expenditures by Year in 1993 Dollars

	Material	Labor	Total
1989	$21,260,716	$6,543,881	$27,804,597
1990	22,648,103	6,495,126	29,143,229
1991	29,701,742	14,645,542	44,347,283
1992	18,425,944	11,244,448	29,670,392
1993	8,176,680	6,251,320	14,428,000
1994	2,143,370	1,334,630	3,478,000

Source: Southwestern Bell. Converted to $ 1993 by IPPBR.

Table 3-3
TeleKansas II Projected Expenditures by Year in 1993 Dollars

	Material	Labor	Total
1995	$17,215,510	$7,117,861	$24,333,371
1996	13,107,793	6,628,141	19,735,934
1997	27,306,318	12,693,180	39,999,498
1998	18,060,765	8,672,515	26,733,280
1999	18,060,764	8,672,518	26,733,282

Source: Southwestern Bell

Table 3-4
Economic Benefits of TeleKansas I:
Impacts of Construction on Income and Employment

Household Income (In 1993 Dollars)

	1989	1990	1991	1992	1993	1994
Direct Effect	$6,544,000	6,495,000	14,646,000	11,244,000	6,251,000	1,335,000
Indirect Effect	5,754,000	5,711,000	12,877,000	9,886,000	5,496,000	1,173,000
Total Effect	12,297,000	12,206,000	27,522,000	21,131,000	11,748,000	2,508,000

Private Sector Employment (Number of Jobs Created Each Year)

	1989	1990	1991	1992	1993	1994
Direct Effect	128	127	287	221	123	26
Indirect Effect	136	135	304	234	130	28
Total Effect	264	262	592	454	253	54

Table 3-5
Economic Benefits of TeleKansas II:
Impacts of Construction on Income and Employment

Household Income (In 1993 Dollars)

	1995	1996	1997	1998	1999
Direct Effect	$7,118,000	6,628,000	12,693,000	8,673,000	8,673,000
Indirect Effect	6,258,000	5,827,000	11,160,000	7,625,000	7,625,000
Total Effect	13,376,000	12,456,000	23,853,000	16,298,000	16,298,000

Private Sector Employment (Number of Jobs Created Each Year)

	1995	1996	1997	1998	1999
Direct Effect	140	130	249	170	170
Indirect Effect	148	138	264	180	180
Total Effect	288	268	513	350	350

APPENDIX 3-1: THEORETICAL, TECHNICAL AND EMPIRICAL CONSIDERATIONS

INTRODUCTION

This appendix provides a verbal description of the mathematical model used to study the economic benefits of TeleKansas I and TeleKansas II for the Kansas economy. Specifically, this appendix will discuss, in a non-mathematical manner: input-output modeling; the construction of the Kansas Social Accounting Matrix (KSSAM2) model used in this study; and the empirical results of the investigations. Appendix 3-2 will provide a more technical description of input-output modeling and the KSSAM2 model used in this study.

THE TOTAL EFFECT OF AN ECONOMIC CHANGE

Primary and Secondary (Direct and Indirect) Effects of Economic Change

When a change occurs within an economy it causes other modifications within that economy. These secondary or indirect modifications of the economy are the result of the structural interdependence of most sectors of a modern economy. These two effects are generally referred to as the direct and indirect effects of an economic change. The initial change is referred to as the direct effect on the economy and is usually easily observed. For example, the laying off of 100 employees with combined annual wage and salary income of $4,000,000 would be a direct effect. As this direct effect reverberates through the economy, it causes further change in that economy: indirect effects. For example, the loss of $4,000,000 in personal income in an economy will result in lower expenditures for retail sales and, if a sales tax exists, less revenue from that tax. Other indirect effects would be a decline in demand in the automobile and housing markets and reduced revenue from an income tax. These indirect effects are not immediately or directly observable, but they penetrate into every sector of an economy.

Methods for Generating Multipliers

The magnitude of these indirect effects can be estimated through the use of multipliers. A multiplier gives a quantitative estimate of the indirect effects of an initial change in an economy, based on the source and the size of the initial change. Regional multipliers can be estimated using three basic methods. The first is the economic base method, which in its simplest form is similar to a simple open Keynesian model for a region. Unfortunately, this type of model operates at an aggregate level and does not provide the ability to analyze the effects of changes at the industrial level. An econometric model is the second possible source for developing regional multipliers. The

most detailed econometric model of the Kansas economy has been developed by IPPBR (its name is KEM). Despite this model's complexity–it forecasts over 100 Kansas variables–it does not have the capability to generate the appropriate multipliers. The third method of estimating multipliers, and the method we have chosen to use, involves a modified input-output model. This type of model provides detailed, inter-industry multipliers. Numerous papers have also documented that when the detailed estimates of an input-output model are aggregated, the aggregate multipliers are similar to the economic base multipliers [Pleeter 1980, p. 27].

SIMPLE INPUT-OUTPUT MODELS

Explanation of the Simple Input-output Model

The simplest input-output model is a series of industrial supply and demand relations treating industries and consumers as the only economic agents. Supply is the output of each industry. Demand for this output is separated into two major components: final demand and intermediate demand. Final demand is the demand for goods and services by individual consumers for their own use. Intermediate demand is the demand for goods and services by one industry for use in the production of other goods and services. For example, the use of steel by an aircraft firm to produce airplanes is an intermediate demand for steel. By the same token, the use of a company airplane by the sales staff of a steel firm for the generation of steel orders is another example of intermediate demand.

The assumption that all goods and services produced in this economy must be used creates the simple accounting identity: an industry's output is equal to the uses of that output as an input to production plus the consumption of that output by individuals. In simpler economic terms, supply is equal to intermediate demand plus final demand for each industry. Thus, the identity yields a series of industrial supply and demand equations. In input-output models we stack these industrial supply and demand relationships on top of each other, number each industry, and use this numbering system to sequence, in each supply and demand equation, the individual intermediate demands for output. For example, suppose the electrical utility industry's supply and demand equation is fifth from the top in the stack of supply and demand equations. Then in each supply and demand equation, the electrical utility's intermediate demand is the fifth intermediate demand from the beginning of the intermediate demands.

By maintaining the industrial order, the stack of industrial supply and demand equations can compactly be depicted by a matrix equation. In terms of matrix algebra, a vector of outputs (the stack of industrial outputs) is equal to a square matrix of intermediate demands (the stack of intermediate demands) plus a vector of final demands (the stack of final demands). This matrix relationship is the heart of any input-

output model. The column vectors both have the same height (the same number of entries), which is the number of industries within the model. The square matrix's dimensions are also determined by the number of industries within the model. If the model has ten industries, then the column vectors are ten entries high and the square matrix has ten columns and ten rows.

The matrix of intermediate demands makes the input-output model unique (and gives it its name). This matrix is a matrix of inputs to production which captures the inter-industry flow of goods and services necessary for production: a matrix of inputs to produce a vector of outputs. A column in this matrix represents the various inputs to production used by one particular industry. In the example of the electrical industry used above, the fifth column represents the inputs necessary for the production of electricity. These inputs are generated by the production of the other industries in the economy. A row of this matrix represents the uses of one industry's production in the production processes of all the industries in the economy. Again using the example above, the fifth row represents the use of electricity generated by the electric utility industry in the production of all other industries. Obviously, in a real economy, some of the cells in the matrix will be zero; that is, some industries will not use the production of other industries in their own production process.

Making the Model Operational

This description of the simple input-output model captures the basic concept of the model. However, to make the model operational, a couple of alterations are necessary. The variables in the model above were described in physical terms, which implies measurement in physical units such as number of hamburgers and tons of steel. In order for the input-output model to be flexible, the output, inputs and final demand for all industries need to be measured in the same units. This is accomplished by substituting the monetary value of the goods and services produced and used for their physical units. Instead of tons of steel produced, the model now works with the dollar value of all the steel produced, and instead of the number of hamburgers eaten, the model works with the dollar value of hamburgers eaten.

A second alteration in the model is necessary to generate multipliers. Each column in the matrix of inputs to production represents the monetary value of inputs to the production of an industry. If each of the inputs to the production of a particular industry (each column entry) is divided by that industry's dollar value of output, a column of input coefficients is created. If this process is followed for all industries, then a matrix of production coefficients (or input coefficients) is created. The assumption made by economists who work with input-output models is that these production coefficients are an adequate description of the production process, except for labor, at all relevant levels of production. At this point of development, the contribution of labor to the production

process is being ignored. These production coefficients are not going to adequately describe the production process at all levels of production, but if the band of expected change is relatively small (less than a 25 percent change in output), then these coefficients are an adequate representation of the production process [Miller and Blair 1985, pp. 266-316].

A second important assumption implied by the use of the matrix of production coefficients is that price ratios are constant. This assumption is necessary because these coefficients are derived from the value, in dollars, of inputs to production. If price ratios change, then the production coefficients would change even if the production process still required the same physical amounts of all goods and services. In addition, if relative prices change, then probably some substitution among the goods and services used as inputs would take place. All of the above means that if the assumption of constant price ratios is violated, then the production coefficient matrix may need to be adjusted. (In a special case referred to as "Cobb-Douglas Technology", changes in quantities just offset any changes in prices so that dollar values remain unchanged.)

The construction of the matrix of production coefficients by dividing all the industrial columns by their industrial output creates an imbalance in the basic supply and demand relationships. To rectify this imbalance, the coefficient matrix must be multiplied by the column vector of outputs. An analogy with a single equation supply and demand model should help explain why this manipulation is necessary. Suppose one has an equation such that output is equal to intermediate demand plus final demand. If intermediate demand is divided by output, then in order to maintain the equality, intermediate demand must also be multiplied by output. This is the old algebra trick of multiplying by one; that is, multiplying by output divided by output.

Derivation of Multipliers

The substituting of the intermediate demand matrix (the matrix of inputs to production) with the production coefficient matrix multiplied by the vector of industrial outputs creates in the simple input-output model the opportunity to generate a matrix of multipliers by algebraically solving the model. Appendix 3-2 provides the procedure for solving the model and generating the matrix of multipliers. The algebraic result of solving the model is that the column vector of industrial outputs is equal to a matrix of multipliers multiplied by a column vector of final demands. (Matrix multiplication must be used in the above relationship.) The matrix of multipliers is the result of subtracting the matrix of production coefficients from the identity matrix and then inverting the result.

The matrix equation, in which the column of outputs is equal to the matrix of multipliers multiplied by the column of final demands, is the basis for our benefit

analysis. This equation links final demand to output. If this relationship holds true at levels of economic activity near the equilibrium level of output and final demand, then changes in final demand are linked to changes in output. The simple mathematical equation does not establish a cause and effect relationship between final demand and output, it only establishes that these variables are related. The cause and effect relationship can only be established in the construction of the mathematical model. Economists distinguish between variables that are exogenous to a model and variables that are endogenous to a model. The values of the exogenous variables are determined outside of the model. The values of the endogenous variables are determined within the model. The relationship between the exogenous and endogenous variables in an economic model reveals the assumed cause and effect relationship within the model.

In the case of this simple input-output model, the equation described above is interpreted as operationally meaning that a change in the column vector of final demands multiplied by the matrix of multipliers yields the change in industrial output. Because the multipliers are derived from the matrix of production coefficients, which in turn were derived from the matrix of inter-industry flows of goods and services, these multipliers take the initial, direct effect on final demand and create an estimate of the direct plus indirect effects on industrial output due to an exogenous change in the economy.

ENHANCED INPUT-OUTPUT MODELS

Incorporating Investment

The simple model is missing many obvious elements of a real economy. In the next two sections, we will add to this simple model to endow it with more realism. The first major addition will be an investment sector. In a real economy, not all of the goods used by firms in production are materials that go into the product. Some of the goods are used as investment. The process used to create the matrix of intermediate demand can be used to create a matrix of investment demand. Essentially demand is split between intermediate demand (operational demand) and investment demand. The matrix of investment demand has the same dimensions as the matrix of intermediate demand. By using market prices, investment demand can also be put into monetary units. By dividing the investment demand matrix by sector output, an investment coefficient matrix is created just as in the case of intermediate demand. Multipliers are calculated in a similar fashion to the simple model; however, the resulting matrix that must be inverted subtracts both the investment coefficient matrix and the intermediate demand coefficient matrix from the identity matrix. Incorporating investment in the simple input-output model simply means adding another matrix to the basic matrix equation.

Social Accounting Framework

The social accounting framework endogenizes more of the variables in the simple input-output model. The simple input-output model with investment consists solely of output, a production process, an investment process, and exogenous final demand. The social accounting framework endogenizes households and government. The model still has the same basic structure as the simple model, with investment added– consumption plus investment plus exogenous final demand is equal to generalized gross state product; however, the individual components will be more complex. The social accounting framework also allows for an analysis of the distributional effects of exogenous changes. In an input-output model, households are one sector; however, in a social accounting framework, households can be separated into different classes with different value added coefficients, consumption coefficients, and investment coefficients. The government can also be unbundled into different jurisdictions.

Endogenizing households

To endogenize households in the model, income to households, the consumption of goods and services by households, and investment by households need to become part of the circular flow within the economy–these factors need to be part of the feedback process in the model. The production coefficient matrix created above does not include labor costs or other value-added costs of production. To add labor cost to the model, consider the dollar value of all labor needed in each sector. Each sector's labor requirement can be converted into a coefficient (as the other production inputs were before) by dividing the dollar value of labor needed for production by the value of output in each respective industry. Multiplying these coefficients by any change in output produces the resulting change in labor income due to the change in output. This increase in labor income is an increase in income to households.

How households spend this income depends upon the pattern of household expenditures on goods and services. The vector of consumer demand for goods and services provides this pattern. By dividing each element in this vector by personal income, a vector of coefficients is constructed which represents the share of personal income spent on each sector's output. This vector of coefficients is a vector of consumption shares. The same can be done with household investment to create a matrix of household investment coefficients like the business investment coefficients created in the last sector. Tying together labor income, household consumption, and household investment adds new feedback facets to the model. The change in output causes a change in labor income which then causes a change in household consumption and investment.

Endogenizing government

For government to be part of the feedback loop in the model, government expenditures, taxes, and government investment all need to be part of the circular flow of the model. The same procedure is followed with government as with households to endogenize it. Rather than being lump sums, taxes and expenditures become coefficients multiplied by output. Government investment is handled as investment is handled for all other sectors.

The effect on the multipliers

A qualitative result of endogenizing households and government is to alter the multipliers. The multipliers derived before only took account of the indirect effect on output as the direct effect moves through the production process. The new multipliers include the influence of the indirect effect on household consumption and investment through changes in wages and salaries which affect household income; in other words, these new multipliers capture the feedback effect on households of a change in exogenous final demand. These new multipliers also capture the influence of changes in output on government income through taxation and the effect on expenditures of changes in income. These effects are called the induced effects because they result from the additional income for households and government induced by the direct effect. The multipliers which are derived from a model where households and government are endogenized capture three effects: direct, indirect, and induced. Endogenizing households makes the multipliers larger [Miller and Blair 1985, pp. 100-105].

A detailed mathematical description of our model, its solution, and the generation of its multipliers is provided in Appendix 3-2. The matrix techniques necessary for the solution of our model and the generation of the multipliers are similar to the techniques used to solve the simple input-output model and generate its multipliers. The result is the same: a matrix of multipliers which links a change in final demand to a change in industrial output.

Empirical Results

Data sources

The data which were used to generate the actual numbers for our model came from the U.S. Input-Output Tables for 1977 and 1985 developed by the U.S. Department of Commerce, Bureau of Economic Analysis (BEA); personal income, farm income, and crop and livestock cash receipt data for the state and various counties developed by BEA; and employment and payroll estimates produced by the U.S. Department of Commerce, Bureau of the Census, *County Business Patterns*.

The structure of the social accounting model·

The social accounting model used in this study is based on the KSSAM2 model. KSSAM2 is a social accounting matrix for Kansas. The model has 55 sectors: 48 business sectors, 4 household sectors, and 3 government sectors. However, the household sectors were collapsed into one sector because distribution issues were not important for this study. A list of the sectors along with their definitions is given in Table 3-6.

Changes in income

Tables 3-4 and 3-5 contain the basic results of the estimated effects of TeleKansas I and TeleKansas II on Kansas household income. The multiplier is 1.88, or in other words, the indirect effect is 88 percent of the direct effect.

Changes in employment

Tables 3-4 and 3-5 also show the aggregated effect of TeleKansas I and TeleKansas II on employment. A sector by sector, year by year estimated effect is provided in Table 3-7. The jobs created are assumed to exist for one year and then disappear. This means that one cannot add the number of jobs estimated to be created in 1992 to that of 1993 and say this represents the total number of jobs created.

Table 3-6
Sector Definitions of the Social Accounting Model

#	Sector Definition	Included SIC Codes
1	Livestock	021, 024, 025 except 0254; 027, 029
2	Crops	01
3	Forestry, Commercial Fisheries	08
4	Agricultural Services	0254, 07 except 074; 085, 09
5	Metal and Nonferrous Mineral Mining	10
6	Coal Mining	1111, 1211
7	Oil and Gas Extraction	131, 132
8	Stone, Clay, and Gravel	141, 142, 144, 145, 149
9	Construction	15-17 except 153; 1112, 1213, 138, 148
10	Food Processing	20
11	Tobacco Processing	21
12	Fabrics and Apparel	22, 23
13	Lumber and Wood	24 except 2451
14	Furniture and Fixtures	25
15	Paper Products	26
16	Printing and Publishing	27
17	Chemicals	147, 281, 286, 287, 289
18	Plastic Materials and Synthetics	282
19	Drugs and Preparations	283, 284
20	Paints	285
21	Petroleum Refining	29
22	Rubber, Rubber Prod., Plastic Prod.	30
23	Leather and Leather Products	31
24	Glass, Stone, and Clay Products	32
25	Iron, Steel, and Other Metal Prod.	33, 3463
26	Metal Prod., Ordnance, Struct. Met	34 except 3463; 3761, 3795
27	Engines and Machinery	35 except 357
28	Computers, Computing Equipment	357
29	Electrical Equipment and Appliances	36 except 367; 3825
30	Electronic Components and Parts	367
31	Motor Vehicles and Equipment	371 except 3716
32	Aircraft and Parts	372, 376 except 3761
33	Other Transportation Equipment	2451, 3716, 373, 374, 375, 379 exc. 3795
34	Scientific and Photographic Equip.	38 except 3825
35	Misc. Manufacturing	39

Table 3-6 (Continued)

#	Sector Definition	Included SIC Codes
36	Transportation and Warehousing	40-42, 44-47
37	Communications Except Radio and T.V.	48 except 483
38	Business Services, Radio and T.V.	483, 73 except 7396; 8100, 89 exc. 8920
39	Electric Services, Utilities	49 except 491
40	Wholesale and Retail Trade	50-57, 59, 7396, 8042
41	Finance and Insurance	60-64 except 613; 67 except 6732
42	Real Estate and Rental	153, 65, 66
43	Hotels, Personal Services	70, 72, 76
44	Eating and Drinking Places	58
45	Automobile Repair and Services	75
46	Amusements	78, 79
47	Private Health, Ed., and Soc. Serv.	074, 6732, 80 exc. 8042; 82, 84, 86, 892
48	Federal Government Enterprises	43, 613
49	Household	N/A
50	State Government Except Education	N/A
51	Local Government Except Education	N/A
52	Public Education	N/A

Table 3-7
The Indirect Job Effects of TeleKansas I and TeleKansas II

Sector	TeleKansas I						TeleKansas II				
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1	1	1	1	1	1	0	1	1	1	1	1
2	3	3	6	4	2	1	3	3	5	3	3
3	0	0	1	1	0	0	0	0	1	1	1
4	1	1	1	1	1	0	1	1	1	1	1
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0
7	1	1	2	1	1	0	1	1	1	1	1
8	0	0	0	0	0	0	0	0	0	0	0
9	4	4	10	7	4	1	5	4	8	6	6
10	1	1	3	2	1	0	1	1	2	2	2
11	0	0	0	0	0	0	0	0	0	0	0
12	1	1	3	3	1	0	2	1	3	2	2
13	0	0	1	0	0	0	0	0	1	0	0
14	0	0	1	1	0	0	0	0	1	1	1
15	0	0	1	1	0	0	0	0	1	1	1
16	2	2	4	3	2	0	2	2	3	2	2
17	0	0	1	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	1	0	0	0	0	0	1	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	1	1	0	0	0	0	1	1	1
23	0	0	1	0	0	0	0	0	1	0	0
24	0	0	1	1	0	0	0	0	1	0	0
25	0	0	0	0	0	0	0	0	0	0	0
26	1	1	2	1	1	0	1	1	2	1	1
27	1	1	1	1	1	0	1	1	1	1	1
28	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0
31	1	1	2	1	1	0	1	1	1	1	1
32	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0
34	1	1	1	1	1	0	1	1	1	1	1
35	0	0	1	1	0	0	1	1	1	1	1
36	4	4	8	6	3	1	4	4	7	5	5
37	1	1	3	2	1	0	1	1	2	2	2
38	9	9	19	15	8	2	9	9	17	12	12
39	2	2	5	3	2	0	2	2	4	3	3
40	31	30	69	53	29	6	33	31	59	41	41
41	8	8	18	14	8	2	9	8	16	11	11
42	6	6	13	10	6	1	6	6	11	8	8
43	11	11	25	19	11	2	12	11	22	15	15
44	13	13	29	23	13	3	14	13	25	17	17
45	3	3	6	5	3	1	3	3	5	4	4
46	3	3	6	4	2	1	3	3	5	3	3
47	25	24	55	42	23	5	27	25	48	33	33
48	1	1	3	2	1	0	1	1	2	2	2

APPENDIX 3-2: THE FORMAL MODEL

A GENERIC INPUT-OUTPUT MODEL

The construction of an input-output model begins with a series of individual industry supply and demand equations. For example, consider industry i:

(1)
$$\phi_i = \xi_{i1} + \xi_{i2} + \ldots + \xi_{ij} + \ldots + \xi_{in} + \gamma_i$$

where ϕ_i *is the output for industry i in physical units*

                 ξ_{ij} *is the intermediate quantity demand for industry i's output by industry j*

                 γ_i *is the final demand for industry i's output*

These equations assume that all output is either used as an input to further production or is consumed as final demand. The quantities in these supply and demand equations are measured in physical terms rather than by monetary value (for example, the number of planes used or the tons of steel produced).

Stacking all the industrial supply and demand equations in order provides the following configuration of equations:

(2)
$$\phi_1 = \xi_{11} + \ldots + \xi_{1j} + \ldots + \xi_{1n} + \gamma_1$$
$$\vdots$$
$$\phi_i = \xi_{i1} + \ldots + \xi_{ij} + \ldots + \xi_{in} + \gamma_i$$
$$\vdots$$
$$\phi_n = \xi_{n1} ++ \ldots + \xi_{nj} + \ldots + \xi_{nn} + \gamma_n$$

These industrial supply and demand equations can be converted to a single matrix equation which describes this simple economy:

(3)
$$
\begin{bmatrix} \phi_1 \\ \vdots \\ \phi_i \\ \vdots \\ \phi_n \end{bmatrix}
=
\begin{bmatrix}
\xi_{11} & \cdot\cdot & \xi_{1j} & \cdot\cdot & \xi_{1n} \\
\vdots & \vdots\,\vdots & \vdots & \vdots\,\vdots & \vdots \\
\xi_{i1} & \cdot\cdot & \xi_{ij} & \cdot\cdot & \xi_{in} \\
\vdots & \vdots\,\vdots & \vdots & \vdots\,\vdots & \vdots \\
\xi_{n1} & \cdot\cdot & \xi_{nj} & \cdot\cdot & \xi_{nn}
\end{bmatrix}
+
\begin{bmatrix} \gamma_1 \\ \vdots \\ \gamma_i \\ \vdots \\ \gamma_n \end{bmatrix}
$$

A more compact method of writing these relationships is given in Equation (4), which describes the production relationships in this simple economy in terms of physical units: numbers of planes, tons of steel, etc.

$$\Phi = \Xi + \Gamma$$

(4)

where Φ *is the vector of industrial output*
   Ξ *is the matrix of intermediate demands*
   Γ *is the vector of final demand*

To proceed with economic analysis, these production relationships need to be expressed in monetary terms.

Changing from measurements in physical units to units of monetary value requires the addition of prices to the model. Let p_i be the market price of the output of the ith industry. Then equation (1) becomes:

(5)
$$p_i \cdot \Phi_i = p_i \cdot \xi_{i1} + p_i \cdot \xi_{i2} + \ldots + p_i \cdot \xi_{in} + p_i \cdot \gamma_i$$

This equation establishes the relationship that the monetary value of output is equal to the intermediate demand for the output plus the final demand for the output, with all variables measured in monetary units. The following new variables make the notation for the model easier to follow:

$$p_i \cdot \Phi_i = x_i , \qquad p_i \cdot \xi_{ij} = z_{ij} , \qquad and \qquad p_i \cdot \gamma_i = y_i$$

Using these new variables, equation (5) now becomes:

(6)
$$x_i = z_{i1} + z_{i2} + \ldots + z_{in} + y_i$$

where x_i *is the output for industry i*
   z_{ij} *is the intermediate demand for industry i's output by industry j*
   y_i *is the final demand for industry i's output*

Stacking all the industrial equations in order, as was done with equation set (2), and converting the result to matrix form, as was done with equation (3), gives:

$$(7) \qquad \begin{bmatrix} x_1 \\ \vdots \\ x_i \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} z_{11} & \cdots & z_{1j} & \cdots & z_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ z_{i1} & \cdots & z_{ij} & \cdots & z_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ z_{n1} & \cdots & z_{nj} & \cdots & z_{nn} \end{bmatrix} + \begin{bmatrix} y_1 \\ \vdots \\ y_i \\ \vdots \\ y_n \end{bmatrix}$$

which can be written more compactly as:

$$(8) \qquad X = Z + Y$$

The rows of the Z matrix in equation (8) represent input demand for industry i's output, while the columns of the matrix represent industry i's input demand for all other output.

Unlike the Ξ matrix from Equation (4), the Z matrix is a description of the production process of the economy in monetary units. If prices in the economy change, then the Z matrix will change even if the underlying physical production process is unchanged. Put another way, if relative prices change but the productive structure of the economy remains the same, then the Ξ matrix will not change, but the Z matrix will change.

The Z matrix can be converted into a matrix of coefficients which describe the economy's production process. The production coefficients are created by dividing each column entry by the output of the corresponding industry. For example, consider the use of industry i's output as an input by industry j:

$$(9) \qquad \frac{p_i \cdot \xi_{ij}}{p_j \cdot \phi_j} = \frac{z_{ij}}{x_j} = a_{ij}$$

This procedure can be followed for all the entries in Z matrix in equation (7), creating a matrix of production coefficients which is commonly referred to as the A matrix.

$$(10) \qquad \begin{bmatrix} \dfrac{z_{11}}{x_1} & \dfrac{z_{12}}{x_2} & \cdots & \dfrac{z_{1n}}{x_n} \\[2mm] \dfrac{z_{21}}{x_1} & \dfrac{z_{22}}{x_2} & \cdots & \dfrac{z_{2n}}{x_n} \\[2mm] \vdots & \vdots & \vdots & \vdots \\[2mm] \dfrac{z_{n1}}{x_1} & \dfrac{z_{n2}}{x_2} & \cdots & \dfrac{z_{nn}}{x_n} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} = A$$

The Z matrix in equations (7) and (8) can not be replaced by the A matrix just created above without some adjustments. Because the A matrix was created by dividing each column by the corresponding industry's output, each entry also needs to be multiplied by that industry's output to maintain the equality in equations (7) and (8). The first part of equation (10) now becomes:

$$
(11) \quad
\begin{bmatrix}
\dfrac{z_{11}}{x_1}x_1 & \dfrac{z_{12}}{x_2}x_2 & \cdot & \cdot & \dfrac{z_{1n}}{x_n}x_n \\[2ex]
\dfrac{z_{21}}{x_1}x_1 & \dfrac{z_{22}}{x_2}x_2 & \cdot & \cdot & \dfrac{z_{2n}}{x_n}x_n \\[2ex]
\vdots & \vdots & \vdots & \vdots & \vdots \\[1ex]
\dfrac{z_{n1}}{x_1}x_1 & \dfrac{z_{n2}}{x_2}x_2 & \cdot & \cdot & \dfrac{z_{nn}}{x_n}x_n
\end{bmatrix}
=
\begin{bmatrix}
a_{11}x_1 & a_{12}x_2 & \cdot & \cdot & a_{1n}x_n \\
a_{21}x_2 & a_{22}x_2 & \cdot & \cdot & a_{2n}x_n \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
a_{n1}x_1 & a_{n2}x_2 & \cdot & \cdot & a_{nn}x_n
\end{bmatrix}
$$

Notice that the right hand side of equation (11) is identical to the A matrix having been post-multiplied by the column vector of outputs. Making this substitution gives:

$$
(12) \quad
\begin{bmatrix}
a_{11}x_1 & a_{12}x_1 & \cdot & \cdot & a_{1n}x_n \\
a_{21}x_1 & a_{22}x_2 & \cdot & \cdot & a_{2n}x_n \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
a_{n1}x_1 & a_{n2}x_n & \cdot & \cdot & a_{nn}x_n
\end{bmatrix}
=
\begin{bmatrix}
a_{11} & a_{12} & \cdot & \cdot & a_{1n} \\
a_{21} & a_{22} & \cdot & \cdot & .a_{2n} \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
a_{n1} & a_{n2} & \cdot & \cdot & a_{nn}
\end{bmatrix}
\cdot
\begin{bmatrix}
x_1 \\ x_2 \\ \vdots \\ x_n
\end{bmatrix}
$$

The right hand side of equation (12) can now be substituted for the Z matrix in equation (7).

$$
(13) \quad
\begin{bmatrix}
x_1 \\ x_2 \\ \vdots \\ x_n
\end{bmatrix}
=
\begin{bmatrix}
a_{11} & a_{12} & \cdot & \cdot & a_{1n} \\
a_{21} & a_{22} & \cdot & \cdot & .a_{2n} \\
\vdots & \vdots & \vdots & \vdots & \vdots \\
a_{n1} & a_{n2} & \cdot & \cdot & a_{nn}
\end{bmatrix}
\cdot
\begin{bmatrix}
x_1 \\ x_2 \\ \vdots \\ x_n
\end{bmatrix}
+
\begin{bmatrix}
y_1 \\ y_2 \\ \vdots \\ y_n
\end{bmatrix}
$$

Equation (13) can be written more compactly by substituting the A matrix post-multiplied by the column vector of outputs into equation (8).

$$
(14) \qquad X = A \cdot X + Y
$$

Solving the above equation for the column vector of outputs generates the multipliers for the model.

$$X - A \cdot X = Y$$
$$(I - A)X = Y$$
$$X = (I - A)^{-1} Y$$

The usefulness of the multipliers depends upon whether around this solution (or equilibrium point), a change in final demand will alter output by the same proportion that is established at the equilibrium point. Given this assumption, the solution can be interpreted as:

(15)
$$\Delta X = (I - A)^{-1} \Delta Y$$

where ΔX is the change in output
           ΔY is the change in final demand
           $(I - A)^{-1}$ is the matrix of multipliers for a change in final demand

ADDING INVESTMENT

The simple model has many obvious elements of a real economy missing. In the next few sections, we will add to this simple model to endow it with more realism. The first major addition will be an investment sector. In a real economy, not all of the goods used by firms in production are materials that go into the product. Some of the goods are used as investment. The logic used to create the A matrix can be used to create an investment coefficient matrix– a B matrix.

With the simple model, the underlying physical use of goods was described by Equation (4).

$$\Phi = \Xi + \Gamma$$

(4)   where Φ is the vector of industrial output
                    Ξ is the matrix of intermediate demands
                    Γ is the vector of final demand

Now a matrix of investment demands, Π, is added, which has the same dimensions as Ξ. Equation (4) becomes:

(16)
$$\Phi = \Xi + \Pi + \Gamma$$

Let the elements of Π be π_{ij}; then by using market prices as in equation (5), a new set of variables is created — $p_i \cdot \pi_{ij} = s_{ij}$, where s_{ij} is the monetary value of investment demand for industry i's output by industry j. Let S be the matrix of these elements of investment demand; then equation (8) becomes:

(17)
$$X = Z + S + Y$$

Just as a production coefficient matrix was created by dividing each z_{ij} by x_j, an investment coefficient matrix can be created by dividing each s_{ij} by x_j. Let B be the resulting investment coefficient matrix with the individual elements being $b_{ij} = s_{ij}/x_j$. Equation (14) now becomes:

(18)
$$X = A \cdot X + B \cdot X + Y$$

which can be solved for the matrix of multipliers:

(19)
$$\Delta X = (I - A - B)^{-1} \Delta Y$$

where $(I - A - B)^{-1}$ is the matrix of multipliers when investment is added to the simple input-output model.

SOCIAL ACCOUNTING FRAMEWORK

The simple model with the addition of investment does not explicitly factor in any income creation, personal consumption, or government activity. The model consists solely of output, a production process, an investment process, and exogenous final demand. In this section, we will extract households and government from exogenous final demand and make these two sectors endogenous. The increase in reality comes at a cost — the notation becomes more cumbersome and we will have matrices of matrices. The model will still have the same basic structure — consumption plus investment plus exogenous final demand is equal to generalized gross state product; however, the individual components will be more complex.

Consumption now includes the consumption of businesses, households, and governments. Businesses are divided into sectors, households are divided into income classes, and governments are divided by jurisdiction. Thus, the consumption matrix, U_1, is a three by three matrix consisting of nine matrices.

$$U_1 = \begin{bmatrix} BusCon & HHCon & GovCon \\ BusValue & HHValue & PayTran \\ BusTax & HHTax & InterGov \end{bmatrix}$$

To make this as intuitive as possible, each term will be defined and, if possible, an example of what each term represents will be given. BusCon is business consumption: the A matrix from before. HHCon is household consumption coefficients: this is a matrix of average propensities to consume by income class for each sector of production. GovCon is governmental consumption coefficients: this contains governmental purchases of goods and services. BusValue is business value-added coefficients: primarily profits, wages and salaries. HHValue is household-to-household value-added coefficients: for example, households paying for babysitting services from other households. PayTran is coefficients for governmental payments and transfers to households: for example, subsidized housing. BusTax is coefficients for business taxes, and HHTax is coefficients for household taxes. InterGov is coefficients for inter-government transfers: for example, federal grants to states for housing.

Investment coefficients are similarly divided into business investment (BusInv), household investment (HHInv), and government (GovInv). The difference between investment and consumption is that investment only takes place with goods and services produced. Thus, the investment matrix, U_2, is also a three by three matrix, but six of its entries are zero.

$$U_2 = \begin{bmatrix} BusInv & HHInv & GovInv \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Two major elements of the model remain: exogenous final demand, F^*, and generalized gross state product, X^*. Each of these elements is a vector with three components.

$$F^* = \begin{bmatrix} FinBus \\ FinHH \\ FinGov \end{bmatrix} \qquad X^* = \begin{bmatrix} Output \\ HHGrossInc \\ GovOperEx \end{bmatrix}$$

FinBus is all other business sales and inventory changes, such as exports. FinHH is other household income sources and net borrowing; this could be income from outside the region. FinGov is other government net cash sources. Output is X in the simple model. HHGrossInc is gross household income. GovOperEx is government operating expenditures.

Using the same technique as was used to create the production coefficient matrix and the investment coefficient matrix,[3] dividing U_1 and U_2 by $\hat{X}^*$ creates a consumption coefficient matrix, R^*, and an investment coefficient matrix, B^*:

$$R^* = U_1 \hat{X}^{*-1} \qquad B^* = U_2 \hat{X}^{*-1}$$

so that consumption and investment can be described in terms of coefficient matrices:

$$R^* X^* = U_1 \qquad B^* X^* = U_2$$

Equation (18) now becomes:

(20)
$$X^* = R^* \cdot X^* + B^* \cdot X^* + F^*$$

which can be solved for the matrix of multipliers:

(21)
$$\Delta X^* = (I - R^* - B^*)^{-1} \Delta F^*$$

where $(I - R^* - B^*)^{-1}$ is the matrix of multipliers based on this social accounting framework.

---

[3] A vector turned into a diagonal matrix will be written with a hat over it.

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} \rightarrow \hat{Y} = \begin{bmatrix} y_{11} & 0 & 0 \\ 0 & y_{22} & 0 \\ 0 & 0 & y_{33} \end{bmatrix}$$

4 | HIGH SCHOOL IMPACTS

INTRODUCTION

Rural and small town high schools in Kansas tend to be significantly smaller than urban high schools. As a result, rural high schools have much narrower course offerings. In particular the smallest high schools offer fewer than 30 one-year courses, while the largest high schools offer more than 200 one-year full-credit courses or the equivalent, as demonstrated in Figure 4-1. This gap in course offerings is probably undesirable from the point of view of local decision-makers, and it arguably may diminish the life opportunities of rural high school graduates.

Figure 4-1

Number of Courses vs. Number of Students
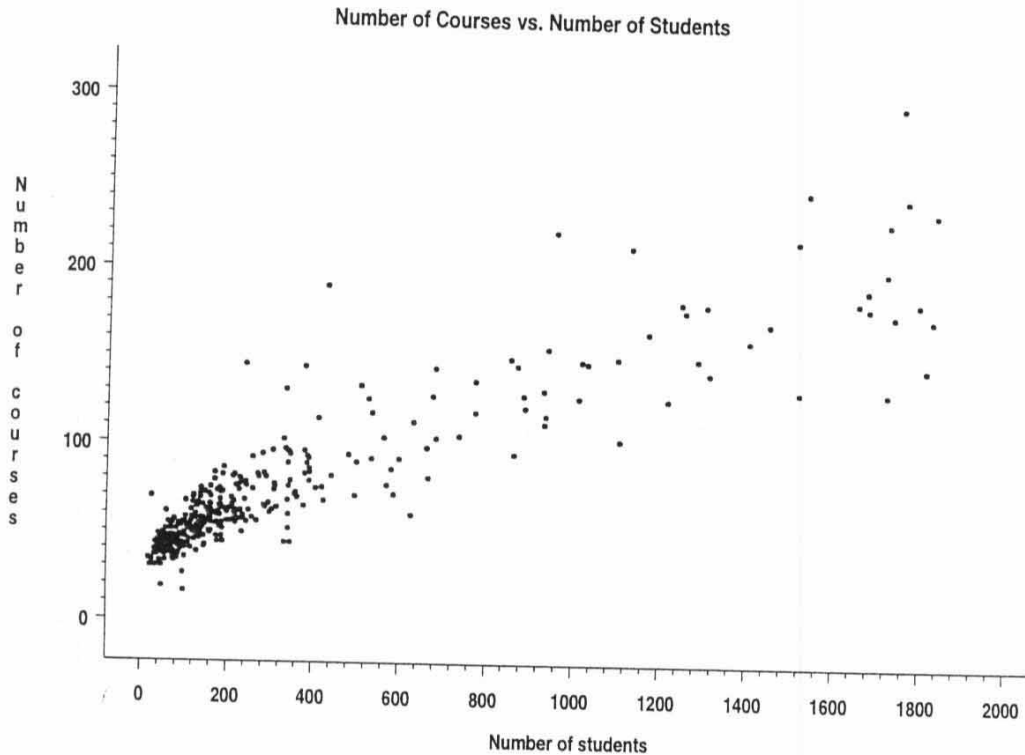
Fiber optic telecommunications can bridge this gap in course offerings by supporting inexpensive two-way interactive video teaching. In particular, a single teacher can reach students in several high schools simultaneously using equipment that allows the teacher and all the students to see and hear one another. This and similar methods of teaching

are referred to as "distance education." Chapter 2 above reviews the literature on distance education, and explains some of the links between technology and learning.

Southwestern Bell's proposed investments in TeleKansas II would make this technology available to all high schools served by Southwestern Bell, which include about one-half the high schools in the state. In this section we will analyze the dollar value of the potential benefits from distance learning for these high schools, focusing on the long run.

THE BENEFITS OF BROAD COURSE OFFERINGS

It is of interest at the outset to ask whether broad course offerings are actually desirable. This question has at least two aspects. First, as we shall see, there is good evidence that local high schools in Kansas do in fact offer the broadest range of courses that they can reasonably afford. In this reductive sense, broad course offerings are in fact being viewed as desirable by local decision-makers. Second, at the same time there is substantial controversy among authorities about the educational value of broad course offerings. Some authorities argue that a broad offering actually is a "tracking" device which lowers the quality of education received by average and below average students. Other authorities argue that tracking increases the ability of teachers to reach all of their students and serve their various needs. Thus, it is a contested question whether broad offerings are sought because they actually improve education, or instead because of mistaken beliefs held by decision-makers (or possibly because of goals decision-makers may have that are unrelated to education).

Evidence that local Kansas decision-makers do seek broad course offerings consists in the average "preferences" revealed by the behavior of their school districts. According to our data and estimates described below, most school districts do offer the broadest selection of courses that they can reasonably afford. First, our data show that the cost of education in Kansas clearly increases with the number of courses offered (provided that the number of students and the salaries of teachers are held constant). Therefore, available resources place an ultimate restriction on how many courses can be offered. Second, our data show that costs per student decline with the size of the high school if other things are held constant. This makes it easier for large high schools than small high schools to offer a broad range of courses. Third, our data show that smaller school districts with narrow course offerings actually are making a much greater effort to offer a variety of courses than are the large districts. This effort is evidenced by data showing that the average cost per course is much higher in small districts, as is the cost of adding an additional course. This implies that cost is the factor that limits the number of

courses.[4] These facts taken together support the idea that decision-makers in most Kansas high schools do desire a very broad range of courses, but only the larger high schools can afford it. This argument is supported with more detail in Appendix 4-3.

Why school districts should desire broad course offerings is another question. There is a substantial strand of educational research that supports several iconoclastic claims:

1. Integrating all students into a few courses may be more effective for most students than tracking them into classes and sequences segregated by ability and interest.

2. The "real" purposes of tracking may not be educational *per se*. Tracking may be a device for maintaining the pre-existing social stratification of a community [Lee 1993]. Or it may be a method for pacifying or maintaining control of students and parents by providing them with wide choices. This argument is made by Powell, Farrar, and Cohen [1985] in their book with the descriptively polemical title *The Shopping Mall High School*.

On the other hand, there is an opposing strand of research that accepts the straightforward interpretation of tracking as a device for economizing on teaching resources, meeting varied student needs, and preparing students for the various jobs and careers they plan to pursue [Berliner 1993].[5]

In this study we do not take a stand on the desirability of tracking or of broad course offerings. When we refer to the dollar-value that results from using fiber optics to provide broad offerings in Kansas, what we have in mind is a potential savings that would result from using fiber optics, given that the broad-offering goal has already been accepted. These savings are calculated in comparison with a more conventional means of providing broad offerings.

Note that any actual decisions to provide broad (or narrow) course offerings will remain in the hands of the local school districts; therefore, our estimate represents only a potential cost saving, not a predicted or actual cost saving. The potential saving is likely to be greater than the actual saving, because for various reasons some school districts will not take advantage of it.

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[4] These facts are implicit in the model developed below. The estimations show that the model fits the data quite well, with estimated parameters showing the expected signs.

[5] Interestingly, a review of several recent textbooks on curriculum planning found that virtually all textbooks had language implying that "broader is better". Yet nearly all avoided making a clear-cut endorsement; further, no textbook we reviewed provided any extended discussion of this very important question.

Moreover, there is an additional sense in which our savings estimate will overstate the benefits. In particular, most rural Kansas schools have at present chosen *not* to provide a wide range of courses; i.e. they haven't expanded course offerings to urban levels by adding more teachers in existing schools, nor have they fully consolidated their schools. Hence their "willingness to pay" for broad offerings is less than its cost using consolidation and expanded staff. If rural schools do eventually adopt two-way video methods, that will imply that their willingness to pay is greater than the cost of two-way video, but still not as great as the comparable cost using conventional methods. Therefore the cost savings of two-way video over conventional methods (which we will measure) is greater than what is often called the "net benefit" of two-way video. In a benefit-cost analysis, the net benefit would be defined as the willingness-to-pay measure less the cost of two-way video. In other words, our measurement of cost savings provides an upper bound on the "net benefit."

GENERAL APPROACH

The study proceeded as follows. First, IPPBR conducted a survey of Kansas high schools and merged it with data available from the Kansas State Board of Education. Next, IPPBR used the data and econometric models to measure two relationships:

1. the number of teachers typically needed in a high school with a given number of courses and a given number of students; and

2. the cost of operating a typical high school with a given number of students, teachers, and courses.

Next, IPPBR used these relationships to estimate the potential cost savings from consolidating small Kansas high schools into fewer but larger high schools; and also the cost increase from expanding course offerings up to an urban level. Finally, IPPBR used TeleKansas II rate proposals from Southwestern Bell together with information on costs of telecommunication equipment to estimate the telecommunications costs of connecting high schools through fiber optics (rather than by additional busing of students).

Survey Methodology

IPPBR designed a two-page survey of high schools. The survey instrument and instructions are reproduced in Appendix 4-1. During February 1994, the survey was mailed to all public high school principals in Kansas along with a cover letter and a stamped return envelope. The sampling frame was an updated computerized list based on a directory published by the Kansas State Board of Education [1993]. After two weeks, non-respondents were sent a similar second-round mailing with a modified cover letter. Returned questionnaires were entered into a computer file and checked for inconsistencies. The data were then merged with data by school district published by the Kansas State Board of Education [1991a, 1991b]. Finally, cross checks were made between

survey data and Board of Education data where possible. Since the survey data were for 1993-94, and the Board of Education data were for 1990-91, these cross checks could be only approximate; however, they did generally support the accuracy of the survey data.

Our sampling frame included 337 public high schools in Kansas; all were sent questionnaires. We received responses from 171 high schools, of which about 160 were useable, yielding a useable response rate of about 47 percent. Most responses had at least some entries left blank, and only a few high school principals were able to provide any high school-specific budgetary information. Therefore, we relied on school-district-wide budgetary data in the cost estimates reported in this paper. Several principals wrote messages stating or suggesting that our survey was too long, or that much of the data was difficult to obtain. We feel grateful that we received as much cooperation as we did.

Initial Findings

Small high schools have up to three times as many teachers per pupil as large high schools in Kansas (see Figure 4-2). Because teacher salaries and benefits comprise the majority of costs, large cost savings may be possible from combining small high schools into larger high schools; this is true to some extent even when the combined high school offers a broader range of courses. Consolidation could be done either physically (by busing more students over longer distances) or electronically (by using two-way video). Of course these projected savings of consolidation would be offset to some extent by costs of busing or video equipment; however, busing and video costs are relatively small in comparison to teacher salaries.[6] Another cost that tends to increase with consolidation is the cost of administrative overhead; in large schools this cost can be significant. However, there is some research at the national level showing that large or at least medium sized high schools tend to be cheaper per student than small high schools, even when busing costs are taken into account, and even in the face of the fact that the larger schools offer more courses [Rieuw 1965; Osburn 1970; Coleman and Hoffer 1987, pp.37-39].

Thirty-seven Kansas high schools reported on our survey that they are already using two-way video education to some extent. This is consistent with a report to the Kansas State School Board stating that 51 high schools in Kansas are now using two-way video, organized into six separate networks.[7] It can, however, be inferred from these numbers that our survey received a higher response rate from schools with two-way video than from those schools without two-way video. Schools with two-way video reported

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[6] See below for a discussion of video costs.

[7] The number was 52 as of April 4, 1994, if we count one more instance known to the consultant who wrote the report: Dennis E. Pellant of Tele-Systems Associates, Inc. [private communication].

between 1 and 20 video sections per high school, but the median was only 4 sections. They reported between 1 and 22 students in a typical video section, but the median was only 6 students per section. These numbers imply that two-way video is having a relatively small impact in Kansas at present, in terms of both the additional breadth of course offerings and the numbers of students affected.

Some Assumptions

As stated above, we are seeking to estimate the cost of adding more rural teachers and classrooms so as to provide broader course offerings, both with and without adding two-way video classes. Since two-way video is projected to reduce costs, the difference between the two dollar amounts represents a potential cost saving from using two-way video rather than adding teachers. This amount of savings will be realized, of course, only if Kansas does actually take steps to provide broader course offerings in rural districts.

These cost estimates assume that there will be no additional busing of students. Consolidation of schools, together with busing rural students further and in greater numbers than they are now being bused, could reduce the budgeted costs of rural school districts. The main reason for this is the reduction in teachers needed per student. However, busing would also place an additional burden in terms of travel time and/or personal auto expenses on individual students and their families. Rural Kansas citizens have in the past offered significant resistance to any proposed expansion of busing. In this study we will assume that rural schools are more willing to adopt distance education techniques than they are to expand their use of busing.

Another assumption about costs is that increases in numbers of teachers at a given high school will *not* lead to increases in the average teacher salary at that high school. According to our survey, the average teacher salary (with benefits) does in fact vary over a rather wide range (between $20,000 and $40,000), depending on the school district, but the majority are clustered around $30,000. This implies that fractional changes in salaries as high as 1/3 could be feasible when conditions change in general. However, a plot of average salaries versus number of teachers suggests that changing the number of teachers at a given high school would tend to produce extremely small increases in salaries (see Figure 4-3).[8]

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[8] A better way to handle this question would be to regress teacher salaries on number of teachers and local cost of living. We didn't try that because of the substantial difficulty entailed in constructing local cost of living indices. However, we point out that the highest cost of living tends to be in cities with large population and large high schools; therefore, including cost of living in the regression seems likely to remove or reverse any apparent dependence of teacher salaries on number of teachers.

Figure 4-2

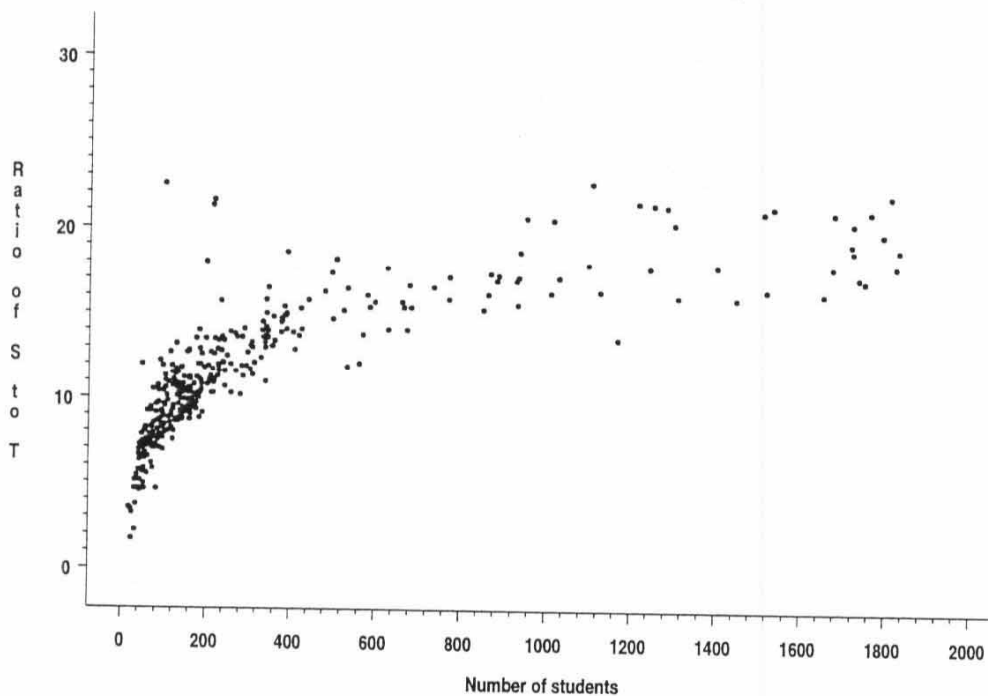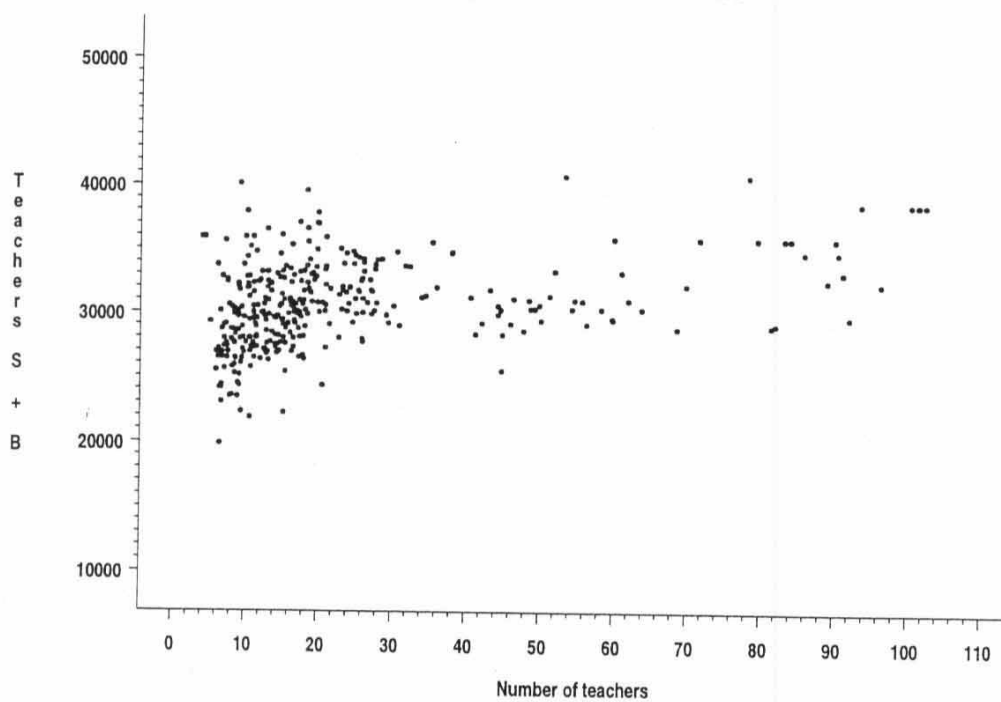### Ratio of Students to Teachers vs. Number of Students

Figure 4-3

Teachers Salaries + Benefits vs. Number of Teachers

Another assumption is that auxiliary staff are *not* needed in the remote classrooms to monitor student behavior. In other words, we assume that a single teacher can maintain a reasonable level of discipline over several distant sections through the audio-video display alone. In fact, however, Kansas high schools with two-way video report somewhat mixed results. Several experienced high school principals report that auxiliary staff are *not* needed in the remote classrooms; others thought that they *were* needed. According to an independent consultant,[9] monitors are not needed in advanced classes if the students are highly motivated and students are asked to sign a contract related to discipline before enrolling in a video class.

Because salaries for auxiliary staff monitors would constitute a significant expense, this question has an important or even critical bearing on the cost-effectiveness of video learning. According to our survey results, monitors would be paid between 1/3 and 2/3 of a teacher's salary; therefore, the monitors' salaries alone would use up about 1/2 of the saving that results from sharing a single teacher across several high schools. Equipment and transmission costs would use up part of what remains. Our judgment is that monitoring costs are a critical question. This is supported at least indirectly by some survey results: principals who believe monitors are *not* needed tend to have a positive view of the cost-effectiveness of distance learning. However, principals of high schools with two-way video who felt that monitors *were* needed, and also principals of high schools not using distance education, tend to view two-way video education either neutrally or negatively. It appears that some amount of persuasion will be needed before distance education can be adopted widely in Kansas. Moreover, adoption may depend on the perceived motivation of students to cooperate in two-way video learning. Alternatively, adoption may be limited in the long run to classes in which the students do historically show a spirit of cooperation.

Due to the absence of data, one kind of cost we did not consider in our model is the cost of acquiring land and building classrooms. Consequently, our model assumes that these costs will not increase much in the long run if the number of students in the high school does not change. Note however that the number of classes and classrooms is increasing and the average class size is falling whenever we add video sections in our model; so holding costs constant probably means that classrooms would be getting smaller. This in turn implies that there would have to be some short-run adjustment costs (for changing classroom sizes); these short-run costs are not considered in our model.

Another assumption has to do with whether students in a given small high school are more clumped together or more spread out with respect to the particular courses

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[9] Pellant, private communication.

they want to take. If the students are very homogenous in their desires in each given semester, then only a very few two-way video sections will need to be added to the curriculum in order to accommodate them. But if student course plans are absolutely as different as possible from each other, then the high school might need to offer as many as 6 or 7 different video courses *per student*. We were not able to gather any data that directly addresses this question. The assumption that we adopted is that small high schools fall halfway between these two extremes. The main effect of this assumption is that costs for hardware and fiber optic transmission were set at one-half of the worse-case amount. Since these costs are a moderate share of total costs, this assumption is significant but not critical.

A final and related assumption has to do with the number of remote classrooms that can be handled by a single tele-teacher. Current technology and applications in Kansas are designed on the principle that a maximum of four classrooms will be connected together (including the classroom with the live teacher). In the worst possible case, where a network of small high schools has very spread-out demands, this means that a single teacher might end up teaching only four students (with only one in each classroom). In our calculations, we assume that this limitation will not be binding in the long run. For example, future technical improvements may allow more than four classrooms to be connected in cases where the total number of students in each class is small; or it may be possible to connect all small high schools up with medium and/or large high schools.

Economic Modeling

These assumptions (plus others of a more technical nature) were incorporated into an econometric model. Full details are provided in Appendix 4-2. In brief, this work entailed the following steps:

1. creating a consistent set of variables for 352 Kansas high schools.

2. defining a mathematical model of the number of teachers needed in each high school. This number depends on the number of students, the number of classes taught per teacher, the number of classes taken per student, the minimum possible class size (assumed to be 1 student), the usual maximum allowed class size, and the ratio of students to the number of different courses being offered.

3. defining a mathematical model of the non-teaching costs in each high school. This amount depends on the number of students, the number of courses offered, and the number of video sections.

4. estimating the "free parameters," i.e. the quantitative relationships built into the two models.

5. evaluating the success, or statistical quality, of the estimated model. (The models were quite successful.)

6. defining a mathematical model of how many new teachers and how many un-monitored classrooms would be needed to provide course offerings equal to those of a large high school, for each small high school. This model draws heavily on the first two mathematical models.

7. establishing a standard for the "number of courses in a large high school" and the "number of students in a large high school."

8. using these models to "simulate," i.e. calculate, the cost of providing broad course offerings to each small high school. This was simulated using two different methods:
   a. by merely adding more teachers; and
   b. by maximal use of two-way video education.

9. aggregating; i.e. adding up the cost saving (which is the difference in cost between the two methods) for all the small high schools in the Southwestern Bell region, and also statewide.

The results are summarized below.

CONCLUSION

High school course offerings throughout Kansas could be equalized to an urban high school level using conventional methods (i.e. adding more teachers) at a cost of about $250 million per year. If transmission charges comparable to the TeleKansas II proposal were available throughout Kansas, then two-way video techniques could accomplish the same goal at a cost of less than $110 million per year. In other words, the statewide savings from electronic consolidation (rather than from adding more teachers) could amount to as much as $140 million per year. However, this result assumes that rural school districts are unwilling to expand their use of busing to achieve physical consolidation of high schools, but they are willing to adopt extensive use of two-way video. This result also includes benefits at high schools already using some amount of two-way video education.

Under the TeleKansas II proposal, rural high schools actually served by Southwestern Bell could potentially provide urban-quality course offerings at cost of $65 million using more teachers, or at a cost of $25 million using two-way video. Therefore, the net saving from using distance learning rather than adding teachers would be about $40 million per year. This estimate omits high schools already using any two-way video education, and it omits high schools outside the Southwestern Bell service area.

APPENDIX 4-1: THE SURVEY OF KANSAS PUBLIC HIGH SCHOOLS

SURVEY OF HIGH SCHOOLS COVER LETTER

February 24, 1994

Dear High School Principal:

This is to ask your help in studying the potential impact of two-way video tele-communications on Kansas high schools.

Distance education via inexpensive telecommunications promises to benefit many high schools by increasing the scope of course offerings, and at the same time lowering costs of offering courses for which local demand is small. Some high schools may never adopt distance education techniques; however, under the Kansas revenue sharing system, their school districts might (eventually and indirectly) share in some of the benefits resulting from lowered costs in other school districts.

The Institute for Public Policy and Business Research at the University of Kansas is trying to estimate the potential size of these benefits in the state of Kansas. To that end we are surveying Kansas high schools. We are requesting that you or a knowledgeable assistant complete the attached questionnaire. The questionnaire is about two pages long and may take around 20 minutes to complete. We do not need exact answers on every question; your best estimate will do.

Your responses are very important to our study. We need information from high schools that do *not* plan to use distance education, as well as from high schools that do use it or plan to in the future. The information we obtain will be made available to the Kansas legislature and to other state officials. We believe that this information will be useful for establishing state policy. We will also provide a free copy of our report to your high school upon your request.

Thank you very much for your assistance in this matter.

Sincerely,

David Burress
Research Economist

SURVEY OF HIGH SCHOOLS SURVEY INSTRUMENT

SURVEY OF DISTANCE EDUCATION VIA TWO-WAY TELECOMMUNICATIONS IN KANSAS HIGH SCHOOLS

This survey is part of a study of the potential usefulness of telecommunications for assisting high school education in Kansas. The study is being conducted by the Institute for Public Policy and Business Research at the University of Kansas.

We are exploring the extent to which increased availability of telecommunications could help high schools increase course offerings and reduce costs. It is especially important to obtain information from high schools that do NOT presently use distance education via telecommunications.

For some of the questions, you may not be able to provide exact answers. In these cases, *any estimates or guesses will be greatly appreciated*. We would also welcome any written comments on the survey. If you have any questions, feel free to call Dr. David Burress at the Institute for Public Policy and Business Research, which is conducting the study.

Please return survey in the enclosed envelope by Thursday, March 10 to:

Dr. David Burress   Phone: (913) 864-3701
Distance Education Project Director   FAX: (913) 864-3683
Institute for Public Policy and Business Research
University of Kansas
607 Blake Hall
Lawrence, KS   66045

Thank you.

Please correct any information below and return this cover sheet with your survey.

Principal or Contact Person Name
Title (if not Principal)
High School Name
Address

Telephone   (_____)_____

Survey of Distance Education in Kansas Public High Schools

1. Grade-levels offered at your high school include:

___ 8-12   ___ 9-12   ___ other; please explain _____

2. Number of full-time equivalent staff during fall, 1993:

____ teachers
____ other staff
____ TOTAL FTE STAFF

3. Number of students enrolled as of September 20, 1993:

____ full-time equivalent students
____ TOTAL STUDENTS

4. Number of full-credit courses listed in the 1993-94 catalog (a course lasting 1 semester counts as 1 course and a course lasting 2 semesters counts as 2 courses):

____ academic/college prep courses
____ vocational courses
____ all other courses
____ TOTAL CATALOGED FULL-CREDIT COURSES

5. Number of sections of classes offered during fall, 1993 (do not include study periods):

____ academic or college prep, full credit
____ vocational or business, full credit
____ all other, full credit
____ TOTAL FULL-CREDIT SECTIONS
____ total part-credit sections

6. Average number of students per section during fall, 1993:

____ students/section

7. Average number of classes taken per semester by a full-time student (do not include home room or study periods; count part-credit classes as fractional classes):

____ classes/student

8. Usual number of full-credit sections or the equivalent taught by a full time teacher:

____ classes/teacher

9. Average annual salary + benefits of full-time teachers (based on 9 months teaching):

_____ 9 months salary and benefits

10. 1993-94 budget (exclude summer school if possible):

_____ teachers salaries and benefits
_____ other staff salaries and benefits
_____ other costs   ___ this total includes summer school
_____ TOTAL OPERATING EXPENDITURES   ___ this total excludes summer school

11. Roughly speaking, what is the smallest and largest class size your high school had scheduled during fall 1993 (based on initial enrollments)? If possible please *omit* classes using distance education; *omit* classes taught by team teachers; and *omit* part credit classes.

smallest   largest
section   section

_____   _____   students per academic or college prep section
_____   _____   students per vocational or business section
_____   _____   students per all other sections

In the following, "video education" refers to classes in which the teacher routinely communicates with some or all of the students using 2-way video telecommunications.

12. Actual or likely salary of paraprofessionals who monitor sections of video education:

_____ 9 months salary + benefits

13. How many video education sections were offered during fall semester, 1993?

____ academic or college prep video sections
____ vocational or business video sections
____ all other video sections
____ TOTAL VIDEO EDUCATION SECTIONS
____ Total other (non-video) distance education sections

14. If video education was offered, what was the average number of students per section in video education sections (count only the local students, i.e. *students at this high school*):

____ local students per video education section

15. Please give your present opinion about the relative merits of video education classes versus conventional classes for cases where the local class size at your high school would be small (e.g. 4 to 8 students). Video classes are likely to be...

(choose one entry from each column)
____ much more effective   ____ much more expensive
____ somewhat more effective   ____ somewhat more expensive
____ roughly equally effective   ____ roughly equally expensive
____ somewhat less effective   ____ somewhat less expensive
____ much less effective   ____ much less expensive
             ...than conventional classes.

16. Do you expect increased use of video education by your high school in the next 5 years?

____ yes   ____ no

Thank you for your help. Please return the completed survey in the enclosed envelope.

APPENDIX 4-2: TECHNICAL METHODOLOGY

THE MODEL

The cost of running a high school is modeled in two parts: a predicted demand for teachers, and a predictor of non-teaching costs. Total cost is defined to equal non-teacher costs plus the number of teachers multiplied by the average teacher's wage in that school district. For a more detailed explanation of this model, see Burress [1994].

The High School's Demand for Teachers

We needed a formula which could estimate the number of teachers typically needed in a high school with a given number of courses and a given number of students. We assumed that the number of teachers depends in an obvious manner on:

1. the number of students;
2. the number of classes taught per teacher; and
3. the number of classes taken per student.

In addition, we assumed that there is a relationship describing the average class size in the high school. That relationship depends on:

1. the minimum possible class size (assumed to be one student);
2. the usual maximum allowed class size (M, a fit parameter); and
3. the ratio of students to the number of different courses being offered.

When this last ratio is large, then most classes can be filled up to the usual maximum, or M. When it is very small, then most classes will end up with only a single student.

In particular, a model with these properties is given by:

(1) $\quad N_{ti} = N_{si}(L_{si}/L_{ti})[\ 2 + (1/M)(\varepsilon\delta(N_{si}/N_{ci}) - 1)\ ]/[\ 1 + \varepsilon\delta(N_{si}/N_{ci})\ ] + u_i.$

where u_i is a random error and δ and M are parameters to be estimated. The other symbols are defined in the next section. The meaning of parameter M has already been explained. The parameter δ controls how rapidly the average class size increases with the number of students per course being offered.[10]

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[10] An additional variable available in our sample data set is the number of years or grades covered by the high school. Note that our model assumes that this variable will not affect the number of teachers, once students and courses are controlled for.

Table 4-1 contains parameter estimates and fit statistics for this equation. These results are very good for a cross-section regression. The δ and M parameters are highly significant. Experimenting with alternate sub-samples and substituting sample data for published data showed that the parameter values are reasonably robust.

Non-teacher Costs

We needed a second formula which could estimate the non-teaching costs of operating a typical high school with a given number of students, teachers, courses, and video sections. The model we adopted was:

$$(2) \quad C^{*i} = C^i - P_t^i N_t^i = V N_p^i + \alpha + \beta N_s^i + \tau N_c^i + \phi N_c^i N_s^i + u^i.$$

The parameters are subject to the restrictions

$$(3) \quad \beta + \phi N_c^j > 0 \text{ [for all j in the observed region] and}$$

$$(4) \quad \tau + \phi N_s^j > 0 \text{ [for all j in the observed region].}$$

This means that non-teacher costs are required to increase with the number of students and/or the number of courses offered.

In our application, the parameter τ was forced to be zero. This was based on two empirical results: first, when τ was left in the regression it received a negative value, violating restriction (4). Second, when τ was left in the regression and estimated appropriately using the method of moments, its value was not significantly different from zero even at the 10 percent level, based on a t test with 350 degrees of freedom.

Table 4-2 summarizes the results of the estimation. These results are based on τ being constrained to be zero. Once again, the fit statistics are very good for a cross-section regression. All of the variables are significant at .02 or better. Most variables are significant at .0001.

Table 4-1
Estimation Results for Number of FTE Teachers

Dep. Var.	$\gamma=(1/M)$	δ
N_t	0.0490 (92.95)[*]	1.9471 (40.56)
$R^2=0.9185$	$\bar{R}^2=0.9182$	N=352

[*] The figures in parentheses are asymptotic t ratios.

Table 4-2
Estimation Results for Non-teacher Costs

Dep. Var.	α	β	ϕ
C*	62215.56 (10.12)[*]	1213.82 (37.29)	0.3774 (2.29)
	$R^2=0.9807$	$\bar{R}^2=0.9806$	N=352

[*] The figures in parentheses are t ratios.

THE DATA

Estimations and simulations were run using data for all 337 public high schools in Kansas. We used published Kansas Board of Education data for 352 high schools or their school districts for 1990-91 where possible. In a few cases where variables were available only from the 1993-94 sample survey responses, we substituted sample means for any missing data values. The important variables we used are described below.

Observed Exogenous Variables (Global)

V = video costs per video section per year (nine month basis).

Based on statements from a consultant, it costs about $25,000 to acquire equipment for a full-motion two-way audio-video classroom that displays four channels. The equipment has an expected lifetime of ten years. Allowing for time costs (i.e. interest), this leads to a rental value under $4,000 per year. There is an additional maintenance cost of around $500 per year. Renting the fiber optic lines will cost between $3000 and $15,500 per year. The total is between $7,500 and $20,000 per year. If six sections per day meet in the room, the total cost is between $1300 and $4,000 per section per year. In our simulations we set V at $4000. (Rate proposals from Southwestern Bell's TeleKansas II are consistent with a smaller value of V, which would lead to a higher cost saving.)

NS = number of students in a typical urban or large school.
NC = number of courses offered in a typical urban or large school.

NC was set somewhat arbitrarily at 200, and NS at 800. See figure 1 for a distribution of numbers of courses and numbers of students, which shows that these values are at least reasonable.

Observed Exogenous Variables (for Each High School)

i = index for high school (1..N; where N=352, the number of high schools).
L_t^i = the number of sections taught per teacher; from the survey.
L_s^i = the number of sections taken per student; from the survey.
P_t^i = salary and benefits per teacher; estimated by dividing 1990-91 school district salary and benefits by the number of teachers in the school district.
N_s^i = the number of FTE students in the high school, 1990-91.

Observed Endogenous Variables (for Each High School)

N_t^i = the number of FTE teachers, 1990-91.

N_p^i = the required number of remote video classes (i.e. classes with no local teacher); estimated from the simulation model.

N_c^i = the number of one year full-credit courses offered in the catalog, 1990-91.

S^i = net cost saving of using tele-teaching instead of conventional teaching to achieve NC courses; estimated from the simulation model.

C^i = nine month operating cost of the high school, 1990-91.

C^{*i} = nine month operating cost of the high school, 1990-91, excluding teacher salaries and benefits.

Weighting Variables Used in the Simulations

Dummy for presence in Southwestern Bell territory; based on a list of high schools provided by Southwestern Bell.

Dummy for previous existence of two-way video; based on the survey findings. Two-way video was assumed absent if the high school was not sampled.

THE SIMULATIONS

We still needed a model of Np, the number of remote classes after tele-teaching is adopted. The model we used is based on a midpoint between two extreme possibilities. At one extreme, none of the local teachers in a high school adds any remote classes to his or her local classes when tele-education is adopted (i.e. all of the old classes were relatively full). At the other extreme, all of the local teachers add remote classrooms (i.e. all of the old classes were relatively empty). Under certain reasonable assumptions [explained in Burress 1994] we can derive Np under either extreme, which leads finally to the formula:

$$(5) \qquad N_p^i = [N_t(NC,NS) - N_t(N_c^i,N_s^i)/2][1 - (N_s^i/NS)].$$

Using equations (1), (2), and (5) we can solve for the change in number of teachers and the number of remote classrooms when tele-teaching is adopted.

To some extent, these simulations extrapolate outside the observed region of the cost model- i.e. we need to assume large course selections for small high schools in order to measure the baseline cost of providing broad offerings using conventional methods. This implies there is substantial statistical uncertainty in the dollar amounts reported in the conclusion to Chapter 4. But we believe there is little doubt about the accuracy of our qualitative findings.

APPENDIX 4-3: DO KANSAS SCHOOL DISTRICTS TRY TO INCREASE THE NUMBER OF COURSES?

The answer is "yes." The argument for this claim depends partly on the credibility of our model in general, partly upon the specific estimated signs of parameters, and partly on other data. For evidence that our model fits the data very well, see above. For *a priori* arguments that the model should provide a very good approximation, see Burress [1994]. The rest of the argument is as follows.

Proposition I: Our data show that the cost of education in Kansas clearly increases with the number of courses offered (provided that the number of students and the salaries of teachers are held constant); therefore, available resources place an ultimate restriction on how many courses can be offered.

Evidence: The cost function consists of two parts, (1) and (2). Joining them, and omitting error terms and the irrelevant term in Np, leads to:

(6) $\quad C^i = P_t^i N_s^i (L_s^i/L_t^i)\{[\, 2 + (1/M)(\varepsilon^{\delta(Nsi/Nci)} - 1)\,]/[\, 1 + \varepsilon^{\delta(Nsi/Nci)}\,]\}$

$$+ \alpha + \beta N_s^i + \tau N_c^i + \phi N_c^i N_s^i .$$

Our survey indicates that the two course load ratios Ls and Lt are generally close to 6 and roughly independent of Ns; hence, they can be treated as constants. From Table 4-1, δ was estimated to be significantly greater than 0, which implies that the quantity in curly braces falls with Ns/Nc (hence it increases with Nc). Recall that τ was set to zero based on statistical evidence. From Table 4-2, ϕ was estimated to be significantly greater than 0, which implies that Ci increases with Nc*Ns. Hence, both terms work in the same direction.[11]

Proposition II: Our data show that costs per student decline with the size of the high school if other things are held constant; this makes it easier for large high schools than small high schools to offer a broad range of courses.

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[11] Of course the procedure of constraining τ to 0 does change the estimated model somewhat. However, the conclusion still follows in the unconstrained case, except when Nc is very large and Ns is very small; but this case falls outside the range of estimation.

Evidence: Set τ to 0 and divide (6) by Ns to obtain:

(7) $C^i/N_s^i = P_t^i(L_s^i/L_t^i)\{[\ 2 + (1/M)(\varepsilon^{\delta(Nsi/Nci)} - 1)\ ]/[\ 1 + \varepsilon^{\delta(Nsi/Nci)}\ ]\}$

$+ \alpha/N_s^i + \beta + \phi N_c^i.$

Since $\delta > 0$, the term in curly braces falls with Ns/Nc. The remaining expression contains only positive terms. Hence by examination, the RHS of (7) is clearly declining in Ns.

Proposition III: Our data show that smaller school districts with narrow course offerings actually are making a much greater effort to offer a variety of courses than are the large districts (i.e. the average cost per student per course is much higher, as is the cost per student of adding an additional course).

Evidence: First, note as argued above that Figure 4-3 and the associated discussion imply that Pt can be treated as a constant.

(a) To obtain the average cost per student per course, divide (7) by Nc. The resulting expression falls with Ns for two reasons.

(a1) At a fixed Nc, we can use an identical logic as for Proposition II.

(a2) In fact, however, Nc is not fixed; it actually rises on average with school size Ns, as shown in Figure 4-1. Hence, the average cost per student (7) falls, and the average cost per student per course (8) falls even faster.

(b) To obtain the marginal cost of a course, differentiate (7) with respect to Nc to yield:

(8) $(d/dNc)[C^i/N_s^i] = P_t^i(L_s^i/L_t^i)(d/dNc)\{[\ 2 + (1/M)(\varepsilon^{\delta(Nsi/Nci)} - 1)\ ]$
$/[\ 1 + \varepsilon^{\delta(Nsi/Nci)}\ ]\}\ +\ \phi.$

The term in curly brackets picks up a minus sign under differentiation, plus another minus sign from the factor $(d/dNc)(Ns/Nc) = -Ns/(Nc)^2$, leading to a net positive sign. The bracket term is decreasing in magnitude with increasing school size Ns, because Ns/Nc is empirically increasing with Ns. (This can be shown from Figure 4-1; Nc/Ns is the tangent of the angle from the origin to a regression line [not drawn], and the angle clearly decreases with Ns.)

The effect of school size on the factor $Ns/(Nc)^2$ is harder to obtain. However, it can be shown, through additional analysis of the data in Figure 4-1, that this factor also falls with school size.

Hence, both factors independently cause the first term to decrease with school size. The remaining term is constant.

Proposition IV: The three propositions taken together support the idea that decision-makers in most Kansas high schools do desire a very broad ranges of courses, but only the larger high schools can afford it.

Evidence: The idea of "affording" something has to do with a relationship between cost and wealth. We can't afford a thing if its cost is too high, or if our wealth is too small. We assume that preferences of school districts are homogeneous, or at least are distributed randomly.

(a) If, contrary to IV, all school districts could afford broad offerings equally, and if wealth were about equally distributed across school districts, then III would have to be false (because in light of I, school districts would choose roughly equal average or marginal costs). In fact, it can be shown that school district wealth is reasonably unrelated to high school size in Kansas. So III implies IV.

(b) If school district decision makers did not desire broad course offerings, but instead had a fixed target number of courses, we would not observe the positive relationship of course to student shown in Figure 4-1; instead, we would observe a flat relationship.

(c) However, II suggests that large high schools will have more free resources with which to purchase course offerings than small high schools have. This explains the upward sloping Figure 4-1, but does so *only* on the assumption that more courses are desirable.

5 | FUTURE WORK

INTRODUCTION

Our current study has raised as many questions as it has answered. Our investigations of the construction impacts of TeleKansas II and of its impacts on education have produced firm and quantifiable results demonstrating the expected benefits of the plan. However, the scope of this study does not allow for similar quantitative analyses of other channels through which TeleKansas II would affect the rural Kansas economy. In particular, we have unanswered questions about the magnitude of benefits that could be expected in the health care area, and about the long-run impacts on rural output, prices and employment. This chapter proposes methods by which those questions might be addressed.

ECONOMIC AND SOCIAL IMPACTS OF TELEMEDICINE[12] IN RURAL KANSAS: A PROPOSAL FOR FUTURE RESEARCH

Investments in telecommunications upgrades such as those proposed under the TeleKansas II plan are expected to provide significant benefits for health care in rural Kansas communities. We propose a research methodology to provide quantitative measures of these benefits.

We envision five phases of the research. First, we propose to identify the specific applications through which advanced telecommunications can influence health care. We would then define indicators by which to measure improvements in health care delivery. In the third and fourth phases of the project we would gather data, both from pilot projects making use of advanced telecommunications and from published sources. Finally, we would estimate the impact of telecommunications for each of the previously defined applications. Details of each of the project phases follow.

Identification of Applications (Phase 1)

Our earlier literature review serves as an initial step in identifying the potential uses of advanced telecommunications in health care. In particular:

- Fiber optic technology is essential for remote emergency care and for remote imaging and diagnosis.

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[12] Our usage of the term telemedicine includes all applications of advanced telecommunications to health care delivery.

- Fiber optic technology will facilitate home-provider links such as remote monitoring and remote triage; rural-rural provider links such as centralized records and remote consultation/diagnosis; rural-urban provider links such as remote expert systems and remote literature searching; and provider-insurer links for billing and referral authorization systems.

- Overall, access to specialty services offered through advanced telecommunications links may help communities to recruit physicians and to prevent hospital closures.

We propose to extend our list of potential channels of influence based on additional literature searching and on information that we find in phase 3 (discussed below). We expect to limit our actual quantitative investigation to the six or seven most important impacts. The list of potential impacts would be narrowed based on the results of other studies and on the information that we gather from pilot projects.

Definition of Health Care Performance Indicators (Phase 2)

Discussions of health care frequently rotate around three dimensions: cost, quality, and access. We believe that these dimensions form an excellent way to organize our research. Thus, a preliminary task would be to define quantitative indicators for each of these dimensions. We expect our cost measurement to be straightforward, based on cost savings that have actually been achieved through the use of telecommunications. The measure would include both the cost savings experienced by hospitals and the savings realized by patients in terms of shorter travel times. Our measurement of quality would center on patient outcomes. Outcomes might include reduced hospitalization times and reduced mortality rates. We would conduct a literature search to decide on an appropriate set of quality indicators. Finally, our discussion of access would focus on the distance that rural patients must travel in order to receive basic and specialty care. We would examine how telecommunications helps to reduce that distance. It should be pointed out that the benefits of any of the specific uses of telecommunications may be multidimensional. For example, the retention of a hospital in a rural area might lower costs and at the same time improve access.

Analysis of Programs Using Advanced Telecommunications in Health Care Delivery and Administration (Phase 3)

The use of telecommunications in the practice and administration of medicine is already underway in many areas of the country. Our earlier review of the literature identified many of these, and we expect additional research to yield more examples. We plan to identify several pilot projects that illustrate potential telecommunications uses. Examples include: Kansas University Medical Center and Texas Tech University (treatment and diagnosis); Colorado Medical Information Network (billing and

information systems); and the Oregon Biomedical Information Communication Center at Oregon Health Sciences University (access to medical literature, networking).

We propose to contact each program for information including the scope of the project, the costs of delivering services, and, in the case of medical treatment and diagnosis, the outcomes for the patients. Since many of these projects were funded as demonstrations, we expect to find written project reports and evaluations that will, in some cases, provide additional detail to our analysis.

Definition of Additional Data Requirements (Phase 4)

Baseline data describing the current situation in Kansas rural areas are essential to any discussion of changes in health care delivery. Kansas-specific data are most appropriate, but nation-wide data for rural areas may provide effective proxies where Kansas data are unavailable. Examples of data that might be useful include the annual *Kansas Medically Underserved Area Report* from the KU Medical Center, which describes the availability of general practitioners and specialists throughout Kansas.

Estimation of Cost, Quality, and Access Benefits for Rural Health Care (Phase 5)

For estimates of cost and quality impacts, our methodology would follow that laid out in a report by Arthur D. Little Inc. Briefly summarized, their methodology is as follows:

a) Use data from pilot projects to estimate the benefits of using advanced telecommunications technology. The benefits should be defined as ratios, such as "cost savings per patient" or "information queries per doctor."

b) Use supplementary information from other studies or from published data to convert benefits into dollar terms wherever possible. For example, a benefit such as "reduced travel time of doctors by 20 hours per month" could be multiplied by an average physician wage to turn this measure into a dollar cost saving.

c) Generalize the benefits for a specific geographic area based on area totals such as population, total patients, etc.

d) Estimate aggregate benefits by summing over the various potential uses.

Our discussion of access issues would take a different approach. We would confine our study to two issues: access to medical specialties, and hospital closure and survival.

We expect to model access to specialists in terms of whether geographic areas are "medically underserved." As mentioned earlier, data are available on underserved areas in Kansas by medical specialty. The underserved designation is based on a comparison

of actual physicians per 100,000 population in an area to optimal standards. We plan to estimate the extent to which the provision of physician specialties through telecommunications linkages could bring underserved areas closer to these optimal standards.

To model hospital closure and survival, we plan to begin with a survey of the literature. We would place emphasis on factors that have been found to predict hospital closures, and we would put together a summary model based on our findings. Once the summary model is in place, we plan to estimate the extent to which telecommunications could alleviate risk factors. Our preliminary literature search has yielded two promising studies [Whiteis 1992; Goody 1993] that we believe could be adapted to Kansas.

Our final report would be organized along the three dimensions of cost, quality, and access. Although dollar value estimates will be made for quality and access changes wherever possible, some quality and access measures will have no dollar equivalents.

ASSESSING THE IMPACTS OF TELECOMMUNICATIONS MODERNIZATION: A PROPOSAL FOR A GENERAL EQUILIBRIUM MODEL

Changes in the telecommunications infrastructure of rural Kansas will have significant impacts on most sectors of the rural Kansas economy. The reasons for this are clear: manufacturing firms and service firms use telecommunications as an input to production, while consumers use telecommunications to facilitate their daily activities. Investments in infrastructure will induce changes in output, employment, income, and consumer welfare.

General equilibrium models are designed to take account of the structural interdependence of an economy. The simplest example of a general equilibrium model is known as an input-output model; such a model traces the flow of dollars and goods between industries. Our earlier chapter on telecommunications construction expenditures made use of an enhanced input-output model, the IPPBR Kansas Social Accounting Model. While this kind of model is an appropriate tool for many applications, it is inadequate for modeling the impacts of price changes and productivity enhancements that are likely to result from the proposed TeleKansas II investments.[13] We propose to design a more complex general equilibrium model that can capture these features. We would then use the model to estimate changes in real Kansas income and in other variables.

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[13] Many authors, including Moses [1974], Melvin [1976], and Cray [1986], have discussed price changes in input-output models and have offered suggestions for incorporating price substitution effects. Our approach implements their suggestions.

Modeling of Capacity Enhancements in Terms of Price Changes (Phase 1)

To begin the research, we would need to tackle the problem of how to model capacity improvements in rural areas. One approach is to incorporate capacity improvements through the price changes they are likely to bring about. We believe that this approach would be useful, and that the data necessary for the approach would be available from Southwestern Bell and other sources.

One difficulty with the above approach is how to model the appearance of totally new services that are economically infeasible without fiber-optic technology. It is our current belief that these changes can be successfully incorporated in the price change framework: we plan to create an estimate of what these services would have cost under the old technology.

A second difficulty is modeling quality of service. Cleaner lines and faster transmission provide added value to businesses and consumers, even if the price of service remains the same. We plan to survey the literature for methods of modeling quality changes.

Construction of a General Equilibrium Model for Rural Kansas (Phase 2)

Once impacts have been modeled as price changes, the problem becomes one of estimating the impact of telecommunications price changes on a wide array of other industrial and service sectors. The modeling done by DRI/McGraw-Hill for Arkansas [Cronin 1993] appears to take such an approach, although their model is not made explicit. But unlike the DRI model, which appears to be essentially national in nature, we plan to build a model specifically calibrated to the rural Kansas economy.

The IPPBR Kansas Social Accounting model would form the core of the general equilibrium model. This model includes 48 industrial sectors plus a consumer sector and sectors for three levels of government: state, local, and education. The model would be adjusted to include only rural counties in the state. We would then add three enhanced features to the model:

i. Input substitution parameters indicating trade-offs between telecommunications and other inputs. We plan to conduct a literature search to find numeric estimates of these parameters. Data from DRI [Cronin 1993 p.13] serve as a preliminary source. These data show overall changes in telecommunications use by industry. The overall changes are attributed to two sources: changes in technology, and substitution due to changes in prices.

ii. Equations for cost changes due to changes in telecommunications input costs.

iii. Equations relating changes in production costs to changes in price. Whether cost changes are passed on in terms of price changes depends on market structure. In particular, we would look at whether a particular sector sells its goods in national or local markets, the degree of competition in those markets, and whether Kansas firms are already operating at full capacity. For most of the sectors of the Kansas economy, we expect that cost savings will in fact translate into an additional round of price changes.

Calculation of Changes in Output, Prices, Employment, and Income (Phase 3)

Our approach would be to run the model developed in phase 2 using the initial telecommunications price changes developed in phase 1. The model would be designed to estimate changes in output by sector, prices by sector, employment, and total dollar income. Real income would be calculated by adjusting dollar income changes by a weighted average of price changes.

CONCLUSION

This chapter has outlined two pieces of research that together would answer many of the remaining questions about the impacts of the TeleKansas II plan. The first proposed project would spell out the impacts of telemedicine in Kansas, not only in terms of cost, but also in terms of quality and access to health care. We believe that this would be the most comprehensive study of telemedicine to date. The second proposed project would build a general equilibrium model of the rural Kansas economy. Such a model would estimate impacts in terms of output, employment, and income. The model would be applied to the increases in telecommunications capacity proposed in TeleKansas II. But the model would also be available for the analysis of related issues.

6 | Conclusions

This report has reviewed fiber optic impacts on rural Kansas from two points of view, one qualitative and the other quantitative. The qualitative review attempted to provide a rather complete overview of the literature. The quantitative review, however, took the form of a work-in-progress; as we pointed out in Section 5, there is still a substantial amount of research left to do. In this conclusion we will try to summarize and integrate the two kinds of results. Most of our summary conclusions are collected in Table 6-1.

As shown in the table, we estimate that the total value of TeleKansas II services will potentially exceed $50 million per year. We estimate that the value of all fiber optic services in rural Kansas may exceed $100 million per year. We emphasize that these projections refer to outcomes made possible by TeleKansas II or by other fiber optic lines, but there is no guarantee that these outcomes will actually be realized. Achieving these outcomes will depend on cooperative efforts among both rural and urban business people and professionals, and also leaders in the public sector.

To make sense of these numbers we need a base of comparison. For example, rural income = $8 billion and non-metro income = $10 billion (for 1989). It is apparent that further work is needed in order to place an overall social value on TeleKansas II. However, we know enough now to predict that the benefits are likely to exceed 1 percent of rural income.

The potential effects on rural economic development could be much greater than that. The presence of fiber optic transmission lines would not *ensure* any development in rural Kansas. Development depends on many other important factors, such as transportation (good roads and commercial airlines), labor skills, local availability of finance capital, and local entrepreneurialism. However, an absence of fiber optics would prevent many kinds of businesses from starting up or expanding. Moreover, the percentage of rural businesses that depend on fiber optics is going to grow over time. We believe that the absence of fiber optic transmission lines would certainly *prevent* much development in rural Kansas.

Table 6-1
Summary of Results:
Potential Contributions of TeleKansas II to Rural Aggregate Welfare

channel:	estimated annual dollar amounts:			main type of benefit:
	short term	medium term	longer term	
construction	$20M	0	0	additional income
education: two-way video	0	moderate	$40M.	potential cost saving
education: other	0	modest	moderate	cost saving; improved services
telemedicine	0	moderate	substantial	cost saving; improved services
business communication	0	moderate	substantial	improved services; additional income
entertainment	0	modest	moderate	improved services
other household use	0	modest	moderate	improved services
Total	$20M	moderate	> $50M	cost saving

Source: IPPBR.
Social benefits are measured in dollar terms; opportunity costs are not estimated.

Therefore, we recommend that every county-level economic development plan in the state of Kansas should provide for fiber optic common-carrier transmission to become available at least in the county seat in the near future. Fiber optic connections to the rest of the county will then be feasible at a cost which can be afforded by at least the larger business enterprises. Moreover, we recommend that the state government adopt policies to help make it happen.

This recommendation (or at least its general intent) is not especially new, and it is not especially original with the authors of this study. Indeed, the Kansas Regents Telecommunications Task Force Report [1993] suggests that we may need to go much further: Action Item 11 (page 145) calls for studying the feasibility of connecting all homes, schools, and businesses into a fiber optic backbone.

At the same time, our statement should not be taken as a recommendation either for or against the TeleKansas II project as a whole. The TeleKansas II project contains specific funding and regulatory recommendations that we have not studied. Kansas policy makers will need to make these funding decisions in light of much information in addition to this report. Rural fiber optics and rural economic development are certainly in the interest of rural Kansans, but it is not in their interest exclusively; these developments will also serve the interests of the state government and even of urban taxpayers. Also, Southwestern Bell as well as other telephone companies themselves stand to gain from growth in the rural areas they serve. Any decision on how to share the costs of new fiber optic infrastructure among these different interest groups is necessarily going to be a political one. We do recommend, however, that the decision should be made sooner rather than later.

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INDEX

87