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each airport on water quality degradation has to be evaluated individually. Factors to be considered include: rainfall (amount and frequency), topography, stream proximity, stream size and capacity, aquifer recharge areas, soil and rock types and permeability, plant cover, and surrounding land use.

ALTERNATIVE MODES AND TRAVEL SUBSTITUTES

Introduction

Mobility, contemporarily considered as a fifth freedom, has become an accepted, and often demanded, product of the American way. A lifestyle and a value structure founded in Westward expansion today holds freedom of movement in exaltation.

One may travel using public or private means. Aboard intercity public modes (bus, rail, passenger air carrier), travel is regulated as to route followed, fare charged, and quantity of route service provided. To be economical, public modes require the use of large vehicles and a scheduled service.

Private modes are those permitting an individual to transport himself or others in his own vehicle. Automobiles and some portions of general aviation fall into this category. Here, one is governed by his personal demand schedule.

Although general aviation constitutes only a small part of the total transportation system, its impacts tend to be very concentrated. Presently, a large portion of the work force in the United States is involved largely in the manipulation and flow of information. While much of this flow is necessarily personal, face-to-face contact at specific locations, significant amounts of data can, and are, transmitted and received by other means.

The era of "information explosion"—particularly in business, engineering, scientific, and social/behavioral fields—has led to dramatic advances in technological communications. In solid state electronics, the rapid growth and lowered costs of computers, communications systems, and instrumentation technology, plus lowered costs have enabled great advances in information flow. "In other words, we can transmit the products of the white collar worker—his ideas and thoughts (information)—electronically and relieve him of being transported physically so as to capitalize upon his outputs."[46] Telecommunications appears to have frequent application as a reasonable and cheap substitute for travel.

Modes alternative to general aviation and the substitutability of telecommunications technology in lieu of intercity travel will be reviewed in this section.

Modal Choice

Transportation modes to be considered in this analysis are those which offer competition with general aviation for both passenger and priority freight. General aviation includes both public and private transportation, the former consisting of air taxis and commuter service; the latter, all other categories.

Highway, railway, and air carrier service are competitive with general aviation service. Highway transportation includes public modes such as intercity buses, priority freight, and common carrier trucking (firms represented by the United Parcel Service or the Railway Express Agency). Private modes using the highway system include the automobile and private trucking. For present purposes, railway services will be limited to passenger movement since railroad freight is not competitive with general aviation in the area of priority freight transport.

A transportation system consists of vehicles, ways, and terminals. The vehicle is characterized by its speed, capacity, range, and energy consumption. The way includes both the physical infrastructure and the control systems, the characteristics of which determine its capacity. The terminal is the point at which access to, and egress from the system occurs. Terminals usually represent a constraint on both the capacity and accessibility of the system.

The following paragraphs describe the technological characteristics of these components for general aviation and for each of the other competing modes, and discusses their integration into an operating transportation system.

The Vehicle

Speed and capacity figures of selected transportation vehicles for both passenger and priority freight are shown in Table II-V. General aviation vehicles are among the fastest, yet they are of limited capacity.

The Way

Three major classifications of the way that are of concern here: (1) airway, (2) highway, and (3) railway. The type of control system associated with the way often determines its

[46] Lathey, Charles E. *Telecommunications Substitutability for Travel: An Energy Conservation Potential.* Department of Commerce. January 1975.

capacity. Positive control is exercised over all planes in the national airways system. Minimum separation of 3 miles within 40 miles of a radar site and 5 miles beyond a radar site is maintained with a resulting airway capacity of 30-120 planes per hour at each designated altitude level.

Highway capacity varies with its functional classification, which is defined in terms of the number of lanes and the type of access control, and is limited by the speed limit now set at 55 mph.

Railroad capacities are determined by the control system as shown in Table II-VI. Block signals refer to signals set by the passage of a train. Control is by means of train orders, which

TABLE II-V
VEHICLE CAPACITIES

A. Passenger	Capacity (passengers)	Speed (mi/hr)
Air Carrier	31 - 500	300 - 650
General Aviation	2 - 30	100 - 560
Highway		
Auto	2 - 10	70 - 120
Bus	30 - 50	50 - 75
Rail		
Car	50 - 70	60 - 125
Train up to 20 cars	50 - 1,400	60 - 125
B. Freight	**Capacity (tons)**	**Speed (mi/hr)**
Air Carrier (tons)	10 - 100	300 - 650
General Aviation	0.1 - 3	100 - 560
Highway		
Auto	0.5 - 1	70 - 100
Truck	1 - 30	50 - 75

TABLE II-VI
HIGHWAY AND RAILWAY CAPACITIES

A. Highways

	No. of Lanes (in one direction)	Access Control	Control	Capacity Veh/Hr/Lane
Freeway	2 - 4	Full	None	2,000
Expressway	2 - 4	Partial	Stoplight	1,000 - 2,000
Arterial	1 - 3	None	Stoplight	600 - 800
Collector	1 - 2	None	Stoplight Stop Sign	500 - 700
Local	1	None	Stop Sign Rules of Road	500 - 700

B. Railways

	Capacity Trains/Hour
Block Signals with Train Orders	
Single Track	30
Two Tracks	60
Centralized Traffic Control (CTC)	
Single Track	65
Two Tracks	125

specify the location of meets between trains, and where each train shall hold, while centralized traffic control (CTC) refers to the control of all signals and switches along a given stretch of track (as much as 500 miles) by a dispatcher in a central location.

Terminals

Airport capacity, usually expressed in terms of operations/hour, is frequently a determining factor of total system capacity. The capacity of an airport is influenced by factors such as the traffic mix, weather, and runway configuration. A "light aircraft" traffic mix includes 10 percent twin engine piston vehicles and 90 percent single engine piston. For example, a single runway can handle 53 light aircraft operations per hour under IFR conditions, 99 under VFR. With dual runways, capacity is increased to 79 and 198 operations per hour respectively. Bus terminals can have capacities of between 6 and 45 buses/hour/berths. Intercity bus terminals tend toward the lower figures, particularly where pull-in back-out angle stalls are used. Rail terminal capacity varies from 6 to 40 trains/hours/track depending upon type of service offered. Again, intercity service tends toward the lower figure. The utility of a terminal is a function of its accessibility. Airports are usually located at some distance from a town's central business district (CBD). Access may be available by private automobile only, or by taxis, limousines, buses and mass transit facilities as well, depending on the size of the town.

Bus terminals tend to be located on the edge of the CBD, with bus service usually operating on a non-stop basis between major terminals. Occasionally major services will stop, briefly, at suburban locations but these usually require time-consuming detours.

Although there may be many rail terminals in a city, there is usually only one per rail line, located close to the CBD on the intercity portion of the line passing through the city.

System Characteristics

System characteristics which will be discussed include availability, reliability, adaptability, routing flexibility, and safety.

The concept of availability is comparable to that of accessibility for public systems. Only private systems will be compared in terms of availability. The highway system is available to all who have a driver's license and have access to an automobile. This is a sizeable portion of the population, especially as compared to the number of licensed pilots and private aircraft. This small number tends to limit the availability of the general aviation system.

The air carrier system is reliable because air carriers fly IFR, which will get them through most bad weather situations. Severe snow, rain, and cloud conditions, however, can still stop flights. Under severe weather conditions, airport operations at crowded airports are slowed down, resulting in extended delays. Due to their ability to land at smaller airports, general aviation aircraft can avoid congestion, but their frequent dependence on VFR reduces their reliability in unfavorable weather.

Reliability of the highway system can also be significantly reduced by adverse weather and congestion conditions. The intercity bus system suffers from the same highway system deficiencies, but is usually fairly reliable, and published schedules are usually adhered to and rarely canceled. The rail system has the potential for greatest reliability, because both the railway and rail traffic movements are under the exclusive control of rail management. The system, however, suffers from deferred maintenance to both the way and the vehicle, causing slow running-speeds and increased accident rates.

Another transportation system characteristic is adaptability both to load and terrain, as characterized by the important factors of weight and space limitations. In dealing with bulk freight for example, the modes with the greatest limitations are general aviation, bus, and autos as compared to trucks and air carriers having larger cargo space.

Terrain adaptability is dependent upon the ability of a particular mode to function in different environments. Highway modes are limited to the highway system. Railroads face fixed right-of-way limitations, and airplanes, although limited by the placement of an airport, have the capability of bypassing all but the most rugged terrain.

Routing flexibility refers to the ability to change a route, or change destinations while en route. Public systems are generally less flexible than private ones, with the most flexible being the intercity bus followed by air carrier (which is limited to certain large airports) and rail (which is limited as to destination and route). Among private systems, the auto is most flexible.

General aviation has the following characteristics: (1) small (2-30 passengers) vehicle capacity; (2) a greater network of terminals than in air carrier transport. This network of facilities is, however, less ubiquitous than other ground transportation modes; (3) more limited availability than other modes; (4) the interface of general aviation with other modes is plagued by the same type of airport accessibility problem as those facing many air carrier airports; (5) the reliability of general aviation services is highly dependent on both pilot qualifications and weather conditions; (6) limited load adaptability; and, (7) excellent terrain adaptability and flexibility depending upon airport availability.

These characteristics suggest several different uses for general aviation, such as (a) high speed point-to-point transportation for small groups or small packages of high value particularly from general aviation airports to other airports; (b) convennient travel where distances are great and weather is dependable; (c) accessibility to remote areas in rugged terrain where landing facilities are available.

Cost Comparisons

In an analysis of the out-of-pocket costs of intercity public transportation mode, fares for one-way trips of different lengths and travel modes were compared. These modes included intercity bus, coach rail, roomette rail, tourist and first class trunk and local service airlines, and commuter airlines. The last mode represents the public transportation sector of general aviation. Data were obtained by random selections of trips from the schedules and rate charts published by these common carriers. A linear regression line was fitted to the data, to produce an equation of the form:

Fare = (Fixed Cost) + (Variable Cost) (Trip Length)

where costs are in dollars and trip length is in miles. All regressions had coefficients of determination (R^2) in excess of 0.955. The following equations were obtained:

(1) Bus Fare = 3.78 + (0.0423) (Trip Length)
R^2 = 0.985

(2) Coach Rail Fare = 8.77 + (0.0423) (Trip Length)
R^2 = 0.990

(3) Roomette Rail Fare = 16.09 + (0.078) (Trip Length)
R^2 = 0.986

(4) Tourist Air Carrier Fare = 20.59 + (0.068) (Trip Length)
R^2 = 0.970

(5) First Class Air Carrier Fare = 27.38 + 0.095 (Trip Length)
R^2 = 0.974

(6) Commuter Airlines Fare = 11.53 + (0.112) (Trip Length)
R^2 = 0.955

These regression lines are shown in Figure 2-4.

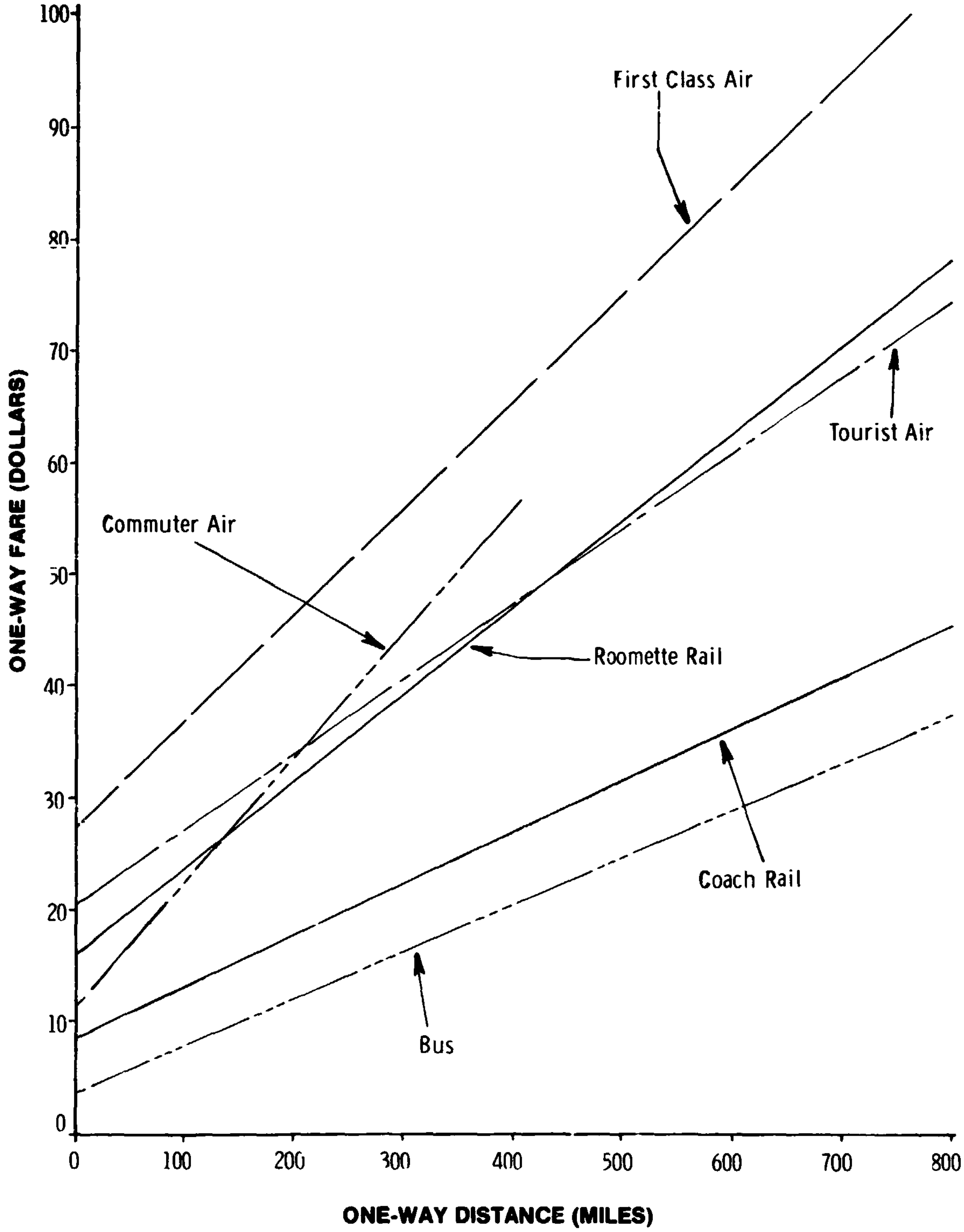
The variable costs per mile for bus and coach rail travel are almost equivalent, but the fixed costs portion of rail travel is about $5.00 in excess of that of bus. As expected, both are less costly than any of the air travel modes. For trip lengths of less than 135 miles, commuter airlines are obviously the most economical mode, exclusive of bus and coach rail. For trips of 135-450 miles, the first class rail is more economical, but the time difference is significant enough to result in these modes accommodating different and separate markets. The traveler who values physical comfort over saving time would probably select first-class rail. The traveler who values his time and who is determined to travel by air, would choose the commuter airline which is the least costly mode for trip lengths of up to 200 miles.

Considering the time differential between rail and air, and assuming that the additional time required for rail or other ground travel is not acceptable to the traveler, then commuter airlines provide the cheapest acceptable mode for trips of up to about 200 miles. It is interesting to compare this with the average trip length of commuter airlines, which was reported to be 102 miles of non-stop travel.[47] The difference between these two figures can be explained by the fact that the average trip is made up of more than one non-stop hop, and that the traveler expresses a preference for the more comfortable air carrier. Upon considering the tradeoffs between cost and convenience, more travelers will opt for the more costly air carrier mode, as the cost difference decreases and the distance traveled approaches 200 miles.

The private automobile remains the most economical mode of travel, and possibly the most convenient for many trips' purposes. Auto travel costs are less than commuter airlines for distances of up to about 500 miles. This distance is based on a single passenger occupancy, and of course increases as car-occupancy increases. Here again, time presents itself as a significant factor, because many travelers would not be willing to drive for ten hours in order to cover a 500-mile trip which should take less than three hours by air. The automobile, however, remains as a serious competitor with general aviation for business trips ranging up to 200-300 miles; for longer recreational trips where the relative value of time is not significant; and, where a higher average automobile occupancy can be expected.

Because of real time expenditures and costs involved in physical transportation, travel substitutes are being studied with a view

[47] "Commuter Airlines Commuter Airline Association Report No 3 July, 1975 p 3



COMPARATIVE FARES OF INTERCITY PUBLIC TRANSPORTATION

FIGURE 2-4

toward reducing unnecessary intercity movement.

Communication

Communication is the complex process of generating meaning by transmitting and receiving messages (information) between one person (or group) and another (or group of others). In a business setting interaction between individuals is usually either by oral, written, or nonverbal cues. A logical communicative extension for point-to-point interaction where personal subtleties are not important is telecommunication. Well known to the general public, telecommunication occurs in a continuous mode—television, AM and FM radio, and the telephone. The impetus of the space age together with integrated, solid state technology has permitted a more diverse, efficient and less known form of communication, discrete or digital in nature, to mature.

Telecommunication Scope

Today telecommunication is used in such fields as clinical diagnosis, education, public services, cultural and entertainment opportunities, banking, access to computer data banks, and computational facilities. Even offices are being reshaped due to the electronics and digital revolution. Not only is telecommunication becoming a substitute for travel, but it is also becoming an integral part of the post-industrial society.

Though substitution of travel for telecommunication can be discussed on both an intracity and an intercity level, since concern here is with aviation, only the latter case is relevant. Of the 370 billion miles traveled intercity in 1972, 315 billion were by car and 43 billion by air, the remaining used other modes. These represented 391 million and 53 million trips respectively.[48] While general aviation is a small part of the total picture described, its growth trends have been significant in recent years. The principles to be discussed below are equally applicable to general aviation as well as other modes of travel.

At the present time, with no disincentives or incentives either way, the relationship between travel and communications is highly correlated. Those who travel more tend to use the communications media more, while those who travel less tend to use them less. This relationship, however, is influenced by considerations of the social, cultural, technological, environmental, and economic characteristics of the substitution mechanism. Taken collectively, these factors can reduce the utility of travel, and thus might result in a substitution of communication for transportation. Technological developments coupled with comfort/convenience and cost savings can be expected to significantly influence modal choice. While travel might appear to be inelastic with respect to cost, attitude change (a behavioral component) is probably its most effective component.

Telecommunication Technology

Today a variety of information transfer methods exist which can impact on the substitutability issue.

Telephone Network. The Bell Telephone System and the independent telephone companies transmit over 155 billion messages annually with a growth rate of 8 percent per year.[49] While the primary purpose of this transmission system has been the continuous transmission of voice in a narrow range of the audio band, research over the years has adapted it to other uses without changing the transmission characteristics. Thus, for example, by coupling special units (modems) at each end of the telephone link, digital data can be sent at medium speeds up to 9600 bits/second. By coupling various numbers of telephone lines together, slow scan video or full video can be sent over ordinary telephone linkages. The latter use is of course inefficient but remains to be cheaper than any travel alternative.

Dedicated Digital Transmission Systems. The famous Canterfone Decision by the FCC in 1968, which allowed non Bell Equipment to be connected to the telephone system, ushered in a new era in telecommunications. More recent decisions have had a direct impact by allowing special digital-only tariff carriers to compete with the telephone system. Such companies as MCI and Datran have set up dedicated digital-wideband-links between regional cities around the country. In response, the Bell System introduced the Data Under Voice (DUV) system and is in the process of putting in its own specialized digital lines. All these are wideband lines, equivalent to many telephone circuits in bandwidth; and, being high speed in nature, could handle video signals as well.

Computer Networks. As computers become more developed, their impact on society increases. Aside from scientific computations, they can also manipulate symbols, thus enabling them to be used as interpreters, string processors, and simulators. They are

[48] Kollen James H *Transportation—Communication Substitutability A Research Proposal*, Bell Canada February 1973

[49] Lathey *op cit*

capable of storing millions of bits of information and accessing millions more in auxiliary storage devices such as magnetic tapes and discs. With the time-saving software now available, terminals remotely hooked up through a telephone line or a dedicated line, have the full use of the computing system at a central location. Thus, simple information retrieval becomes a reality. If entire libraries can be stored in a data bank, trips to specialized facilities are no longer necessary. Resources savings like these have been developed through the Advanced Research Projects Agency (ARPA) and are being extended to Europe via satellite.

Cable Television. The advent of cable television has caused further consideration of two-way systems like the telephone system. Since cable television is broadband by nature, its extension to a two-way system would be simple, though much development remains to be done on the practicality and economics. The potential of a two-way switched system similar to the telephone system has profound implications for shopping, library services, banking, education, and even home offices. Such a system, however, is expensive and might not be practical in the near future, except for special applications such as those in business or education.

Other Visual Media. While two-way cable television might be impractical, there are other useful picture transmission applications such as *Picturephone**,[50] conference television (closed circuit), alpha numeric terminals (intelligent and passive), graphic terminals, and facsimile. Each of these media has the attribute of providing visual information to the user yet each requires different types of facilities.

Picturephone uses long distance, two-way picture transmission for business applications By its very nature video transmission requires large bandwidths. Even at the slow scan speed used, many ordinary telephone channels are required: 80, three-kilocycle channels as opposed to 1500, three-kilocycle telephone channels for ordinary television. Picturephone has turned out to be expensive and requires special hookups, since it is not operated through the regular telephone switching system. Conference television requires large bandwidths and special facilities. But used in place of travel, these approaches can effect significant cost savings.

Terminals used with computers, if operated at normal teletype (TTY) speeds (100 characters/second), are very effective but limited. They provide useful output from data banks and are capable of sending messages to other users. Graphic terminals, while also connected to computers, can draw lines in addition to writing text. Some of both types can operate in the intelligent mode—involving user interaction and having its own computational ability—and can also operate at high speeds up to 60 kilobits/second. But the higher the speed, the higher the capital and operational costs. An advantage of both types is the ability to connect to a hardcopy device for a permanent record (very slow).

Finally, with facsimile, a permanent hardcopy is sent with slow to medium speeds, usually over regular telephone lines. For those cases where a specific document is required, this procedure is cheap and adequate.

Communications Satellites. Such equipment allows any signal, slow or fast, to be transmitted over long distances where cables are not available. Many telephone and television circuits are now available through this medium at less cost than equivalent land point-to-point facilities.

Future Thinking

In dealing with the overall substitution problem a significant amount of research in several areas is necessary. Attitudes must be studied to discover the reasons why people do what they do, and underlying assumptions about human needs and behavior must be scrutinized. Extensive substitution of electronic communications for travel and face-to-face interaction requires a restructuring of values and both affective and cognitive behavioral change. One must re-evaluate the reasons why, and ways in which, people interact interpersonally within a decentralized industrial facility. Fortunately a beginning has been made in answering some of these questions. Current research in this area is increasing at a rapid pace. It is an opportune time because transportation, a highly visible network is slowly becoming saturated, while telecommunications is much less visible and its saturation level much higher. Research areas include: innovation towards more efficient use of the present telecommunications network; the effects of disincentives towards travel; and studies of the costs and benefits of substitution. In addition the behavioral aspects must be considered.

The New Rural Society Program (NRSP), a program supported by the Department of Housing and Urban Development (HUD) and oper-

[50] Picturephone is a registered trademark of the Bell System

ated by Goldmark Communications through Fairfield University, has undertaken a long-range program to address a number of issues of this type.[51] Principal conclusions relevant to the present discussion can be summarized as follows:

(1) For companies which had recently relocated, top management felt that movement was done for space, modern facilities, costs in cities, crime, and transportation. Communications was not a problem, however, those companies which had considered moving but did not, stated communications as a prime reason. This was because of dissatisfaction with future phone service, and a possible reduction of face-to-face relationships.

(2) A major conclusion of audio-only conferencing systems was that they are more acceptable than previously thought. Specifically:
   (a) multichannel audio was not more acceptable than monaural between two people;
   (b) multispeaker (one speaker for each person) audio systems are more advantageous than monaural in a group conference call; and,
   (c) the multispeaker arrangement had the advantage of
      (i) separate sound image for each person
      (ii) facilitating a more stimulating discussion
      (iii) a better quality sound
      (iv) warmer contact between conferences.

(3) Given a problem-solving task, acquainted persons peformed better than unacquainted persons using an audio only system. In addition face-to-face contact under the same conditions was less desirable.

(4) If bargaining was involved in the communication, the tendency was to compromise, except in audio, between unacquainted people where the stronger case dominated. The situation of number (3) above was not supported with bargaining involved.

(5) A full test between two facilities using audio, visual, and facsimile transmission indicated that such a method were useful and important.

These results of studies conducted by the New Rural Society are not generalizeable beyond the organizations in which the studies were conducted, nevertheless they demonstrate that attitudes and behaviors toward substitutability can be modified.

Telecommunication is not a total substitute because people miss face-to-face contact even when video is provided. This is particularly true in a direct sales environment, in counseling, and in areas where empathic sensitivity is required. The Joint Unit for Planning in England reported that audio conferees found meetings to be more business-like and more tiring than conventional meetings, possiblly resulting from concentration fatigue.[52]

Teleconferencing Utility

Two excellent examples illustrate the utility of teleconferencing: **(1) Union Trust Company** from December 1973 to May 1974: the Union Trust Company with offices in Stamford and New Haven, Connecticut, 25 miles apart, conducted a teleconferencing experiment under the auspices of the NRSP.[53] Using a special electronic "sound imaging" procedure, which uses stereo techniques and isophonic loudspeakers, audio communications were set up between two officers using both Class A audio-grade and Class C voice-grade lines (the latter proved acceptable). The system allowed each participant, with a separate microphone, to be identified Documents were sent via the facsimile part of the system for hardcopy. Video was eliminated as being too expensive and not really necessary. The system had: (1) simplicity and tamper-proof design; (2) portability; (3) aesthetic appeal not detracting from the conference room; and, (4) a design for up to six participants (more could be handled if necessary).

The project was **designed to test** users' attitudes and feelings **before and after** the experiment, the effectiveness of the operation, and the frequency of use as a substitute. The results were significant:

(1) Throughout the extended field trial,

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[51] Abstracts, New Rural Society Project Stamford Connecticut 06904 November 1974

[52] "The Scope for Person-to-Person Telecommunications Systems in Government and Business," Communicative Study Group, University College London September, 1973 in Lathey, *op cit.*

[53] Tomey J F "Union Trust Installs NRS Sound Imaging Teleconferencing System, *Communications News*, May 1975

the use of the teleconference system was high. Nearly all participants in the trial substituted use of the system for at least 50 percent of their face-to-face meetings. More than one-third substituted teleconferencing for 80 percent or more of their face-to-face meetings.

(2) Users of the system reported that teleconference meetings were as effective as the face-to-face meetings that teleconferencing replaced. This evaluation was reported in each questionnaire administration during the length of the field trial.

(3) Teleconference meetings were generally 30-35 percent shorter than the prior face-to-face meetings.

(4) In comparrison to previous face-to-face meetings, participants were more attentive to what was being said, it was easier to get a point across without a lengthy debate, and discussion of particular items tended to be shorter.

(5) Participants reported that the human aspects of meeting were maintained in the teleconferencing environment.

(6) The teleconference system proved to be cost-effective, saving approximately $500 per month, considering only system cost in comparison with the value of saved travel costs and executive travel time. Executive time saved by achieving objectives in a briefer time period would add significantly to the cost-effectiveness of the teleconference system.

A particularly significant benefit gained from the system was reported by Thomas Richardson, the bank's chairman and chief executive officer:

> Not only does this type of meeting save energy and travel time, but it requires less executive time during the actual sessions. Participants are more inclined to adhere to the prepared agenda and not get sidetracked into irrelevant discussions. Everyone agrees that most meetings show an actual increase in efficiency. [54]

(2) NASA: In order to expedite the tremendous volume of complex information—technical, planning, and administrative—associated with the Apollo program, NASA in 1968 set up a teleconferencing capability between the manufacturing, testing, and decision-making centers of the program. It included a capability of handling up to 50 people at a conference with high and low speed facsimile. No video has been used. For each dollar spent for teleconferencing, an estimated 3 to 5 dollars has been saved in travel. [55] The present Viking Project, scheduled to soft-land on Mars in July 1976, has been involved in a similar project at considerable savings. [56]

Because of initial successes, NASA has made a total commitment to the teleconferencing arrangement. A modification of the Bell Systems Model 50-A teleconferencing system with facsimile facilities, became a permanent part of the entire NASA system in January 1975 and an effort has been made to encourage teleconference use between and among the NASA centers.

In the first three months of operation, 395 teleconferences were held with 13,084 people involved. The facsimile network transmitted 84,172 pages. This amounts to an average conference of 37 people using five terminals for about three hours. It is estimated that 2,414 trips have been saved in the three months at a cost savings of $521,000. [57] So-called "saved trips" are difficult to estimate since they are "trips" which may not have been taken or for which other trips were substituted.

NASA is interested in both evaluation of present facilities and research into new undeveloped modes of teleconferencing. Presently a hardware device (modem) is being built to supply both audio and slow scan pictures between Houston, Texas, and Rockwell International in California using Frequency Shift Keying (FSK) techniques. It will take place in real time providing a hardcopy in less than one minute.

Video transmissions have not been neglected. In cooperation with the Canadian Government, NASA is designing a high speed

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[54] *Ibid*

[55] Polishuk P., "Review of the Impact of Telecommunications Substitutes for Travel" to appear in the *IEEE Transactions on Communications*, October 1975

[56] Sincoff, M. Z., *et al*., *Urban Transportation Perspectives on Mobility and Choice*, NASA No NGT-47-003-028 August 1974

[57] Fordyce S. 'Evaluation of the Teleconference Pilot Project After Three Months of Operation,' NASA internal memo June, 1975

digital transmission system in the 12-14 Gigahertz range for the Canadian Television System (CTS) relay satellite. Transmission rates will be about 11 megabits. While probably not cost effective since it is experimental, the system will be available to NASA users on a sharing basis with Canada for the cost of the receiving and transmitting units.

Finally, using the electronic blackboard developed by the Bell Telephone System, NASA hopes to install 12 such units when they become available at each center presently hooked up in the telenet. These have been designed for the 50-A Portable Conference Telephone and will provide the ability for written communications in real time. Other teleconferencing experiments and operational systems are described by Polishuk[58] and Lathey.[59] They include: Confravision—British Teleconferencing, Australia CCTV Teleconference, Bell System Video Teleconferencing, Metropolitan Regional Council Television System (MRC-TV), Dow Chemical USA Interactive Television System, Vermont-New Hampshire Medical Interactive Television Network, Massachusetts General Hospital-Veterans Administration Hospital CCTV Network, Arizona Telemedicine Network, New York-Boston Banking Video Teleconferencing System, GSA Teleconferencing System, Forum-A Computer Teleconferencing System.

Conclusions

Intercity transportation will continue, albeit modified, perhaps in speed, frequency, and cost. The future of telecommunications as a substitute for intercity transportation is bright. Telecommunications technological improvements coincident with continued, demonstrable applications in the practical use of the media in intercity transmission, will secure the place of this travel substitute. Modifications in our attitudes and behaviors will allow electronic communications to substitute where travel in the past has been considered a necessity.

ENERGY RESOURCES AND USE

Introduction

As one of the most industrialized nations in the world, the U.S. requires enormous amounts of energy to function. It is projected that the U.S. will require a doubling of energy demand in the period 1970-1985.[60] Based on 1971 estimates, it is anticipated that dependence on coal and the use of imported oil will both increase in the future. About 92 percent of all our energy is derived from fossil fuels today, while in 1990 it is expected that this proportion will drop to 70 percent, the difference being absorbed mainly by nuclear energy sources.

The increased use of energy in the United States is due to both increased industrialization and population growth. This fact is brought out more clearly in Table II-VII where past trends and future projections have been made for total energy and for transportation energy demand in the United States along with the trend of petroleum consumption.

While the demand for energy increases exponentially, transportation is expected to continue to consume the historically stable 25 percent of the total. More serious, however, is the lagging domestic energy production making the nation more dependent on foreign sources for energy supplies.

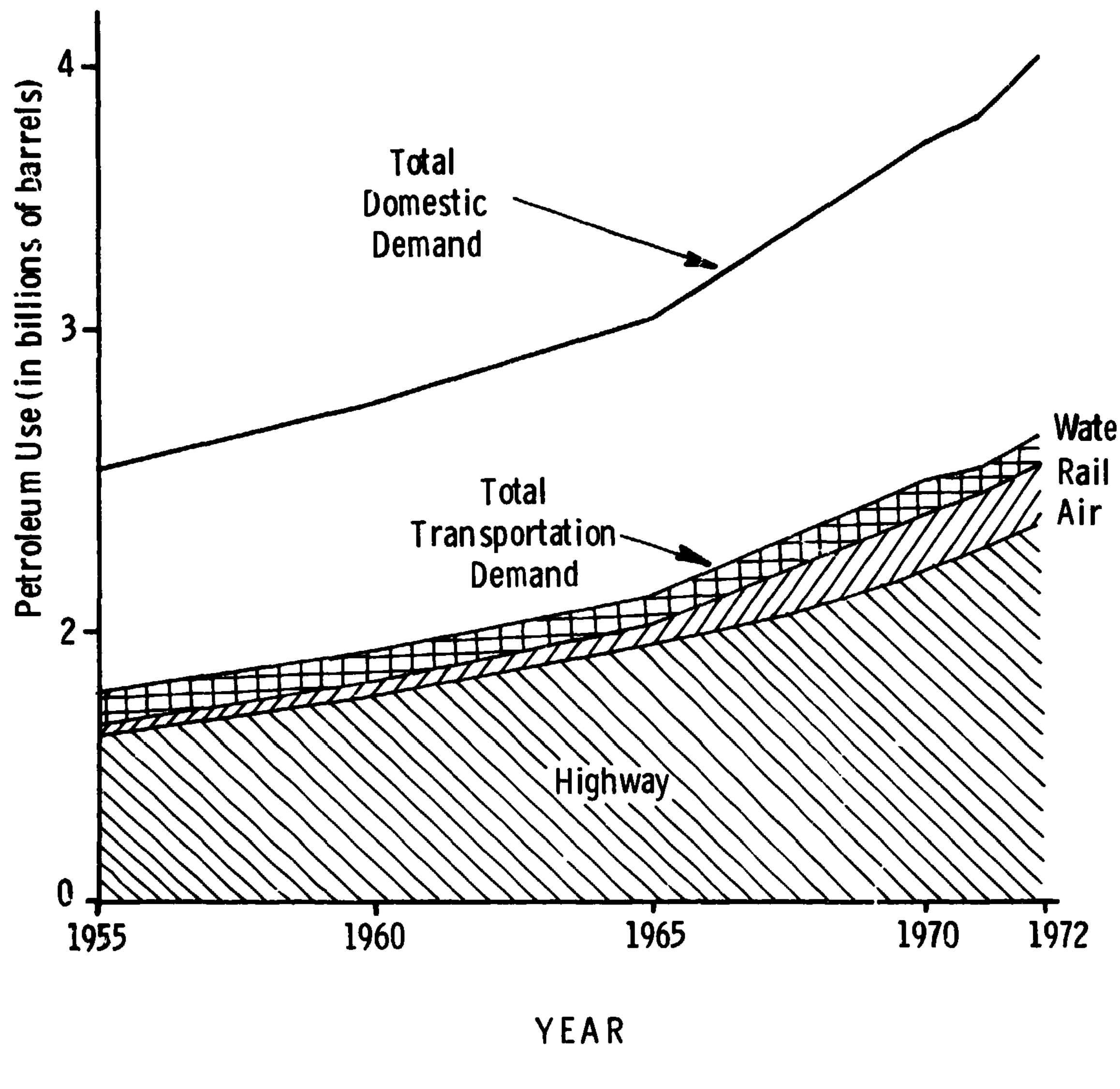
Our most critical energy source now and in the near future is petroleum. As shown in Table II-VII transportation is one of the largest users of petroleum and presently derives 96 percent of its energy from it. With its increasing **dependence** on a source of energy which is not only dwindling but subject to future political vagaries, the transportation industry—the lifeblood of any nation—is in a very difficult situation.

To further elaborate, Figure 2-5 shows the total historical use of petroleum by industry in the U.S. along with various transportation demands. Each category has been exponentially increasing and projections are for a 75 percent increase in the six years ending in 1978. Indica-

[58] Polishuk, *op cit*

[59] Lathey, *op cit*, McDowell C B, *et al*, "Remote Blackboards System for the DDD Telephone Network" *Proc IEEE Electronic Conference*, Chicago Ill Oct, 1971, "Confravision The New Post Office Service for Business Meetings Between Two Centers," British P O Telecommunications, London England May 1973, Morlco R and Bruggeeman H, "*A Discussion of Multi-Location TV Conference Arrangements*" Australia P O Research Report No 6736 May 15, 1975 Horkuess, R, "Telecommunications Substitutes for Travel, Dept of Commerce OT-SP-73-2 December 1973, "Two-Way Television Conferencing for Government The MRC-TV System" The Rand Corp and R-1489-MRC April, 1974 "How Dow Talks to Dow on Closed-Circuit TV" *Business Week*, August 10 1974, Reeves J, *et al*, "A Description of the Vermont-New Hampshire Medical Interactive Network" *Proc IEEE National Telecommunications Conference*, April 1971 Siebert D J "Development and Evaluation of a Model Interactive Television System" Dartmouth Medical School December 1972 "Arizona Tele Medicine Network Engineering Master Plan" University of Arizona College of Medicine December 1972, *Communications News*, October 1974 Letter Automated Data and Telecommunications Services GSA, March 1974 Vallee J and Miller R H, "Group Communications Through Computers" Report No R-32 Institute for the Future, Menlo Park California

[60] *Penner, S S and Icerman L, Demands, Resources Impact Technology and Policy*, vi Addison-Wesley, Reading, Mass 1974



Source: Adapted from "Transportation Facts and Trends," Transportation Association of America, December 1974.

U. S. PETROLEUM USAGE (1955-1972)
FIGURE 2-5

TABLE II-VII
THE USE AND CONSUMPTION OF ENERGY & PETROLEUM

	Total Energy				Total Petroleum Consumption			
Year	Total Used (BTU X 10^{15})	Total Produced (BTU X 10^{15})	Transportation Uses (BTU X 10^{15})	Transportation Uses Percent	Total Petroleum Used (BTU X 10^{15})	Percent Import	Percent Used in Transportation	Transportation Energy from Petroleum in Percent
1950	34.2	34.5	8.7	25.5	13.5	10.6	50.3	77.8
1960	44.9	41.6	10.9	24.2	20.1	17.8	51.7	95.3
1965	53.8	49.1	12.8	23.7	23.2	21.4	52.5	95.5
1970	68.8	61.9	16.5	24.0	29.6	22.2	53.2	95.5
1980	88.1	-	21.6	24.5	35.9	50.0	57.6	96.1
2000	168.6	-	42.9	25.4	57.6	?	72.3	97.1

Source: Hirst, E., *Energy Consumption for Transportation in the U.S.* (Oak Ridge National Labs, No. ORNL-NSF-EP-15, 1972).

TABLE II-VIII
TRANSPORTATION STATISTICS

	Vehicles (10^3)		Vehicle Miles (10^9)		Ton-Miles (10^9)		Fuel Gallons (10^9)	
	1960	1972	1960	1972	1960	1972	1960	1972
Car	56,935	87,000	587.4	1004.2	-	-	41.2	73.46
Intracity*	65.2	60.7	2.14	1.756	-	-	-	-
Rail (Pass.)	25.7	7.76	21.28	8.57	-	-	-	-
Scheduled Air (Pass. and Freight)	1,842	2.35	.821	2.00	-	-	1.90	7.89
G.A. Pass. and Freight)	78.8	134.9	1.77	3.14	-	-	.242	.734
Truck (ICC)	279	530	7.2	14.2	7,200	15,500	15.88	30.72

*All Intracity Public Transit Modes

Source: U.S. Dept. of Commerce, *Statistical Abstracts of the United States* (Washington, D.C., 1974).

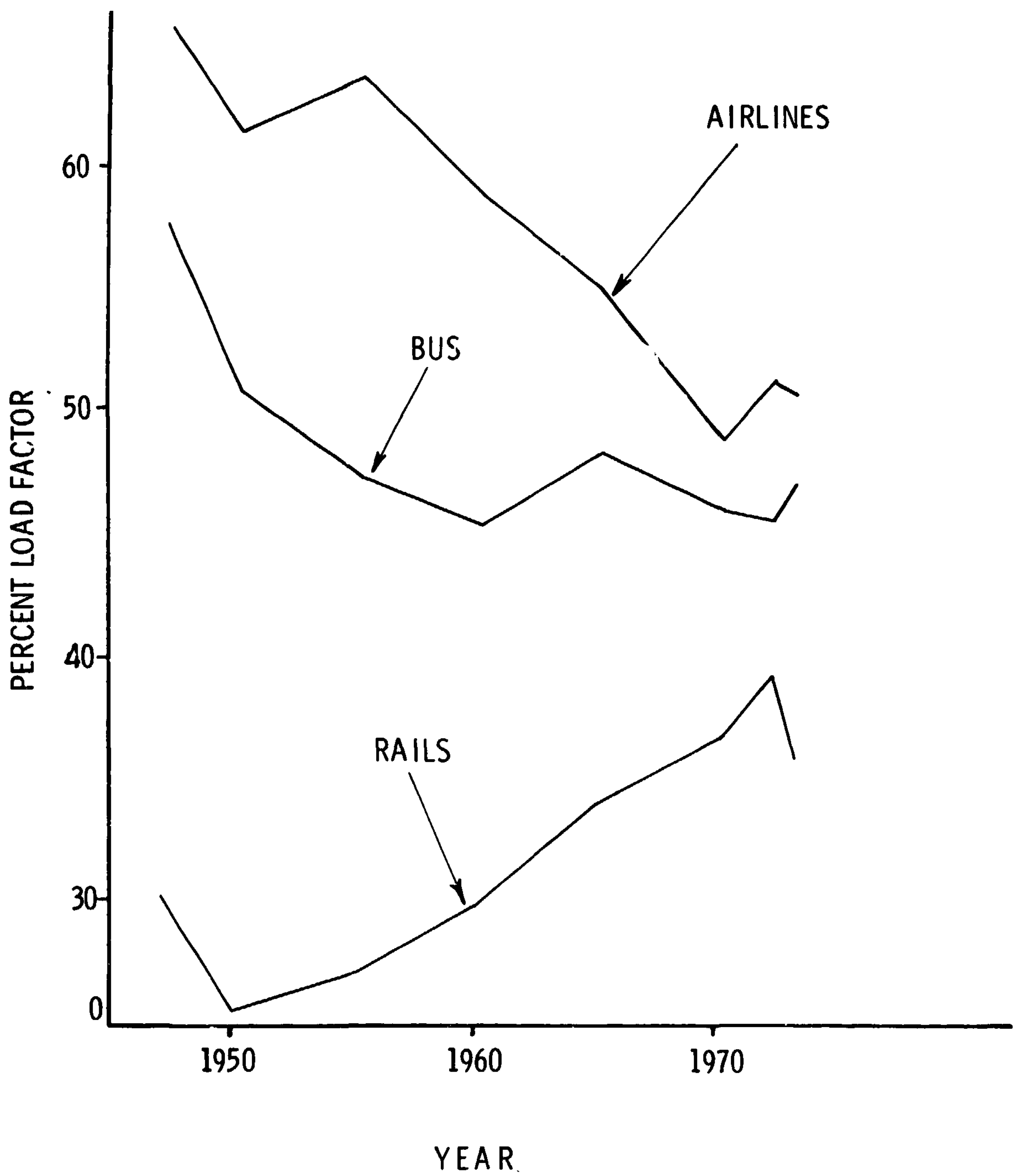
tions are that aircraft demand, though only a fraction of the total, is increasing at a faster rate than other modes. Compounding the problem is an expected increase of energy loss (waste) due to conversion processes from about 49 percent in 1970 to 58 percent in 1985[61].

[61] *Certain Background Information for Consideration When Evaluating the National Energy Dilemma*, Joint Committee on Atomic Energy, U S Government Printing Office, Washington, D C 1973

Energy Intensiveness and Efficiency

Both passenger miles and freight ton-miles for automobiles and aviation have been increasing at a faster rate than the number of vehicles in operation. Table II-VIII summarizes the situation for the 12-year period 1960-1972.

The use of gasoline is increasing not only because of increased vehicle miles, but also as a result of the decreased efficiency of automo-



Source: Adapted from "Transportation Facts and Trends," Transportation Association of America, December, 1974.

TRANSPORTATION LOAD FACTORS FOR CLASS 1 INTERCITY CARRIERS
FIGURE 2-6

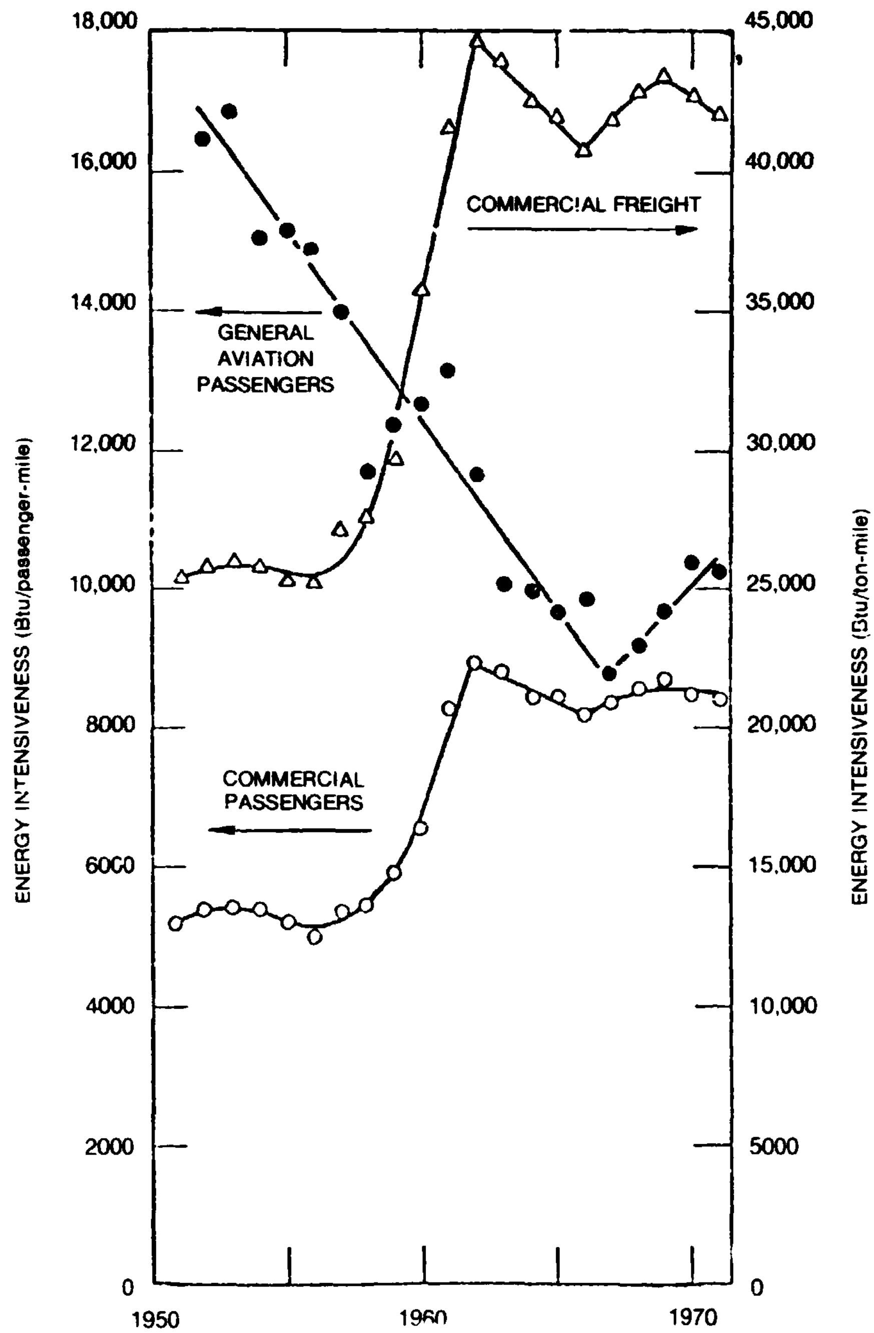
biles as reflected in decreasing automobile mileage per gallon (m.p.g.). It has been recommended by the Federal Energy Administration that the latter figure be raised to 20 m.p.g. from the present 12.67 m.p.g. as a conservation measure.

Since transportation has many aspects, attempts to classify each for comparative purposes is difficult. In terms of energy, it has become common practice to measure the efficiency of transportation in Btu's per passenger-mile or Btu's per ton-mile, *i.e.*, energy intensiveness (EI). This figure of merit is affected by many parameters such as speed, mode, seat capacity, design, and typical load factor. Table II-IX which is a composite set of average numbers drawn from many sources has been compiled to allow ready comparisons. It is immediately obvious that walking and bicycling are the most efficent in the use of energy while autos and airplanes are the least efficient, with the business jet being by far the worst. Load factors used for the calculation values given in the table were chosen so as to reflect what seems to be reasonable averages. Actual load factors over the last 23 years appear in Figure 2-6 for airline, rail, and bus carriers. Clearly,

TABLE II-IX
THE ENERGY INTENSIVENESS OF ALTERNATIVE TRANSPORTATION MODES

	Speed (mph)	maximum Capacity (Seats)	EI* at 100%LF** (BTU/PM)	Average Load Factor (Percent)	EI at Average Load Factor (BTU/PM)
Urban					
Bicycle	1- 10	1	200	100	200
Walk	1- 5	1	300	100	300
Auto (Large)	5- 20	6	2060	30	6870
Auto (Compact)	5- 20	4	2000	30	6670
Auto (Electric)	5- 20	4	1360	30	4500
Motorcycle	10- 25	1	2260	100	2260
Bus (Diesel)	5- 15	50	660	58	1170
Bus (Gas)	5- 15	30	1000	45	2220
Van (Gas)	15- 20	10	1000	45	3330
Subway	15- 30	1000	850	35	2430
Urban-Suburban					
Commuter Rail					
Elect	25- 45	125	570	35	1636
Diesel	25- 45	90	940	35	2700
Gas Turbine	25- 45	80	1700	35	4860
Helicopter (3-engine)	95-150	78	10030	58	17300
Intercity					
Bus (Diesel)	40- 60	50	390	46	850
Rail (feet)	50-100	360	540	35	1540
Rail (cross country)	40- 60	360	650	35	1860
747 Jet	500	360	3250	55	5900
707 Jet	500	136	3850	62	6200
STOL	200	99	3960	55	7200
VTCL	200	100	4533	55	8240
G.A. Recreational (Cherokee 180)	141	4	2073	50	4146
G.A. Business (Twin) (Baron B55)	225	6	2670	50	5340
G.A. Business Jet (Learjet 35)	500	10	9527	50	19054

*Energy Intensiveness
**Load Factor



Source: E. Hirst, "Total Energy Use For Commercial Aviation in the United States", ORNL-NSF-EP-68, April, 1974.

DIRECT ENERGY INTENSIVENESS OF CIVIL AVIATION
FIGURE 2-7

there is room for improvement and together with increased vehicle efficiency, substantial energy savings can be achieved.

To balance the picture a similar efficiency rating can be made for freight movement. One ton-mile of air freight consumes 42,000 Btu while trucks and railroads have respective ratings of 2,700 and 700 Btu/Ton-mile.[62]

As shown in Figure 2-7, the EI for both the airlines and general aviation in the 1950-71 period reveals that the EI for commercial freight and passengers has dramatically increased due mainly to declining load factors and the use of turbojets which are more energy intensive. However, in this period the average speed of travel increased by 100 percent from 200 mph to more than 400 mph. General aviation improved in this same period due to an increased load factor.[62] In fact while passenger traffic in general aviation increased, fuel use grew more slowly, a trend which reversed itself in 1966. It is important to note that general aviation is still more energy intensive than commercial airlines.

In addition to the direct energy costs of transportation, there are also indirect costs associated with transportation which include the "energy needed to extract, transport, and refine oil; to manufacture, maintain airports; and to carry out other air-travel-related activities.[63] Fuel use represents a larger portion of direct cost for aircraft than it does for autos. Typical EI's in terms of direct and total energy uses of commercial air travel are 8400 and 11200 Btu/passenger mile. Corresponding values for intercity auto travel are 3300 and 5700 Btu/passenger-mile.

Future Research

In addition to work directed toward the solution of well-identified technical problems, it may be conjectured that there are two ways in which research and development might impact general aviation favorably over a long range:

> First, research and development's efforts directed specifically toward moving general aviation out of areas of resource use wherein the long-range outlook for resource availability is poor.
>
> Second, efforts directed toward other transportation and public utility areas, the results of which will remove pressure on general aviation and so allow a slower abandonment of present technology. Some of this work would presumably be of both direct and indirect benefit to general aviation.

The dismay of the public over energy availability appears to be directed more toward the increasing costs of fossil fuels than toward their enventual exhaustion. The ultimate problem, however, is truly resource exhaustion rather than cost. The rising prices simply emphasize the diminishing availability of the resources. It is cynical to suggest that a 200-year coal supply affords significant energy relief to a race whose problem of survival presumably extends thousands of years beyond. It is likewise thoughtless to neglect our present technology by stating that the technological level on which future generations will live simply will have to be lower than the present one. This thinking has never been generally acceptable, and it is reasonable to expect that gains we have so far made will be given up reluctantly. But we must realize that research and development in the direction of long-range relief from the fossil-fuel exhaustion problem must be done now, while the short-range outlook still indicates that a few years are left.

The two general deficiencies in the area of energy resource conservation have been that we have not developed the ability to use free and renewable resources within the rate limits that would avoid exhaustion, and that we have not developed the ability to store energy over long periods of time. Our two principal means are the hydroelectric reservoir and the tank farm, as they have been for forty years.

It is also worthy to note the directions of change that have taken place specifically in the aircraft area. Fuels and lubricants have the same source as they did at the start: non-renewable fossil resources (though castor oil was used during World War I as a lubricant). The choice of materials of construction has swung from renewable to non-renewable ones—from wood and fabric to metals, and lately to energy-intensive materials, the plastics.

The hold that general aviation has on the small percentage of our resources that it does use is very insecure. A fuel panic such as that of 1973 can cause general aviation fuel supplies to be imperiled in the search for the most visible ways to alleviate the trouble. Continuing increases in resource use can cause repetitions of similar crises and can eventually put general

[62] Hirst E., 'Total Energy Use for Commercial Aviation in the U.S.,' Oak Ridge National Labs. No ONRL-NSF-ED-68, April 1974

[63] *Ibid*

aviation quite literally on the ground.

There are no means of stepping completely outside the areas of resource use of non-aeronautical technologies. There are, however, ways in which at least temporary relief can be secured.

The search for alternate aircraft fuels is on already. There has been considerable speculation over the possible direct use of liquid hydrogen as an aircraft fuel. The manufacturers of large airframes have conducted studies indicating that hydrogen-fuel technology might enable development of airframes weighing substantially less per pound of useful load carried, than do airplanes using hydrocarbon fuels. This advantage apparently does not extend to smaller airplanes. The use of hydrogen also depends upon the development of a hydrogen economy, which in term waits upon construction of inexpensive hydrogen generating plants in large capacities. Similar remarks can also be made regarding the next runner-up, liquid methane.

It would appear that the small general aviation airplane in roughly its present form and using fuels requiring no more special handling than does avgas, should be the best candidate for survival. If this is granted, the search should now shift to acceptable means of obtaining replacements for the present fossil source of the fuel. The chemical composition of such fuels must be generally similar to that of avgas to yield similar performance and handling properties. The desirable elements of the fuel are, to start with at least, only carbon and hydrogen.

The production of liquid hydrogen is no longer a technological problem in the sense of the difficulties it presents, but is rather a problem of cost. In 1974 the cost of liquid hydrogen was stated to be from $2.50 to $8.50 per Btu (taken by itself as a fuel), the highest cost of any aircraft fuel considered, except boron (B_5H_9). Nevertheless hydrogen is abundantly available, and is returnable to the environment in the form from which it can be extracted in largest quanity, water.

Obtaining carbon, however, is another matter. Coal, which is being talked of popularly as a source of gaseous fuel as well as for direct use in its natural form, will have heavy pressures placed upon it for non-aviation uses as petroleum resources dwindle. Since aviation is a small consumer of energy even in the transportation market, it would seem wise from a strategic point of view to attempt to sidestep the blow that is sure to be felt as non-aviation uses impact the supply, and seek other sources of carbon, such as vegetable matter, atmospheric carbon dioxide, and limestone. Of these three, the visible environment will be influenced least by extraction from atmospheric carbon dioxide, and most by extraction from limestone. Of the three, two methods meet the desirable goal of utilizing renewable energy sources.

Little commercially-usable technology is in hand for any of these extraction methods yet, but it is not too early to consider acquiring it.

Aviation fuel synthesizing, in the general fashion called for by the exploitation of the above techniques, is being explored by the Air Force. To illustrate how far the development has to go, in 1974 the price of a gallon of one such fuel was $85. The fact that the Air Force interest is along the line of tailoring fuels and engines to each other brings up the entertaining possibility of exploring the feasibility of doing the same thing for non-military power plants.

Conclusions

The overall energy picture for the United States and the world is not very promising. With only 5 percent of the world's population, the United States uses over 30 percent of the world's energy. This use is predicted to increase even in the face of competition for energy resources by developing nations seeking to raise their standards of living. The result, even considering only the most optimistic predictions, is that by 1985 the nation will be only 62 to 89 percent self-sufficient.[64]

However some saving in energy used can be effected by increasing vehicle passenger and cargo load factors and changing the present transportation mode mixes away from trucks and airlines and toward railroads. Voluntary conservation to date has not worked. The use of electricity did drop by 1.5 percent in the last quarter of 1973 after continuing its normal 7 percent growth rate up to that time. By by "1974, a substantial return to normalcy had occurred. Imports were approaching 40 percent of U.S. petroleum consumption. . .and the U.S. had become even more dependent on foreign supplies that it had been before the crisis of 1973-74 The needed dedication to implement Project Independence was absent."[65] In fact, domestic production of petroleum has declined in the past year and relaxation in conservation

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[64] Nassikas J N "National Energy Policy Directions and Developments *IEEE Transportation on Industry Applications*. VIA-9 NO 5 Sept Oct

[65] Hirst E *op cit*

appears total. We now draw 26 percent of our oil imports from Arab countries as opposed to 16 percent in late 1974.[66]

The effect of energy shortages will affect automobiles and airplanes the greatest because of their energy intensiveness. If fuel were allocated on the basis of national need, general aviation is bound to be affected the most, although it only uses about .42 percent of total fuel needed by transportation.[67] Furthermore, because of its characteristics, aviation cannot easily switch to alternative modes or even take easy advantage of those technological advances persently on the drawing board such as solar, geothermal, or nuclear.

[66] *Time Magazine*, July 21, 1975 p 42

[67] "General Aviation Aircraft," GAMA, Washington, D C, 1974