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CAC Document No. 142

ENERGY, EMPLOYMENT AND TRANSPORTATION

By

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ABSTRACT

The total energy and employment demands of various transportation modes are determined using a large matrix model. The results are then used to examine the resource demands of policy alternatives such as urban car-bus substitutions, competitive freight transport alternatives and alternatives to the Federal Government's Highway Trust Fund.

I. INTRODUCTION

It is the purpose of this paper to present an estimate of the impact of transportation systems on energy use and on employment. Planners and policymakers in both government and industry should find the results both interesting and useful.

The first part of the paper describes the method used to calculate the energy and employment impacts. The general results of application of the model to various modes of freight and passenger transport are also given in this section. The reader should be aware that the applications were thought of before the model was developed, rather than the reverse.

The second part of the paper discusses the application of the model to three principle policy alternatives: urban car-bus substitution, intermodel vehicular freight competition and alternatives to the Highway Trust Fund. These three applications typify the historic tension between the public and private sectors on transportation planning. Hopefully, the knowledge of the respective drains on the energy and employment resource bases will have a positive effect on how we move both things and people.

II. THE ENERGY-EMPLOYMENT OUTPUT MODEL

a. Description

We will first discuss the options for energy conservation in transportation systems by describing a model and early results obtained by the Energy Research Group at the Center for Advanced Computation in the University of Illinois at Champaign-Urbana (Hannon, 1974 a).

Before one can speak of conserving energy (or of increasing the supply one should understand in some detail where energy is going: the total cost of every good and service. Then one could determine the energy conserved by switching from one good or service to an alternative or by completely eliminating its consumption. Likewise, the energy cost of the substitution of new technology--a new manufacturing process, for example--could be estimated.

To calculate the energy cost of one unit of an item, we ask: What are the direct inputs of goods and services required to produce that item? For each of these inputs, we ask: What are <u>their</u> inputs? and so on until we reach such a multitude of small inputs that leaving off the next round does not significantly change the total requirements. For example, the direct inputs rqquired to produce this paper were quantities of paper, ink, and glue, labor, and printing machinery. The secondary round of inputs to the paper, for example, included wood pulp, cotton, clay, labor, and paper-making machinery. The tertiary round of inputs to the wood pulp included wood, chemicals, labor, and machinery. The process continues as a tree of inputs, infinitely branching. In some cases, branches interlock, as in the case of the consumption of paper (packaging, for example) in making ink. With each branch of this complex tree of inputs, one can associate the energy required to produce the desired unit. Summing all these energies yields the total energy required per unit of final output. When this process is completed for a single issue of this paper, we find that the total required fossil fuel energy is the equivalent of that in about 1.2 quarts of gasoline.

A more manageable way to accomplish the same result is based on input-output theory, for which Wassily Leontief recently received the Nobel Prize in Economics. The kernel of the method is to first divide an economic system into recognizable sectors such as steel production, feed grain production, railroad services, etc. Then for a given period, usually a year, assume that the total dollar output of a given sector is the sum of a certain fraction of the total dollar output of each sector of the economic system plus that delivered for final consumption. The needed fractions are found from actual dollar-transaction data between each sector and all the others. The result is a set of equations in which the total sector outputs are the unknowns. The object of the method is to simultaneously solve these equations for the total sector outputs. The process requires large, modern computers if the economy is divided into many sectors.

The result is a second set of equations, this one expressing the total dollar output of each sector as the sum of a certain fraction of each sector's deliveries to final consumption. The sum of these fractions required for one unit of a given sector's deliveries to final consumption is called the dollar intensity or output multiplier for that sector. For example, we might find that a dollar's worth of output of automobiles for consumption requires a total of three dollars worth of outputs from the other sectors. Then we say that the dollar intensity (or multiplier) for automobiles is three. This intensity would include, for example, the value of all the steel production resulting from the dollar's worth of consumer demand for autos, which would in turn include the value of the steel consumed directly by the auto manufacturing plants, and the value of steel consumed indirectly-in replacing depreciated trucks which deliver autos to salesrooms, perhaps.

With knowledge of the way in which energy is consumed by each sector, dollar flows can be transformed into energy flows, in British thermal units (B.t.u.), of a given type of energy (coal, oil, electricity, natural gas, etc.). Thus one can derive the energy multiplier for a unit of delivery to final consumption by a given sector. Dollar outputs can similarly be converted to employment figures (by occupation), amounts of pollution (by type), land use, etc.

The U.S. Department of Commerce has collected sufficient dollar data on 363 sectors of the economy for the years 1963 and 1967 to enable the calculations described above to be made. R. A. Herendeen (1973) has transformed the 1963 sector dollar flows to energy flows between sectors, and we have developed the total employment requirements for each sector in 1963. These data allow analysis of tradeoffs between human and mechanical energy. This will be discussed below in more detail where the results of the 1963 data is updated to 1971 through the judicious use of dollar inflators and changes in energy and labor productivity.

b. General Application

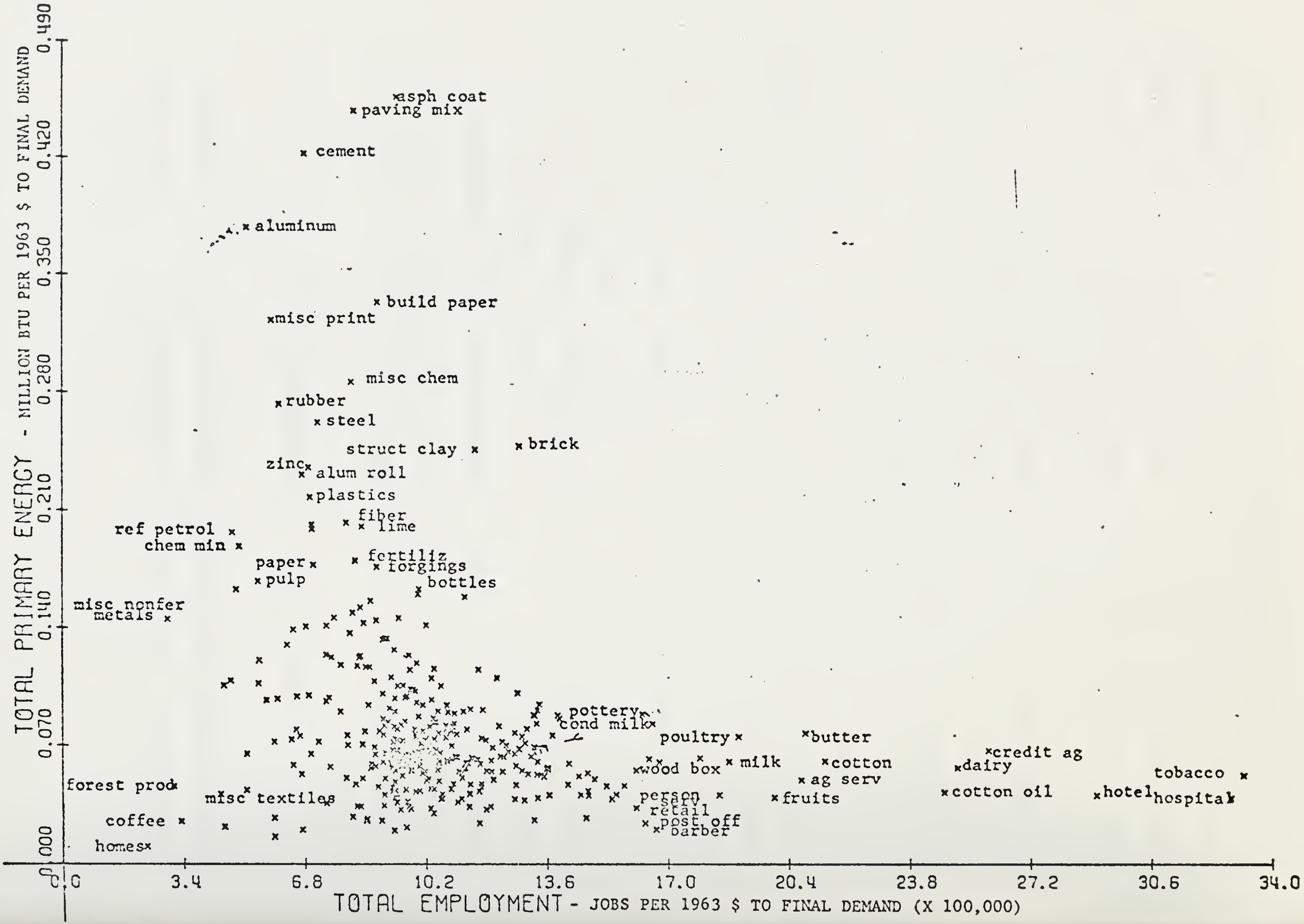
Because of the low cost of energy (only 3.6 per cent of producers' price in 1963), it is presumed by many that industries simply do not strive to use energy efficiently in their production processes. Compelling arguments for this point of view are made by Charles Berg, 1972, who claims that about 25 per cent of the total U.S. energy use could be saved through efficiency.

The most ubiquitous energy increase in industrial processes is believed to have occurred via automation, that is, by the displacement of labor from the production process. The ratio of production workers' wages to the cost of electricity increased by 225 per cent from 1951 to 1969 (Bureau of Labor Statistics, 1972 and Edison Electric Institute, 1970). During that time, the wholesale price index for electrical machinery increased by 50 per cent (Department of Commerce, 1971). These factors indicate the pressure on decision-makers to eliminate the increasingly expensive worker from industrial processes and substitute machines--which increases the energy-intensity of a process. Thus energy productivity is sacrificed to increase labor productivity.

We have examined automation in some detail, with the method described above. Figure 1 shows the amounts by which energy use and employment will change throughout the economic system if a given industry's delivery to final consumption increases by one dollar. While a large proportion of the industries are centrally clustered, there are some very energy-intensive ones--asphalt coatings and asphalt paving, cement, primary aluminum, building paper, and chemicals--and some very labor-intensive ones--hospitals, hotels, credit agencies. (The calculations were made with the Department of Commerce's 1963 figures (Department of Commerce, 1969). The figure does not include the multiplier effects of the expenditure and is therefore inappropriate for use in an impact analysis.)

Another way to consider the problem is to examine the effects of a ten per cent proportionate growth in a given sector, with an offsetting decrease prorated among the other sectors in proportion to their share of deliveries to final consumption. See Figures 2 and 3. Thus, the economy's Gross National Product is unchanged, and the net multiplier

FIGURE 1. TOTAL (DIRECT AND INDIRECT) ENERGY VS EMPLOYMENT INTENSITIES FOR 362 SECTORS IN 1963.
SOURCE: CAC ENERGY - EMPLOYMENT POLICY MODEL FEBRUARY 1973.



ABSORBED FROM ALL OTHER INDUSTRIES, FOR 362 SECTORS IN 1963. SOURCE: CAC ENERGY-EMPLOYMENT POLICY MODEL, FEBRUARY 1973.

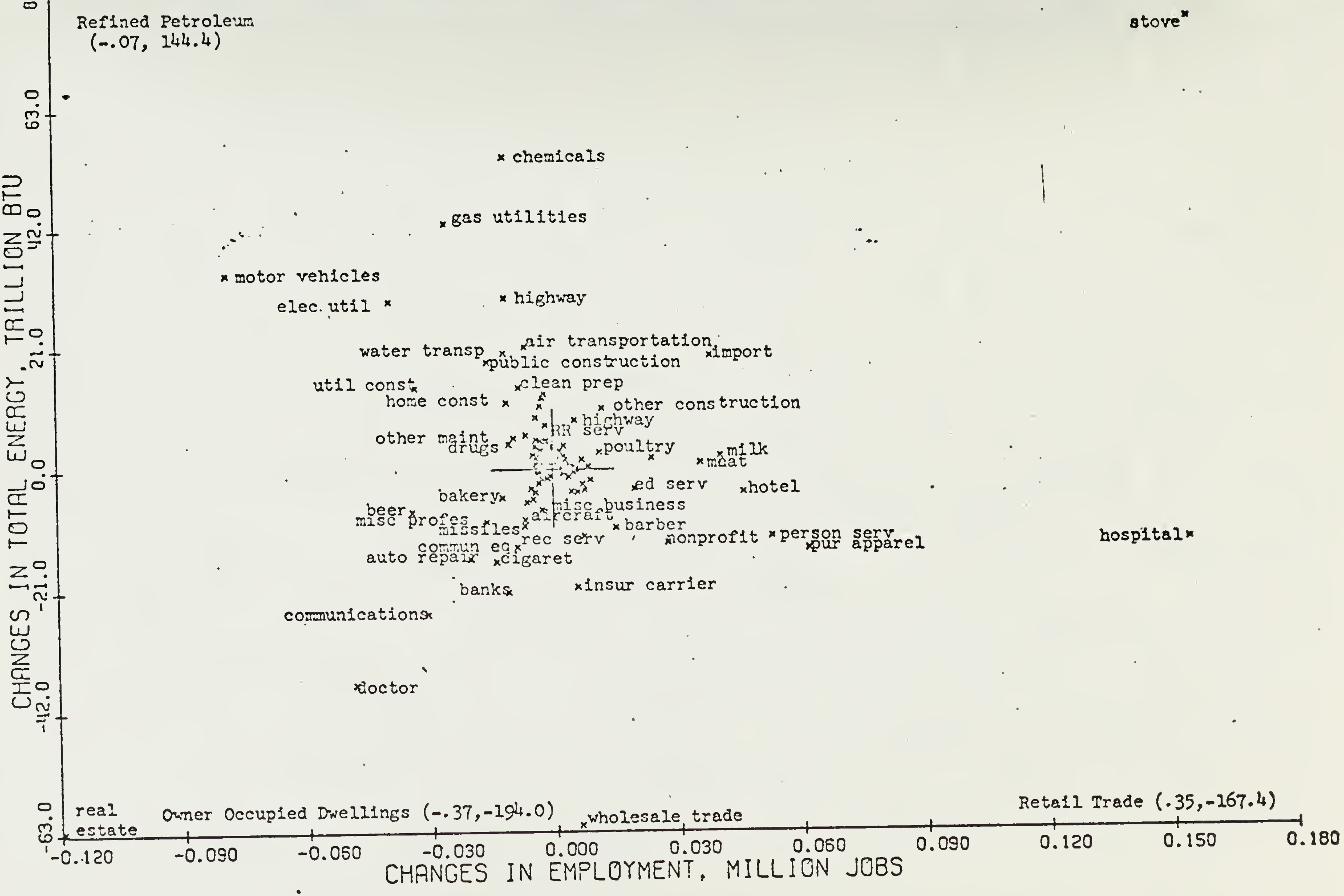
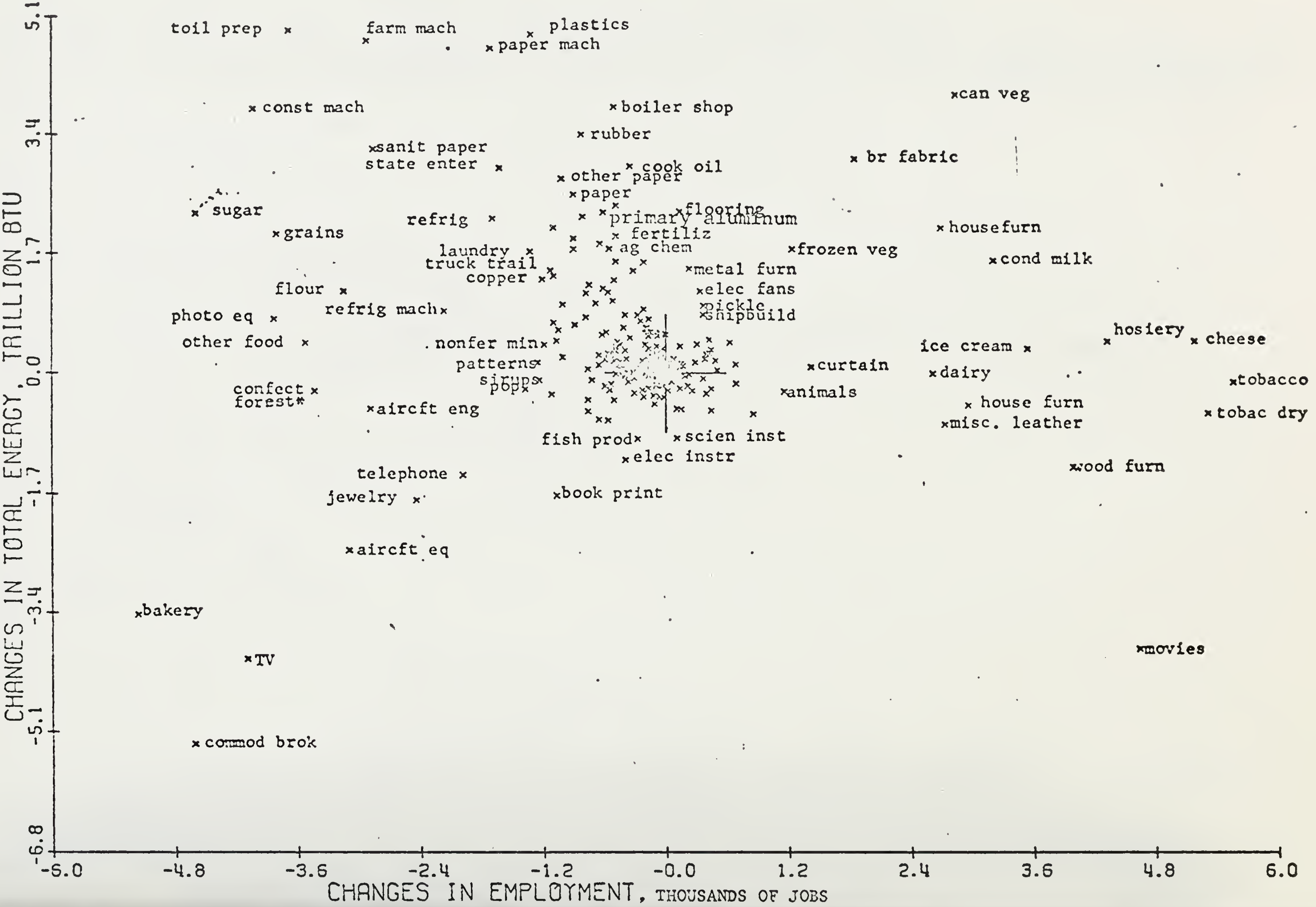


FIGURE 3. CHANGES IN TOTAL ENERGY AND EMPLOYMENT FOR A 10% GROWTH IN THE NOTED INDUSTRY'S DELIVERIES TO FINAL DEMAND AND A PROPORTIONATE DECREASE IN THE DELIVERIES OF ALL OTHERS FOR 362 SECTORS IN 1963. AN ENLARGEMENT OF THE CENTER PORTION OF FIGURE 2. SOURCE: ENERGY-EMPLOYMENT POLICY MODEL, FEBRUARY 1973.



effect is assumed to be non-existent. In the illustration on pages 7 & 8 industries in the upper right quadrant--those in which a ten per cent growth results in more employment and more energy use--are primarily agricultural. Upper left quadrant industries--less employment, more energy use--include basic material production, fabrics, and construction. Lower left quadrant industries--less employment and less energy use--are service oriented, with high wages and a high degree of technology. Lower right quadrant industries--less employment, more energy use--are service oriented, without a great degree of special labor saving technology and with low wages. Fifty per cent of the industries fall into the upper left quadrant, indicating that the 1963 economy tends to respond to an increase in production by becoming more energy-intensive and less labor-intensive.

Figures 1, 2, and 3 are addressed to the policy-maker concerned about the question of growth. The numbers reflect the relative dependence of the U.S. society in 1963 on each of its industries. For example, a 10 per cent increase in delivery to final demand by "motor vehicles" would have required--throughout the economy--an energy use increase, directly and indirectly, of 34 trillion B.t.u., and a decrease in employment, directly and indirectly, of 104,000 jobs. A 10 per cent increase in deliveries of postal services to final demand would have reduced energy consumption by about 4 trillion B.t.u. and increased employment about 36,000 in 1963.

A problem with this approach is the assumption that one industry's gain in delivery to final demand is absorbed by proportionate losses in all other industries. Actually, the product of a given industry competes with only a few other products--for example, aluminum with steel and wood as structural members, steel with glass and plastic as food containers.

If one industry's gain were at the expense of a few competing industries, the complexion of the illustration would change. Suppose, for instance, that a one-billion-dollar gain in primary aluminum deliveries was obtained at the expense of an identical loss in steel deliveries. Then, using Figure 1, energy use would increase by about 116 trillion B.t.u. (about 0.2 per cent of the U.S. total and employment would decrease by 15,000 jobs (about 0.3 per cent of the total). A one-billion-dollar gain in primary aluminum deliveries at the proportional expense of all other industries would produce, according to Figure 3, an increased use of energy of 332 trillion B.t.u. and a loss of 65,000 jobs.

The results so far indicate that most U.S. industries are trading labor for energy (becoming more energy-intensive, less labor-intensive) as they grow. Such industries, as well as their competitors, can be identified through the use of our models. Thus, if economic growth is desired, it can be guided so as to minimize the impact on energy use and maximize employment demands. In any event, the model clearly provides an estimate of the total energy and employment impact of shifts in demands. We, of course, can examine specific competing products (e.g., food, transportation modes) and family incomes, government budgets, etc., for their energy and employment imports.

III. THE MODEL APPLIED TO TRANSPORTATION RESEARCH

As the growth in demand for energy becomes greater than the growth in supply, the concerned public and policymaker alike are taking a keener look at the efficiency of the energy-intensive sectors of our modern society. One of the most fruitful areas appears to be the use of energy for transportation.

The approximate distribution of United States energy use by selected transportation categories is shown in Table 1.

Directly and indirectly, all modes of transportation consume approximately 41.8 percent of the total energy consumed in the United States (1963). We estimate that about one-quarter of the U.S. work force is denoted to transportation. Automobiles consume almost one-half of the total energy (12.5% of all U.S. employment) used for transportation. The direct energy is the fuel used by the engine of the vehicle. Indirect energy is that needed to refine and sell the fuel and oil, to make and sell the vehicles, tires and spare parts, and to provide maintenance, roads, garaging, parking insurance and financing.

Table 1 shows that approximately 17 percent of the total United States transportation energy is consumed directly as fuel by urban automobiles. This is a direct consumption by the urban automobile of approximately 7.1 percent, or a total consumption of 12.3 percent of all the annual United States energy consumtpion. In comparison, the urban (and suburban and school) bus consumes approximately 0.33 percent of all the direct energy used for transportation in the United States annually. This is a direct consumption by urban buses of 0.14 percent, or a total consumption of 0.24 percent, of the total annual United States energy.

Transportation Category		Percent of All Transportation Energy	Percent of All U.S. Energy
Total Transportation Used ..... (1963)	Directly	55.3[d]	23.1[c]
	Directly and Indirectly	100	41.8[c]
All U.S. Autos Used ..... (1963)	Directly	28.5[e]	11.9[c]
	Directly and Indirectly	49.5[f]	20.7[c]
All Urban Autos Used ..... (1971)	Directly	17.0[g]	7.1[h]
	Directly and Indirectly	29.4[j]	12.3[i,r]
All Urban Buses[b] Used ..... (1971)	Directly	0.33[k]	0.14[l]
	Directly and Indirectly	0.58[n]	0.24[m,s]

a. Total refers to the sum of direct and indirect energy.

b. This includes urban, rural, and school buses (not intercity).

c. Herendeen (1973).

d. Assumes that transportation and the CNP have similar indirect energy. intensities (55.3% = 23.1/0.418).

e. (28.5% = 11.9/0.418)

f. (49.5% = 20.7/0.418)

g. (17.0% = 55.3 x 0.307[q])

h. (7.1% = 17.0 x 0.418)

i. (12.3% = 7.1/0.577)

j. (29.4% = 12.3/0.418)

k. (0.33% = 0.006[q] x 55.3)

l. (0.14% = 0.33 x 0.418)

m. (0.24% = 0.14/0.577)

n. (0.58% = 0.24/0.418)

p. The ratio of all auto direct enrgy to total transportation direct enrgy was 0.515 in 1963 and 0.571 in 1972[c].

q. Goss and McGowan (1972).

r. Assumes that urban autos and average autos have similar indirect energy intensities.

s. Assumes that buses have similar indirect energy intensities to average autos.

Table 1. Approximate percentage distribution of annual direct and total[a] United States energy used by selected transportation categories.

Clearly the automobile dominates urban passenger transport energy comsumption and is a major single consumer.

2. General Results

The dollar, energy and employment cost of various competing modes of transportation are compared in Table 2. As in the previous table, these data account for the entire system associated with the particular transport mode. Thus for example, the total energy cost of the intercity car contains the energy used to make and supply the car and its spare parts and the highway and all the materials which went into their making, the energy to make and supply the fuel (and the fuel energy) and the energy to provide the services of maintenance, police, garaging, parking insurance, financing, etc.

From Table 2 we see that flying is a relatively energy intensive process whether it is used for passengers or freight. Cars are more energy intensive than buses, trucks than trains and barges. In general the slower, the less energy intensive (energy use varies mainly as the square of the velocity).

Note that these data are the average of the mode as it existed in 1971. The cost intensity will vary over the range of use. For example trains in direct competition with inland barges are about 20% more energy efficient when circuitry (deviations from great circle distances) and specific freight origins and destinations are considered.

TABLE 2. SELECTED RESULTS ON THE TOTAL DOLLAR, ENERGY, AND LABOR IMPACTS OF CONSUMER OPTIONS IN TRANSPORTATION, 1971.

TRANSPORTATION

To move a million passengers one mile by...	Requires			
- Intercity	Load Factor	Thousands of Dollars (1971)	Million BTU of Energy (% direct)[1]	Jobs
Car	2.9 people	55	5,900 (51)	3.7
Plane	53% full	58	9,800 (73)	3.8
Bus	47% full	39	2,700 (51)	3.1
Train	37% full	44	4,000 (58)	7.2
- Interurban Electric Commuter Railway[2]	31% full	128	9,900 (11)	8.5
- Urban				
Car	1.9 people	69	8,900 (58)	4.2
Bus	12.0 people	105	5,300 (57)	8.3
Motorcycle	1.1 people	57	4,200 (49)	1.55
Bicycle	1.0 people[3]	26[3]	1,300 (59)[3]	1.7[4]
Walking	1.0 people	NA	710 (51)	0.7
To move one million ton of freight one mile by...	Circuity			
Air	1.1	200	80,000 (69)	37.0
Rail	1.2	16	1,600 (51)	1.4
Truck[5]	1.2	99	5,300 (49)	10.3
Barge	1.7	3	1,600 (48)	0.6

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[1] vehicle transportation fuel only.

[2] The "PATH" commuter system, New York--New Jersey, 1971.

[3] Hirst, Eric, NSF-EP-65, Oak Ridge National Lab.

[4] CAC estimate based on NSF-EP-65.

[5] Class I General Freight.

Trains in direct competition with trucks ("piggyback" operations) are more energy intensive than the average cited in Table 2.

Note that the urban bus is less energy intensive but more dollar expensive than the urban car. This pair and the competing freight modes are compared in more detail below.

b. Application to Urban Car-Bus Substitution

Using auto data from 28 cities and data from 38 bus companies (Hannon and Puleo, 1974) in the Energy-Employment model, we computed the average total dollar, energy and labor costs for the four main purposes of auto travel and for average bus travel. We then used a simple passenger transfer model (assuming constant bus costs per passenger) and computed the change in these costs under two separate transfer scenarios.

First, we assumed the average car passenger switches to the bus and sheds the entire auto expense. This would be the long term result or the result if an individual sold their second car; for example, used only to get to work, and took the bus to their job, and if land use patterns changed such that the residence-work area of the present average car user became identical to that of the present average bus user. The net changes in cost are shown in Table 3. In brief, the average passenger would save money if they switched to the bus for work and recreational trips and lose small amounts of money on the business and educational trip uses of the bus. All transfers saved energy. Labor cost changes varied with the dollar cost changes.

Second, we assumed that an individual wishes to transfer some of his trips from car to bus, and keep his car for the remaining purposes. The net changes in cost are shown in Table 4. Dollar costs increased for

TRIP PURPOSE	DOLLAR	ENERGY ($BTUx10^6$)	LABOR ($JOBSx10^{-3}$)
Work	+302.542	+ 64.751	+16.516
Family Business	- 30.178	+ 22.920	- 6.065
Education	- 53.882	+ 3.287	- 5.169
Recreation	+169.002	+ 49.144	+ 7.275
Weighted Average	+338.634	+139.122	+ 8.465

Table 3: Total DEL Decrease (+) Per Car Per Year, Nationwide Transfer 1971.

Source: Hannon and Puleo, 1974.

TRIP PURPOSE	DOLLAR	ENERGY (BTUx10^6)	LABOR (JOBSx10^{-3})
Work	- 14.72	+ 49.68	- 5.43
Family Business	-186.46	+ 15.50	-16.88
Education	- 92.17	+ 1.47	- 7.82
Recreation	- 91.21	+ 36.78	-10.72

Table 4: Individual Transfer DEL Cost Decrease (+) Per Car-Year, 1971.

Source: Hannon and Puleo, 1974.

every purpose, energy use decreased and employment increased. Thus we find the transportation dilemma in the urban area. That is, the equilibrium transfer system is less dollar, energy and labor expensive but no one will likely pay the dollar cost which must be overcome to get started. We have calculated that the price of auto gasoline would have to rise to 93 cents per gallon (1971) or bus ridership increase 77 percent (from an average of 12 to 21 passengers per bus) before the individual auto passenger would become economically indifferent.

Another problem arises with the question of what a consumer might do with any dollar savings resulting from the transfer to a bus. A method for approaching this question which is largely behavioral in nature, is developed in Tables 5 and 6. In Table 5 we compute (from Tables 3 and 4) the energy and job savings intensity (BTU or jobs per dollar saved) in the transfer process. In Table 6, we present the results of applying our model to the various activities of personal consumption to determine their total energy and labor intensities. For example, as long as the average former auto passenger doesn't spend his dollar savings (410,830 BTU per dollar) on electricity or gasoline and oil, he will save energy in the transfer to buses. Suppose he spent it on "furniture" which has a total energy intensity of 36,664 BTU per dollar. Then his net energy savings intensity is 374,200 BTU for each dollar saved.

c. Application to Intercity Freight Movement

The operation of vehicular freight carriers (barge, train, truck) have been examined for flexibility, costs, subsidies, regulation and resource demands (Hannon, 1974 b). The conclusion reached was that trains compete with both barge and truck but the latter two do not compete with each other.

TRIP PURPOSE	NATIONWIDE CHANGE		INDIVIDUAL TRANSFER	
	ENERGY (BTU/DOLLAR)x10^{3})	LABOR (JOBS/DOLLAR)x10^{-6})	ENERGY (BTU/DOLLAR)x10^{3})	LABOR (JOBS/DOLLAR)x10^{-6})
Work	+214.02	+ 54.59	-337.50	+368.89
Family Business	-759.49	+200.97	- 83.13	+ 90.53
Education	- 61.00	+ 95.93	- 15.95	+ 84.84
Recreation	+290.79	+ 43.05	-403.25	+117.53
Weighted Average	+410.83	+ 24.99	-230.36	+102.94

Table 5: Energy and labor impacts per dollar for a nationwide change and individual transfer for 1971 (decrease is +)

Source: Hannon and Puleo, 1974.

Personal Consumption Expenditure Sector Description	Energy Intensity BTU/$	Labor Intensity Jobs/$
Electricity	502,473	0.04363
Gasoline and oil	480,672	0.07296
Cleaning preparations	78,120	0.07332
Kitchen and household appliances	58,724	0.09551
New and used cars	55,603	0.07754
Other durable house furniture	45,593	0.08948
Food purchases	41,100	0.08528
Furniture	36,664	0.09176
Women and children's clothing	33,065	0.10008
Meals and beverages	32,398	0.08756
Men and boys clothing	31,442	0.09845
Religious and welfare activity	27,791	0.086365
Privately controlled hospitals	26,121	0.17189
Automobile repair and maintenance	23,544	0.04839
Financial interests except insurance co.	21,520	0.07845
Tobacco products	19,818	0.05854
Telephone and telegraph	19,043	0.05493
Tenant occupancy nonfarm dwelling	18,324	0.03502
Physicians	10,271	0.03258
Owner occupancy nonfarm dwelling	8,250	0.01676

Table 6: The Energy and Labor Intensity of the Largest Twenty (Dollarwise) Activities of Personal Consumption Expenditures, Ranked in Order of Decreasing Energy Intensity, 1971. Source: Hannon & Abbott, 1974.

Truck-train competition is reaching equilibrium while barge-train competition continues. Trains are substantially outsubsidized relative to the other two modes. Rail companies have an unattractive financial status. Yet rail energy demands are the smallest for any mode on a freight ton-mile basis. Employment requirements of the three modes vary generally with the freight costs. Trucks are most sensitive to the dollar cost of fuel; water transport is slightly less sensitive than train transport.

Flexibility, as represented by average speed and range, is generally regarded as a measure of competition. Another measure of competition is the average revenue per ton mile, provided it is an accurate assessment of all expenses. Still another measure is the total right-of-way network length and circuity. These measures are shown in Table 7 for barge, rail, and truck freight. The cost range between modes is sizeable, but barge costs do not include any right-of-way costs, and truck costs include approximately half to three-fourths of their allocated amount of right-of-way costs. Rail costs reflect private ownership of the right-of-way, including right-of-way taxes. It is not known how much these costs are influenced by the large land subsidies given, more than a century ago, to the railroads, particularly in the West. Since the costs do reflect the scale of the average speeds and geographic intensity of the right-of-way network, it is somewhat surprising to find that the railroads haul farther on the average than the slower barges. The more flexible trucks haul about half as half as far as rail on the average, at twice the average speed. Trucks, characteristically moving "overnight" distances, are well suited to the recent dispersion of industry along the interstate system. Offsetting, to some extent, the large difference in cost of hauling between the three

	Barge(a)	Rail(c)	Truck(c)
Speed(b), Miles/Hour	6	20	40
Haul Distance, Miles	330	490	260
Miles of Right-of-Way	25,000	335,000	920,000(d)
Circuity(e)	1.70	1.25	1.20
Revenue, (Cents) Per Ton Mile	0.29	1.35	7.21

(a) Inland Barges; includes intra- and inter-coastal and Great Lakes movement.

(b) Average route speed: includes waiting for locks, "slow orders," etc. Barge speed is upstream-downstream, loaded-unloaded average on Mississippi and Ohio Rivers.

(c) Class I railroads and Class I intercity trucks.

(d) Primary and secondary federal-aid only.

(e) Average deviation from great circle distance.

Table 7. The Average Speed (1970), Range (1970), Miles of Right-of-Way (1971), and Revenue (1969) Per Ton Mile for Intercity Barge, Rail and Truck. Source: Hannon, 1974b.

modes is the fact that inventory and warehousing costs are generally smaller for the faster modes. Small inventories, however, have the disadvantage of being especially sensitive to resource shortages, for example, a fuel shortage which would affect freight deliveries.

The numbers in Table 1 are, of course, averages and do not reflect the detail of modal competition which prevails in specific areas. Table 1 is intended to allow a relative ranking of the modes. In general, it appears that both barge and truck compete with rail, but not with each other. Barges are competing with rail on the long haul commodities such as minerals and grain, while trucks have already taken most of the shorter haul rail deliveries. From 1960 to 1970, the intercity haul distance by barges increased 16 percent, by rail it increased 11 percent, and by truck it decreased 4 percent (U.S. Department of Transportation, 1972, pp. 25, 30, 35, indicating again that barges and trains are competing for unit long-haul operations, and that train and truck competition has probably reached equilibrium. This arrangement is further indicated by the increasing number of trucks traveling by rail (Association of American Railroads, 1973a, p. 36). Such an arrangement is probably not the most energy-efficient rail hauling process since these "piggyback" trains run especially fast, have higher than normal wind resistance, and have lower than normal cargo-to-gross weight ratio. Trains sometimes act as feeder lines for barges, and trucks occasionally perform this role for both of the other modes. Truck-barge or truck-rail combinations sometimes act to compete with the remaining mode.

We have applied the model to each transportation mode by first determining the fractional breakdown of the dollar cost of a ton-mile of freight. These categories included purchases of fuel, machinery, buildings, equipment and right-of-way maintenance, insurance, financing, right-of-way construction, etc. These values must be deflated to the year 1963 and identified with the appropriate sector in the model. The dollar values in each sector are then simply multiplied by the energy multiplier from the model (direct fuel energy is tabulated directly from user data) and summed to the total direct and indirect energy per ton-mile of freight by that particular mode. The results are given in Table 8. The truck freight system is obviously more expensive than the rail freight system, per ton-mile. These cost differentials reflect the truck system's greater flexibility and speed. They also demonstrate the effects of air drag and the stronger railroad labor union and circuity.

It is apparent that initially a move from truck to rail shipping would save energy, reduce dollar cost, and reduce employment. Some of the dollar cost reduction would probably be required to build, operate, a and maintain expanded railroad terminal facilities. Nevertheless, the following calculations are instructive. Assuming that average and marginal costs per ton mile are equal, and that the cost difference shown in Table 2 persist throughout the change period, about $28 billion dollars would have been freed in 1971 had all intercity truck freight moved by rail. Under the same assumption about costs, the switch to rail would have saved about 190 million barrels of oil (energy equivalent) in 1971, and disemployed about 450,000 workers. If the $28 billion was absorbed as a federal tax and spent on railway construction (Bezdek and Hannon, 1973), the net savings from the shift of truck freight to rail would be 10 million barrels of oil (energy equivalent) per year, and a net increase of 1.6 million jobs.

From Table 8 we find that if all barge traffic had moved by rail, freight cost would have increased about $4 billion per year. Assuming this cost increase was passed through to the consumer (Sebald and Herendeen, 1973) and reduced his general expenditures proportionately, energy use would have decreased about 48 million barrels of oil (energy equivalent) per year, and 130,000 jobs would have been lost, in 1971.

Table 9 shows the freight modes' sensitivity to the dollar value of energy in 1963. From Table 3 we see that the three transport modes spend most of their energy dollar on refined petroleum. The second most important energy source in terms of dollar cost is electricity, followed by natural gas and coal. Railroads paid slightly more for all energy forms than did water transport, and trucks paid substantially more than railroads. As an example of using the information in Table 9, suppose that the price of refined petroleum doubled, and all price increases were fully passed on to the consumer. Then the consumer of water transport services would see a 3.6 percent increase, the consumer of railroad services would see a 3.8 percent increase, and the consumer of motor freight services would see an increase of 4.8 percent, in dollar costs. Thus, trucks were 25 percent more sensitive to the producer's price of refined petroleum than were railroads and railroads were 7 percent more sensitive than water transport. Note that here, water transport includes ocean going vessels. The dollar cost of energy for inland water transport is probably higher than shown in Table 9 due to the lack of streamlining of barges, and the relatively small loads per barge tow. I conclude, therefore, that inland barges and railroads are about the same in sensitivity to energy prices.

Mode	Cost or Revenue, Cents	Total Energy Use	Total Employment Demand
Truck[(c)]	8.0	5200	10.3
Rail Freight[(b)]	1.6	1600	1.4
Barge[(d)]	0.3	1600	0.6
Truck/Rail Ratio	5.0	3.3	9.0
Barge/Rail Ratio	0.2	1.0	0.4

(a) Costs are: Dollars and energy: Cents and Btu per ton mile; Employment, man-years per million ton miles. Employment does not include household or government industries. All costs are for services given between mode terminals only. Note that these data are the average for the entire mode.

(b) The railroad companies which compete directly with the barges are somewhat (1330 Btu/TM) more energy efficient than barges. The trailer train, hauling trucks ("piggyback"), competes directly with long-distance highway trucking, and is substantially less energy efficient than the average for rail shown above.

(c) Dollar cost: American Trucking Associations, Inc. (1973). Energy and Labor costs: Penner (1974). Does not include full right-of-way costs.

(d) Does not include right-of-way cost. Barge circuity is 38 percent greater than rail and the above barge costs were increased accordingly to compare with truck and rail.

Table 8. A comparison of the Estimated Average Dollar, Energy and Employment Costs (a) of the Freight Transport Modes Using Intercity Highways or Railroads for 1971. Source: Hannon, 1974b.

Fuel Type	Water Transport[b]	Railroads[c]	Motor Freight[d]
Coal	0.16	0.18	0.09
Crude Oil	1.84	1.94	2.40
Refined Petroleum	3.55	3.79	4.75
Electricity	0.73	0.70	0.82
Natural Gas	0.51	0.53	0.47
All Energy[e]	5.07	5.45	6.33

(a) Values do not include taxes.

(b) Includes ocean going vessels.

(c) Includes all classes of railroads, passenger and freight.

(d) Includes all trucks, urban and intercity.

(e) Double counting, i.e. counting the cost of electricity which includes say, the cost of coal input, and then adding on the cost of coal, is avoided.

Table 9. Total (Direct and Indirect) Dollar Values[a] Expended for Energy of Various Types per Dollar of Services Delivered to Final Consumption by Water Transport, Railroads and Motor Freight, in Cents per Dollar, 1963. Source: Hannon, 1974b.

d. Policy Application: Alternatives to the Highway Trust Fund

The direct and indirect dollar, energy, and employment costs of reinvesting the $5 billion (1975) Highway Trust Fund in six alternative federal programs were determined using the energy-employment model (Bezdek and Hannon, 1973). These alternative programs are: Railroad and Mass Transit Construction, Educational Facilities Construction, Water and Sewer Facilities Construction, the Law Enforcement Program, National Health Insurance Program, and Tax Relief Program.

Energy consumption would be reduced by shifting the Highway Trust Fund to any of these categories except the Tax Relief Program. Employment would be increased in all cases. Energy consumption impact by type of energy are presented and employment impact by occupation for the shift to rail construction is shown.

Model Application

The first step in simulating the net employment impacts of alternative uses of the Highway Trust Fund required projecting broad economic parameters and control data to 1975 to provide an economic framework for simulation. This required projecting gross national product, capital investment, rates of price change, and other aggregate economic variables on the basis of regression analyses of time series data on these variables for the postwar period. We estimated that by 1975 the size of the Highway Trust Fund was likely to be about $5 billion. While this estimate may turn out to be somewhat in error, the point is that we were concerned here with determining the energy and manpower effects of reallocating a specified level of funds from highway construction to other uses.

To generate the direct output requirements of $5 billion of expenditures on each of the seven program alternatives considered here, we utilized the appropriate "final demand" vectors from the 1975 version of the CAC Energy-Employment Policy model. Each of these vectors showed how funds devoted to each program were likely to be distributed as direct output requirements in the near future. Since the base year of the model is presently 1958, expenditures on each type of program had to be first translated from current (1975) dollars into 1958 constant dollars via separately derived price deflators. Once this was done a separate manpower impact simulation was conducted for each program alternative. Each simulation showed how $5 billion dollars allocated to a specific program was likely to be translated into direct and indirect occupational manpower requirements in the near future.

The program alternatives considered here can be interpreted in a straightforward manner. Four of them--Highway Construction, Railroad and Mass Transit Development, Educational Facility Construction, and Water and Waste Treatment Facilities Construction--refer to different types of construction programs. Criminal Justice and Civilian Safety refer to public expenditures on all types of law enforcement and criminal justice programs, while National Health Insurance pertains to a comprehensive federal program of direct medical assistance payments. The simulated tax relief alternative was developed assuming an across-the-board tax cut equal to the size of the Highway Trust Fund and proportioned among the different detailed categories of personal consumption expenditures. In developing this latter alternative we assumed that the marginal propensity to consume for the tax rebate would be equal to one and that the funds would be spent proportionately among detailed personal consumption goods and services.

At the time our research was being conducted the necessary data were not yet available which would permit us to project the energy input coefficients to 1975. To determine the likely direct and indirect energy requirements of each of the program alternatives we had to utilize the energy components of the model developed at the 367 level of industry detail for 1963. First we aggregated the energy matrix to match the 90-order sector detail of the activity-industry matrix. Then, using the distribution of the total inputs to each activity, we determined the energy intensity (BTU/$) of each specified program alternative by multiplying the total primary (direct and indirect) energy vector by the activity-industry vector. We next deflated the projected $5 billion 1975 Highway Trust fund to 1963 prices to convert it into the constant dollar units of the energy matrix. Finally, we estimated the total energy cost of the expenditures on each program alternative by multiplying the deflated expenditures on each program times the total energy intensity of that activity. This step completed our simulation of the energy and employment effects of the Highway Trust Fund and of various alternatives.

Before discussing the empirical results of this study it is important to note the assumptions involved in our analysis. First of all, the input-output model assumes that all industries possess a linear homogeneous production function and exhibit constant returns to scale. Our approach thus implies that output, energy and manpower requirements will change proportionately with the level of production in each industry. Second, we assume that an increase or decrease in spending on any of the programs will not change the distribution of expenditures on the program inputs and, analogously, that any change in total employment requirements for an industry will be reflected in proportionate changes in demand for the occupations employed within that industry. Especially for some programs and certain industries this is a very strict assumption, but the incorporation of comprehensive nonlinear relationships into our model was not feasible. Finally, the employment concept used here is short run and does not include any employment effects which may arise indirectly from the expenditure shifts simulated. Thus, for example, while our analysis allows us to estimate the change in manpower requirements likely to result from transferring $5 billion from highway construction mass transit development, we make no attempt to estimate here the net occupational effects which may come about as commuters begin to shift to mass transit from automobiles.

Results

The estimated energy and employment impact of the Highway Trust Fund and the six program alternatives to it are summarized in Table 10. For every program alternative to Highway Construction except the Criminal Justice Program, energy requirements decrease. If the funds are spent on Railroad and Mass Transit rather than Highway Construction, the total primary energy demands would be about 62 percent lower, mainly because of significantly lower steel and concrete usage. But if the reduction in the Highway Trust Fund is used to provide Criminal Justice and Civilian Safety, then energy demands would increase about three

FEDERAL PROGRAM	BTU[b] per $(1963) of PROGRAM	TOTAL ENERGY-TRILLION BTU	% DECREASE[c]	JOBS PER HUNDRED THOUSAND $(1975) OF PROGRAM	TOTAL JOBS	% INCREASE[c]
HIGHWAY CONSTRUCTION	112,200	409.53	-----	8.1	256,180	-----
R.R. AND MASS TRANSIT CONSTRUCT.	43,100	157.32	+61.6	8.4	264,430	+ 3.2
WATER AND SEWER FACIL. CONSTRUCT.	65,400	238.71	+41.7	8.2	259,490	+ 1.3
EDUCATIONAL FACILITIES CONSTRUCT.	70,600	257.69	+37.1	8.5	268,980	+ 4.7
NATIONAL HEALTH INSURANCE	40,400	147.46	+64.0	13.4	423,220	+65.2
CRIM. JUSTICE & CIVILIAN SAFETY	118,500[a]	432.53	- 3.4	12.4	393,520	+53.6
PERSONAL CONSUMPTION EXPENDITURES (Tax Relief)	86,000[e]	313.90	+23.4	8.7	275,120	+ 7.4

(a) Includes energy to provide offices and supplies for government workers.
(b) British Thermal Units.
(c) Percent changes are relative to highway construction program.
(d) 1975 dollars. This amount is equal to $3.65 Billion in 1963 and $3.165 Billion in 1958 dollars. Calculated with the ERG Energy and Employment Policy Model, July, 1973. No attempt was made to correct for the technological impact on energy use efficiency between 1963 and 1975. It is generally expected that 1975 technology will be more energy intensive.
(e) Includes Direct Energy purchases, trade and transportation margin's energy and labor demand.

Table 10. The Energy and Employment Impact (Direct and Indirect) of a $5 Billion[d] Investment in 7 Federal Programs
Source: Bezdek and Hannon, 1973.

percent relative to Highway Construction. This increase is due primarily to a substantial amount of office heating and lighting and to gasoline use in patrol cars. Spending the Highway Trust Fund for the Construction of Water and Waste Treatment Facilities reduces energy requirements by 42 percent; spending it for the construction of Educational Facilities decreases energy demands by 37 percent; while reallocating it to a National Health Insurance Program or to a Tax Relief Program decreases energy requirements by 64 percent and 23 percent, respectively.

The effects on total employment requirements can be read in a similar manner from Table 10. Here we see that each of the program alternatives considered generate higher total labor requirements. The net job creating advantage of some programs, such as Railroad and Mass Transit Development and Waste Treatment Plant Construction, is likely to be quite low (three percent and one percent, respectively); while the increase in total employment resulting from a reallocation to other programs, such as National Health Insurance or Criminal Justice and Civilian Safety, is likely to be substantial. The results of Table 10 should thus be of special interest to federal executives and legislators concerned with energy and manpower policies. It is clear that certain programs have low energy and high employment demands relative to Highway Construction. All of the alternative construction programs are less energy and more labor demanding.

For manpower policy, however, it is important to break down the aggregate employment shifts listed in Table 10 into the net effects upon demand for specific occupations, jobs, and levels of skill. The net positive and negative effects of one of the simulated program alternatives upon selected categories of manpower resources is in Table 11. This table summarizes the major net occupational manpower shifts likely to result from transferring Highway Trust Fund monies to The Railroad and Mass Transit Construction alternative. The occupational changes in this table were weighted by the total forecast 1975 U.S. employment in that occupation, and ranked in descending order of impact for each program alternative.

Table 12 shows the direct and indirect energy demand for the four basic types of energy created by the seven federal spending options of 5 billion 1975 dollars. A Personal Consumption dollar provides the major demand for electricity. Water and Sewerage Construction is the most coal demanding, probably because of a relatively high consumption of basic structural steel (coke). The Criminal Justice Program is the largest, or nearly the largest, consumer of all energy forms, although Highway Construction is the leading consumer of refined petroleum, through cement manufacturing. National Health Insurance is the third major user of electricity (to run small machines, air conditioners, and lighting). Most (77 percent) of the Health Insurance funding goes into the highly labor intensive medical services sector. Highway Construction is also a major consumer of natural gas, again probably due to cement manufacturing. Personal Consumption and Educational Facilities Construction require a very diverse range of products. It is therefore difficult to make a priori estimates of the energy use in these three categories, as it is almost all consumed indirectly by the many industrial and commercial sectors involved.

The central conclusion is that if the Highway Trust Fund were diverted into Railroad and Mass Transit Construction, energy demands

Table 12

Direct & Indirect Energy Use by Type[a] for a $5 Billion (1975) Expenditure on 7 Alternative Federal Programs[c]
Source: Bezdek and Hannon, 1973.

	Coal (Million Tons)	Refined Petroleum (Million Gallons of Gasoline Equivalent)	Electricity (Billion Kilowatt-Hrs.)	Natural Gas (Billion Cubic Feet)
Highway Construction	2.58	2157	4.31	81.0
Mass Transit Construction	1.64	362	3.35	64.5
Water & Sewer Construction	3.41	680	3.45	63.0
Education Construction	3.10	797	4.52	74.0
National Health Insurance	1.47	682	4.40	47.1
Criminal Justice[b]	3.42	1841	5.16	117.6
Personal Consumption[d]	2.48	1213	6.15	93.7

(a) Coal, 26 million BTU per ton; Gasoline, 125,000 BTU per gallon; Electricity, 3412 BTU per kilowatt-hour; Natural Gas, 1034 BTU per cubic foot.

(b) Includes energy to provide offices and supplies for government workers.

(c) No attempt was made to correct for the technological impact on energy use efficiency between 1963 and 1975. It is generally expected that 1975 technology will be more energy intensive.

(d) Includes direct energy purchases, trade and energy demand of the transport margins.

1975 dollars. Personal consumption provides the major demand for all types of energy, except coal, where Waste Treatment Plant Construction is the highest, probably because of a relatively high consumption of basic structural steel (coke). Highway Construction is the largest consumer of refined petroleum primarily through cement manufacturing. National Health Insurance is the second major user of electricity (to run small machines, air conditioners, and lighting). Most (77 percent) of the Health Insurance funding goes into the highly labor intensive medical services sector. Highway Construction is also a leading consumer of natural gas, again probably due to cement manufacturing. Law Enforcement, Mass Transit Construction, and Educational Facilities Construction require a very diverse range of products. It is therefore difficult to make a priori estimates of the energy use in these three categories, as it is almost all consumed indirectly by the many industrial and commercial sectors involved.

would be reduced and employment would rise (even in the construction trades). We can also see from Table 2. that the main (auto-truck) highway users are more energy intensive operations than rail passenger and freight transport. Thus the fund diversion would have a long term energy conserving effect.

IV. CONCLUSIONS

The energy and employment intensities for each of 362 industrial-commercial sectors of the U.S. economy was demonstrated for data from the year 1963, the latest available. These data were updated to 1971 and applied to various modes of freight and passenger vehicular transport.

The entire U.S. transport system accounts for about 42% of all U.S. energy use and about 25% of all employment in the U.S. The auto is responsible for about half of these demands.

Energy demands per unit of service varied for intercity passengers from the highest by plane, then auto, then train, to the lowest, bus, although the energy intensity varies substantially with the load factor. Freight transport energy demands varied from the highest, plane, then truck, to the lowest, barge and rail.

Average car-bus substitution produces increased employment and decreased energy use and dollar cost if land use patterns change from that currently experienced by the average car owner to that currently experienced by the average bus rider. Under this assumption, an individual car user who switches to the bus for some purpose but who retains his car for the remaining uses, will reduce employment and energy use and increase his dollar costs. This lack of dollar incentive to the individual experimenter represents the classic barrier to change to a much less energy resource demanding system. The paradox calls for external regulation to provide the incentive for the timid individual to slowly give up his car for mass transit, the lowest demander of energy resources and the highest demander of employment.

The disposition of the dollars saved by the average car-bus transfer is unknown. He will probably dispose of these savings through some form of increased personal consumption, the total energy and labor demands for which are detailed in this paper. A behavioral model is needed to determine the actual net energy and employment effects.

The financially destitute railroads are found to be the most flexible, competitive and least energy using mode for vehicular freight transport.

The final policy example was the effects on energy and employment use of diverting five billion dollars from the federal interstate highway construction program into each of six alternative federal programs: Railroad and Mass Transit Construction, Water and Sewer Facilities Construction, School Construction, National Health Insurance, Criminal Justice and a Tax Relief Program. Employment would increase under all alternatives and energy use would decrease under all but the Criminal Justice Program. Knowledge of the energy and employment effects should excite the resource and social policymakers as well as the labor union leaders.

Acknowledgement. I wish to thank Robert Herendeen, Roger Bezdek, Clark Bullard, Hugh Folk, Michael Rieber, Anthony Sebald, Peter Penner, Francisco Puleo and Ernest Dunwoody for their contribution to this paper.

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