REPORT NO. DOT-TST-76T-39

TRANSPORT OF SOLID COMMODITIES VIA FREIGHT PIPELINE

IMPACT ASSESSMENT
VOLUME V

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July 1976

FIRST YEAR FINAL REPORT

UNDER CONTRACT: DOT-OS-50119

PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION

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16. Abstract
This report describes findings of research performed during the first year of work under Contract DOT-OS-50119 for the Office of University Research, Office of the Secretary of Transportation. The application of freight pipeline for the movement of solid goods offers a new option in the field of transportation. Thus, the purpose of the first year of research was to evaluate the technical and economic feasibility of freight pipeline as an intercity transportation mode.

The report for the first year consists of the following five separate volumes:

VOLUME I - Cost and Level of Service Comparison
VOLUME II - Freight Pipeline Technology
VOLUME III - Cost Estimating Methodology
VOLUME IV - Demand Analysis Methodology
VOLUME V - Impact Assessment

The second year of research currently is being devoted to sharpening the concepts, broadening the areas of concern and applying the tools of analysis developed in the first year to a specific origin-destination transportation corridor.

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PREFACE

This report describes findings of research performed during the first year of work under contract DOT-OS-50119 for the Office of University Research, Office of the Secretary of Transportation. The application of freight pipeline for the movement of solid goods offers a new option in the field of transportation. Thus, the purpose of the first year of research was to evaluate the technical and economic feasibility of freight pipeline as an intercity transportation mode.

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I.	Cost and Level of Service Comparison	I. Zandi; B. Allen; E. Morlok, K. Gimm; T. Plaut; J. Warner
II.	Freight Pipeline Technology	I. Zandi and K.K. Gimm
III.	Cost Estimating Methodology	Section A: J. Warner and E. Morlok Section B: K. K. Gimm and I. Zandi
IV.	Demand Analysis Methodology	B. Allen and T. Plaut
V.	Impact Assessment	I. Zandi and K.K. Gimm

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The authors wish to acknowledge gratefully the assistance given by Mr. David C. Ryan Jr. of the Office of R & D Policy, Office of the Secretary of Transportation. His numerous technical and editorial suggestions have been of great help to us.

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<u>Impact Assessment</u>

<u>Executive Summary</u>

In order to establish the feasibility of the intercity freight pipeline, it was necessary to assess the impacts of various competing transportation modes.

Time did not allow a full and quantitative analysis of impacts. Instead, these were identified and for each, as much data as was readily available was presented. Based on data presented in this report, it can be stated that, to the extent that a freight pipeline reduces truck traffic, it helps to reduce street congestion, noise, energy consumption, accidents and air pollution. As compared to rail, however, accident and noise reduction are certain, but the impact on energy consumption and air pollution depends on local conditions. The report of the second year of research will examine some of the impacts in more detail.

IMPACT ASSESSMENT

I. Introduction

Freight pipeline is a transportation technology fundamentally different from either truck or rail. Therefore, in satisfying transportation service needs where a freight pipeline would be considered for use in lieu of truck or rail movement, there would be non-monetary consequences which must be taken into account. Thus, there are questions as to what these impacts are, and to what extent they can be expected. These questions may be answered quantitatively when analyzed for a specific transportation system using such information as market location, freight volume, means of access and egress, modal share, and origin and destination points of freight. The work discussed in this report was performed assuming general transportation service needed rather than the specific case of a given system. It aims to identify the major areas of impact. Considerably more work than what was allotted for this task would be needed for a full exposition of all impact issues. Consequently, this report should be considered a very preliminary survey of the major impact issues. Impact questions were explored in a qualitative manner by considering only one extreme case: a transportation system with pipeline line-haul and pipeline access.

II. Full Pipeline Operation

There are three types of impacts associated with the replacement of another mode by pipeline: 1) those types which always favor pipeline; 2) those types which only sometimes favor pipeline; and, 3) those types which always disfavor pipeline.

The first group includes:

Traffic reduction
Air pollution reduction
Noise reduction

Accident reduction
Less land disturbance
Independence from weather
High degree of automation
Vibration reduction

The second group includes:

Reduction of energy consumption
Reduction of loss or damage

The third group includes:

Dependence on large volume of traffic
Size limitation of freight
Adverse effect on competing modes
For slurry pipeline: the requirement for water and its disposal.

There is as yet no uncontroversial methodology available to adequately determine the total negative and positive impacts which may flow from replacement of existing transportation modes with freight pipeline. But the fact that these impacts exist is undeniable.

The following is a brief discussion of the impacts.

Traffic Reduction

This impact was not easily quantifiable, although it was difficult to dispute the fact that whenever a truck or a railroad was replaced by a freight pipeline, overland traffic would be reduced, assuming that demand did not change. The reduction in surface vehicles could be significant for both inter-city and urban traffic.

As previously mentioned, the proposed 1030 mile Wyoming-Arkansas coal slurry pipeline (see Volume II) will deliver 25 million tons of coal per year when fully operative. If a railroad were to accomplish the same task, it would have to operate 2500 unit trains of 100 cars each, per year, in each direction, implying a steady flow of unit trains every hour and forty-five minutes, at any given point, day and night, 365 days a year(1)

(1) Huneke, J. M. Testimony before the Committee on Interior and Insular Affairs, U.S. Senate, Hearing on Coal Slurry Pipeline, June 15, 1974.

In urban areas where the traffic is heavy (perhaps bumper-to-bumper during rush hour), the impact on traffic of using freight pipelines could be significant. According to the Motor Vehicle Manufacturers Association, in high density areas 65 to 90 truck trips were generated daily per 1000 population during 1974[(2)]. In a large urban center, this would amount to a large number of trips. Therefore, any reduction of urban traffic would be significant. It was reported that an average truck in Manhattan, New York, in 1973, lost 4 hours per day as a result of congestion and that 83 percent of trucking costs in urban areas were attributable to time as opposed to miles of operation[(3)]. No documentation seems necessary to argue that 1) considerable savings in the cost of freight transport could be achieved if these four hours of congestion delay were eliminated or reduced, and 2) the elimination of any portion of truck traffic through diversion to freight pipeline would bring about commensurate relief in congestion for other urban vehicles.

In urban centers a reduction of traffic congestion might have significant impact upon energy wastage because of the reduction in idling time of the traffic, especially at exits to expressways and traffic lights.

Air Pollution

The motor carrier industries were reportedly responsible for 65 percent of the air pollution in the business district of New York during 1973[(3)]. How much of this was directly (due to the trucks themselves) and indirectly (due to the effect of trucks on the performance of other vehicles) related to the operation of trucks is a matter of conjecture. If the contribution of trucks had been proportional to their relative numbers (on a nationwide basis), this would have corresponded to about 10 percent of the air pollution. Because: 1) the level of emission from motor vehicles is heavily influenced by the mode of operation of that vehicle, 2) in large urban centers, the relative number of trucks to other vehicles is more than the nationwide average[(4)], and 3) trucks, on the average, emit more pollutants than passenger cars), it may be safely

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(2) "1974 Motor Truck Facts", Motor Vehicle Manufacturers Association, 1974.

(3) Kriebel, W. R. and F. A. Sailer. "A Simulation Study of the Effects of Consolidating Deliveries on the Economic Cost of Convenience Store Supply System", Transportation Research Forum, 1973.

(4) Bragdon, C. R., "Noise Control in Urban Planning", Journal of Urban Planning and Development Division, Proceedings of ASCE, 99, VPI, pp. 15-23 March 1973.

assumed that the contribution of trucks to air pollution in Manhattan in 1973 was well over the 10 percent figure. Reduction of the size of the truck fleet in Manhattan through substitution with freight pipeline could bring about a corresponding level of improvement in air quality.

The trucking industry claims[5] that the contribution of trucks to the cities' air pollution is rather small. This claim was apparently based on the fact that only 0.9 percent of the total air pollutants emitted from all sources (stationary and non-stationary) on a ton per year basis was due to diesel vehicles[5]. Three points need to be mentioned: 1) diesel vehicles comprise only a portion of the total number of trucks[6], 2) there are proportionally more trucks in the large urban centers[7], and 3) diesel engines emit a much higher percentage of the total oxide of nitrogen (about 30 to 100 percent higher)[8].

A rough estimate of the contribution of various modes of transport to polluting air was made by combining information provided in Tables 1, 2 and 3. Table 1 shows the amount of air pollutants emitted from diesel fuel burning engines in pounds of pollutant per 1000 gallons of fuel consumed. Column 2 of Table 2 shows the energy intensiveness of each transportation mode. Amounts of combined pollutants emitted per btu consumed for truck and rail (Column 4 of Table 2) were calculated by using information in Table 1 and noting that 1000 gallons of fuel contain approximately 185,000 btu. On the other hand the amount of combined pollutants emitted per btu utilized in a freight pipeline (Column 4 of Table 2) was obtained by changing units of measurement regarding the value in the last column of Table 1 by observing that 3412 btu is equivalent to one kwh. Amounts of combined pollutants emitted per ton-mile(air distance) transported for various modes (Column 5 of Table 2) were calculated by combining information in Columns 2 and 4 of Table 2.

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(5) "Clean Air and the Diesel", Bulletin No. 952725 4-70, Cummins Engine Company Inc., Columbus, Indiana.

(6) In 1972, the number of diesel trucks was 16% of the total trucks, excluding pick-ups and panels. However, diesel truck-miles were about 47% of the total truck miles, excluding pick-ups and panels. 80% of the truck-miles of long haul trucks (over 200 miles) were operated on diesel fuel ("Truck Inventory Survey", Census of Transportation, 1973, U.S. Bureau of the Census, Volume II, Government Printing Office, Washington, D.C. 1974.

(7) Fresko, G. and F. Spielbert, "Analysis of Need for Goods Movement Forecasts", Journal of Urban Planning & Development, Proceedings of the ASCE, 98, UPI, July 1972.

(8) Tomany, J.O., Air Pollution, The Emissions, The Regulations and The Controls, America Elsivier Publishing Co. , New York, 1975.

Table 1. Air Pollutants Emitted

Pollutant	Pounds of Pollutants in 1000 Gallons of Diesel Fuel Consumed (1973) (9)		Pound of* pollutants produced by utilities per kwh generated (1974)
	Heavy Duty Diesel Powered Trucks	Locomotive	
Particulate	13	25	--
SO_x as SO_2	27	57	--
CO	225	130	--
HC	37	94	--
NO_x as NO_2	370	370	--
HCHO	3	6	--
Organic Acids	3	7	--
Combined Total	668	689	29.87×10^{-3}

* This value was estimated by assuming pipeline uses "utility's electricity". In 1974, approximately 1,968. x 10^9kwh has been generated(10) by utilities producing 29.4 x 10^6 tons of pollutants.

Table 2. Air Pollutions Calculations

-1-	Range of Energy Intensiveness btu/ton mile -2-	For References See -3-	Pounds of Combined Pollutants emitted per btu consumed -4-	Pounds of combined pollutants emitted per ton mile(air distance) -5-
Truck	1800-2800	Table 10	3.63×10^{-6}	6.53×10^{-3} to 18.28×10^{-3}
Rail	140-1920	Table 10	3.74×10^{-6}	$.52 \times 10^{-3}$ to 7.18×10^{-3}
Freight Pipeline	163-791	Table 12 and reference 10	8.76×10^{-6}	1.40×10^{-3} to 6.93×10^{-3}

(9) "Compilation of Air Pollutant Emission Factors", U.S. Environmental Protection Agency, 2nd Edition, EPA Publication No. AP-42, April, 1973.

(10) Huneke, J.M., Testimony before the Committee on Interior and Insular Affairs, U.S. Senate, Hearing on Coal Slurry Pipeline, June 15, 1974.

Table 3. Circuity Factors

Mode	Factor
Truck	1.20
Rail	1.25
Pipeline	1.10

Table 3 shows the assumed circuity factors for various transportation modes which were used to adjust the values in Column 5 of Table 2. The results are shown in Table 4 which gives the pounds of combined pollutants emitted per ton mile of freight transport.

Table 4. Emission for Various Modes in Tons of Pollutant per Ton Mile

	Pounds of combined pollutants emitted per ton mile (times 10^{-3})	Location of Emission
Truck (inter-city)	7.84 - 21.93	At the point of truck operation
Rail	.65 - 8.97	At the point of rail operation
Freight pipeline	1.04 - 7.623	At the point of generation of electricity
Freight pipeline	0	At the point of pipeline operation

Table 4 does not portray the real impact on air pollution by each mode. While truck and rail emissions occur wherever trucks operate, pollutants emitted due to the operation of pipeline would occur only at the site of power plants. For pipeline, a measure of control exists to isolate a source of air pollution from urban areas. Thus, each pound of pollutant emitted by truck and rail in urban operation would be likely to impact more negatively on the environment than would be the case for a freight pipeline. In addition, the type of fuel utilized by truck and rail is different than that used by pipeline. Truck and rail normally use the scarce oil supplies while pipeline uses coal, which is more abundant. A more detailed analysis of this subject is undertaken during the second year of research (current year) and will appear in the second year report.

Noise Pollution

All motor vehicles produce some noise. Noise affects human health, ranging from nuisance to injury and invading the accoustical privacy of citizens. Ward reported on results of a survey where only 3 to 7 percent of residents were annoyed by trains, compared to 33 to 62 percent by aircraft and 18 to 32 percent by autos and trucks[11]. The recognition of the inter-relationship between noise and health has created an impetus for noise control within urban communities. Highway noise litigation has also gained prominence. According to Bragdon, during 1971, the New Jersey Superior Court awarded $160,000 to the Elizabeth, New Jersey Board of Education because highway noise interfered with the teaching process[4].

There are three components of the noise problem: the source, the path and the ultimate receiver. On the average, trucks are the source of a sound level 10 db higher than automobiles[12]. Consequently, any reduction in the size of the truck population would have a more pronounced effect on traffic noise than would be indicated by the sheer number of vehicles reduced. In most traffic-noise situations, the sound of any one individual vehicle (a source) is often indistinguishable from the merged sound of all the traffic unless the noise of that particular vehicle is significantly higher than average (which is the case for diesels). On the other hand, when the proportion of diesel trucks to passenger vehicles is higher than a few percent, traffic sound exhibits a bimodal distribution where truck noise occupies the higher db band.

In the future, noise abatement will cost both the truck industry and the tax payers a substantial amount of money. Table 5 shows the noise reduction required to meet the noise standard by 1980 according to a Chicago ordinance[13]. Hauskin[14] claims that for most of the new highways some type of noise abatement measure will be required if residences, schools, or parks are located within 250 ft. of the nearest lane of traffic.

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(11) Ward, E.J. "Noise in Ground Transportation Systems", High Speed Ground Transportation Journal, 7, 3, pp. 297-305, 1973.

(12) Beaton, J.W., and L. Bourget, "Traffic Noise Near Highways: Testing and Evaluation", Highway Research Record, NRC, NAS-NAE, pp. 32-42, 1973.

(13) Bugliarello, George, et. al. The Impact of Noise Pollution, Pergamon Press Inc., 1976.

(14) Hauskins, John B., Jr. "Kinematic Sound Screen: Unique Solution to Highway Noise Abatement", Proceedings of the ASCE, Vol. 100, No. TE1, February, 1974.

The second year of this study has dealt with noise impacts in considerable detail. This effort will be described in the second year report.

Table 5. Chicago Ordinance for Noise Emission from Vehicles[13]

Date of Construction	Maximum Limit in dba (at 50 ft)
Motorcycles	
Before January 1, 1970	92
After January 1, 1970	88
After January 1, 1973	86
After January 1, 1975	84
After January 1, 1980	75
Vehicles heavier than 8000 lbs.	
After January 1, 1968	88
After January 1, 1973	86
After January 1, 1975	84
After January 1, 1980	75
Private cars and other motor vehicles	
After January 1, 1973	86
After January 1, 1973	84
After January 1, 1975	80
After January 1, 1980	75

Accidents

The fatality rate has been significantly less for trucks than for passenger cars. However, during daylight hours in the metropolis, more trucks were involved in accidents. In the 1969-71 period, there were 2.06 deaths per 100 million vehicle miles of tractor trailers travel versus 2.41 for passenger cars.
On the other hand, according to Smith et al., the number of accident involvements per 100 million vehicle miles in 1969 was 207 for automobiles, 281 for light trucks, and 220 for medium and heavy trucks[15]. In Philadelphia alone, trucks were involved in 8,160 accidents in 1973 which resulted in 1,441 injuries and 20 deaths[16]. These accidents could be eliminated if freight pipeline were to replace trucks*. A rough estimate of social cost of accidents was developed from examination

(15) "Motor Trucks in the Metropolis", The Automobile Manufacturers Association, W. Smith and Associates, 1969.

(16) Philadelphia City, Traffic Accidents 1973 Philadelphia, Traffic Engineering Division, Department of Streets, The City of Philadelphia, 1974.

* Since freight pipeline is not expected in the foreseeable future, to replace 100 percent truck movement, the accident reduction will be proportional to the extent of replacement.

of Tables 6 and 7. Table 6 provides information as to the rate of accidents per million vehicle miles travel for truck and rail. Table 7 shows how much cost various government agencies assign to an accident. Combining information in these two tables yields a rough estimate of equivalent dollar cost of accidents per ton mile of freight transported, see Table 8. These estimates, although very rough and perhaps controversial, at least provide a basis for quantification of impacts.

Table 6. Accident Rate (Reported Accidents Only)

Description	Truck	No. of cases per million vehicle mile travel		
		Railroad	Trucks - Common Carriers: Intercity	Trucks - Common Carriers: City
Accident	0.95	12.67	2.98	33.31
Fatalities	0.0713	3.57	- -	- -
Injuries	1.02	21.50	- -	- -
Source	FHA[17]	FRA[18, 19]	NSC[20]	NSC[20]

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(17) "Societal Costs of Motor Vehicle Accidents", National Highway Traffic Safety Administration, Preliminary Report, May 1972.

(18) National Safety Council, Accident Facts, p. 64, 1975 Edition.

(19) National Transportation Safety Board, 8th Annual Report to Congress, 1974, Washington, D. C., p. 5, April, 1975.

(20) Philadelphia City, Traffic Accidents 1973 Philadelphia, Traffic Engineering Division, Department of Streets, The City of Philadelphia, 1974.

Table 7. Social Cost of Accidents According to Various Federal Agencies

	Cost in Dollars per Case		
Agency	Fatality	Injury	Property Damage
NHTSA(21)	200,000	7,300	- - - -
FAA(22)	500,000	- - -	- - - -
FHA(23)	- - - -	- - -	4,600

Table 8. Social Cost of Truck Transport Due to Accidents*

Mode	Cost in ¢/ton-mile
Truck	0.33
Rail	0.05

* This table was based on the assumption of NHTSA and FHA of Table 7. In addition, average freight per vehicle is taken as 1844 tons for rail and 8 tons for truck according to an AAR report and a TRB report(24, 25).

Land Disturbance - Table 9 shows the right-of way requirements of various transpor-

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(21) Rouse, E. Substantial Theft of Cargo is Plaguing Philadelphia", Philadelphia Inquirer, October 25, 1974.

(22) Statistical Abstract of the U.S., 1974, U.S. Bureau of the Census, (96th Edition), Washington, D.C. 1975.

(23) "Truck Inventory and Use Survey", Census of Transportation, 1972, U.S. Bureau of the Census, Vol. II, U.S. Government Printing Office, Washington, D.C. 1974.

(24) U.S. Bureau of Land Management, The Need for a National System of Transportation and Utility Corridors, July, 1975.

(25) U.S. DOT, Transportation Systems Center, Energy Statistics, DOT Report No. DOT-TSC-OST-75 --3, Final Report, August, 1975.

tation modes.

Table 9. Right-of-Way Requirements (During Operation)

Mode		Average width feet	Land Area Allocated for a 700 mile system in sq. miles
Highways	Interstate	250	33.1
	Primary	125	16.6
Railroad	Class "A"	200	26.5
Pipelines		50	6.5

This table however, does not convey the whole story.

1) Almost everywhere in North America, highways and railroads already exist. Additional right of way will only be required if a given highway has to be upgraded because of additional traffic. In other cases the additional land requirement is almost zero.
2) A new pipeline will require the right of way shown in Table 9 unless it is allowed to be located within the rights of way of existing highways, railroads, electric transmission lines, and other pipelines.
3) Even when a new right of way is set aside for pipeline, that strip of land can be utilized for many diverse purposes in addition to its primary purpose of accommodating the pipeline(26).

Energy Consumption

A total of 67,827 trillion btu's (equivalent to 11.7 billion bbls of crude oil) or about 7 percent of the total United States energy consumption was utilized to transport freight during 1968. Every single percent reduction in the fuel requirement of freight transportation would have been equivalent to a savings of some 8 million bbls of crude oil.

A number of investigators have compared the energy consumption of various modes of freight transport by calculating a term known as "Energy Intensiveness", EI. EI is defined as btu energy required to move a ton of materials a mile. Table

(26) "Where the Deer and the Antelope Play, Transco has a Right of Way", Transgas, No. 3, 1975.

10 compiled by Zandi and Gimm(27) shows the EI's calculated on the basis of national figures for all materials moved inter-city via various modes of transport.

While EI calculated in this manner imparts some useful information, it suffers from two basic deficiencies: 1) it represents an almost useless average value, and 2) it signifies energy consumption in only a portion of the system.

The first deficiency occurs because energy consumption is not only a function of the transportation mode, but also depends on the characteristics of the roadway, the nature of the environment that it serves, weather conditions, packaging, freight density and the method of operation. The second deficiency occurs because EI calculated from national fuel consumption figures, usually stops short of considering all the steps involved in various processes required to make either coal or oil available to vehicles.

Scrutiny of these deficiencies reveals that no significant conclusion can be drawn about a specific freight transportation project on the basis of these national averages. EI is a function of too many variables to be useful when it is stated in terms of statistical averages, even for a single mode of transport. For instance, using actual fuel consumption data for the Reading Railroad Company System, one finds that the EI varied between 140 and 1,920. It should be obvious that the average values given in Table 10 do not convey much information for comparison of the various modes in terms of the area specific situations which are of considerable interest to investors and operators.

Table 10. Energy Intensiveness, EI (BTU/TM)(26)

Investigators	MODE				
	Pipeline (oil)	Rail-Road	Water-way	Truck	Air
Hirst (1973)	450	670	680	2,800	42,000
Railway Age (1973):	---	536-791	---	2,518	---
Battele's Columbus Labs				2,800	
Railway Age (1973): Missouri Pacific's Traffic Research Division	---	500	---	1,800	---
Mooz (1971)	1,850	750	500	2,000	63,000
Reading Railroad Data	---	140-1920	---	---	---

(27) Zandi, Iraj, and Kyong Sup Kim, "Solid Pipeline Conserves Energy", Transportation Research, 3, pp. 471-479,October, 1974.

The value of EI for freight pipelines also covers a wide range as it is a function of diameter of the pipe, velocity of the flow, characteristics of solids to be transported (size, shape,density), characteristics of flow (concentration of solids and apparent viscosity of the suspension), and the nature of the conveying fluid.

A meaningful comparison can be achieved only when the EI is obtained for a given area specific situation and specific transportation requirements. Zandi and Gimm[(26)] made such a study for one specific situation. For inter-city transport, the actual EI of an existing coal slurry pipeline was compared with the EI of a railroad designed to perform the same task[(26)]. Table 11 shows the results of these comparisons. In addition we have also added in Table 11 the EI for a pneumo-capsule pipeline, a hydro-capsule pipeline, and truck operating within an urban setting.

Table 11. EI for Total System, BTU/TM[(26)]

Mode	EI at Work	EI for Total System
Railroad (intercity Transport)*	492	544
Slurry pipeline*	171	465
Pneumo-capsule pipeline	---	400**
Hydro-capsule pipeline - Spherical capsule	161	436
Hydro-capsule pipeline - Cylindrical capsule w/collar	600	1,627
Truck, Urban traffic (average)	5,040	5,583

* These two are for identical conditions. Pipeline data is actual, while railroad is calculated.

** This value is calculated from Equation 14 - in Volume II of this series of reports and it is rounded upward. Reference (26) does not include this figure.

"EI at work" implies that the energy is employed at the job site to accomplish the task. However, work must be done to get this energy to the point of utilization. "EI for total system" includes this required work and is the total chemical energy input before conversion or refining[(26)].

Table 11 shows the energy needs of various modes. It is important to note that only the IE's for railroad and slurry pipeline can be directly compared. They represent exactly the same activity. Other data in the table are for average conditions, and therefore, subject to criticism expressed before.

It also should be noted that a great reduction in energy requirements of pipeline may be achieved by more sophisticated designs. Table 12 shows some of the recent test data which clearly indicates improvements of the EI for pipeline.

A further observation may be made that there is a qualitative difference between energy consumed in trucks and energy consumed in freight pipeline. Trucks use oil which is domestically in short supply, but freight pipeline uses electricity which can be produced either from coal for which a plentiful domestic supply exists, or from nuclear power plants as they become available.

Table 12. Recent Data for the Freight Pipeline's EI

Freight Pipeline	Energy at Work	Energy at the System Level
Hydro-capsule pipeline Field test in U.S.S.R.	60*	163
Pneumatic Wheeled Capsule Pipeline**		
Field test in Japan (36")	446	1212
Field test in U.S.S.R. (40")	178	482
Field test in Atlanta (36")	216	586
Field test in Germany (45 cm)	291	791

* This is an estimated value based on the report by a U.S.S.R. engineer that capsule pipeline consumed 35% of the energy required by slurry pipeline. The value of EI for slurry pipeline was taken from Table 11.

** These are experimental data and are useful for the specific experimental set-ups used to obtain them.

Loss and Damage

A Department of Transportation report puts the total annual direct and indirect cost (administration, cost of processing claims and cost of lost business, etc.) from loss and damage in the transportation industry at the $8-10 billion level[28]. Of this amount, approximately 66% (of the direct cost) was attributed

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(28) Rouse, E. "Substantial Theft of Cargo is Plaguing Philadelphia", Philadelphia Inquirer, October 25, 1974.

to the trucking industry and 25% to railroad. Other reports estimated costs as high as $13 billion. Only 10 percent of this loss occurred as a result of hijackings, another 5 percent involved breaking and entering kinds of burglaries of terminals and the remaining 85% was unknown disappearance recorded as shortages, shrinkage, etc.[29]. How much of the total annual loss was susceptible to improvements in modal technology cannot be specified. What is certain, however, is that a fully automated transportation system, such as freight pipeline, could be designed to minimize undesired accessibility to cargo in transit, which in turn would reduce the opportunity for theft.

III. Conclusions

This assessment study has only identified the areas where truck and/or rail substitution by pipeline may have impacts. Considerably more work is required to make an acceptable evaluation of these impacts. It only can be said that pipeline, if it can substitute for surface traffic without correspondingly increasing it at another location, is inherently a more environmentally compatible mode of transport.

Based on data presented in this report, it can be stated that, to the extent that a freight pipeline reduces the truck traffic, it helps to reduce street congestion, noise, energy consumption, accidents, and air pollution. As compared to rail, however, accident and noise reduction are certain, but the impact on energy consumption and air pollution depends on local conditions. The report of the second year of research will examine some of the impacts in more detail.

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(29) U.S. Senate, Select Committee on Small Business, "Cargo Theft", Joint Conference, Part 4, Washington, D.C., 1971.

Cut Out Along This Line

REQUEST FOR FEEDBACK TO The DOT Program Of University Research

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